DRAINAGE & SANITATION

E. H. BLAKE

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A PRACTICAL EXPOSITION OF THE CONDITIONS VITAL TO HEALTHY BUILDINGS, THEIR SURROUNDINGS AND CONSTRUCTION, THEIR VENTILATION, HEATING, LIGHTING, WATER AND WASTE SERVICES

For the use of Architects, Surveyors, Engineers, Health Officers, Sanitary Inspectors, and for Candidates preparing for the Examinations of the various Professional Institutions

BY

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PREFACE TO THE SECOND EDITION.

DURING the last few years there has been but little activity in regard to Domestic Sanitation. The unfortunate conflict in which the country has been engaged, and the importance of placing the speedy termination of that conflict before all else, have caused a suspension of building operations so far as domestic buildings are concerned.

Valuable work has been done in regard to the sanitation of military camps and the purification of waste liquids peculiar to munition factories, but it is felt that these are matters outside the scope of the present volume.

The necessity for a second edition has, however, afforded an opportunity of such revision as is called for in the light of the foregoing.

E. H. BLAKE.

34 RUSSELL SQUARE,
LONDON, W.C.,
September, 1920.

PREFACE TO THE FIRST EDITION.

INTENDED primarily as an introduction to the subject, it is hoped that the following pages may prove of interest to both the novice and the experienced practitioner.

There are many conditions which a really healthy building should fulfil. It should, for example, be placed in hygienic surroundings, be well built, free from damp, well planned, ventilated, warmed, and lighted, have an efficient water supply and good sanitary fittings, be well drained, and be kept free from accumulations of refuse. An attempt has been made to deal with the subject in a systematic manner. Thus, in the case of water supply, the matter is started at the various sources of supply, traced to the point of distribution, and laid on to the house.

Then follow the sanitary fittings and waste pipes, through which the fouled water leaves the house and enters the drainage. From the drains, one goes on to the sewers, and from them, to the works for the disposal of sewage.

An attempt has also been made to avoid continued reference to manufacturers' specialities, which too often gives text-books on this subject the appearance of trade catalogues, and to give types rather than exact reproductions of makers' goods.

E. H. BLAKE.

82 VICTORIA STREET,
WESTMINSTER,
July, 1913.

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CHAPTER I

THE BUILDING—ITS ENVIRONMENT.

IT has been said that " Governments may stamp the manners, but it is the air they breathe that moulds the form, temper, and genius of a people".

In selecting a situation for a house, commercial and economic considerations prevent this point being considered in its broadest sense. The question of climate is one, however, that must, theoretically at any rate, be considered as one of the many points to be taken into account in determining a healthy situation.

Some of the old philosophers have written largely on the influence of climate on race. Vitruvius was one of the first to point out the greater physical and mental endowment of the inhabitants of some countries than of those of others.

Perfection in the arts and sciences hardly ever appears in very high or very low latitudes. In these extremes, it has been pointed out, the passions are sluggish, and the inhabitants show sterility of thought in their arts and manufactures. The soul of the poet is not stirred in icy regions.

In the temperate zone one finds greater mental and physical energy, enterprise, perseverance, and courage.

The effects of climate are as noticeable in regard to the body as in regard to the mind. In polar regions one finds the inhabitants stunted, short-limbed and stiff-jointed, but in travelling southward one finds them of increased stature, and greater perfection of shape and features.

Climate has been said to have been a considerable factor in the formation of language. The close, serrated way of speaking common to northern nations has been attributed to the natives not wanting to open their mouths widely in the cold air, and in warmer climes one certainly finds the softer languages, abounding in vowels.

Narrowing down this question of climate, one often finds people varying in disposition with changes of weather, becoming joyful, sullen, sprightly, or dejected as the case may be. There are days, too, when one finds the faculties of memory and imagination more acute than on others.

Instinct teaches animals to migrate with the changes of season. To a very limited extent one finds man actuated by the same instinct, restrained chiefly by economic and commercial considerations.

It may be said that a man can live in any climate, but he can only do so by ingenuity. That is to say, he takes with him suitable dress, which is merely a mechanical means of preserving his own bodily heat and so forming a portable climate.

Other points bearing in the selection of a situation for a house are such as rainfall, death-rate, local sanitary administration, freedom from artificial nuisances, elevation and aspect of the land.

When comparatively warm air, more or less laden with moisture, is suddenly chilled, by its ascent into a colder atmosphere, or by its contact with the cold surface of the ground, what one terms rain falls. The rainfall varies greatly with the locality. From observations taken over a long period of years, the average rainfall of Great Britain is 36·69 inches. For England and Wales it is 33·76 inches and for Scotland 46·56 inches. The average rainfall is much greater in the West of England than in the East, averaging only a little over 20 inches in the Eastern Counties. The Lake District is a particularly rainy quarter, as much as 150 inches a year having been recorded there, the whole year's rainfall representing, in other words, a sheet of water 12 feet 6 inches deep.

It will not be inopportune to refer here to the subject of humidity. Water evaporates into the air and is held by it to an extent varying with the air's temperature. The relative amount of moisture in the air is described as the degree of humidity. Very humid air is not good for one and is said to be largely associated with the spread of disease. The higher the temperature of the air, the larger the proportion of moisture it will take up. When one speaks of saturated air, one means that the air has absorbed all the moisture it can hold. The average humidity of the air in Great Britain is about 75 per cent; that is to say, it contains about three-fourths the amount of moisture it could hold. Since the lower the temperature of the air the less the quantity of moisture it will hold, it will be seen that, if the temperature of the air were gradually lowered, a point would be reached at which the quantity of moisture present could only just be held by the air, which would therefore become what is termed "saturated". A further decrease in temperature would lead to the air parting with some of its moisture in one of the many ways in which this is possible, such as rain, mist, dew, or snow. The degree of humidity of the air is calculated from what is termed the dew-point; that is, the temperature at which the air parts with its water. The temperature of the dew-point is determined by means of instruments called hygrometers, a description of which will be found later herein.

Dry air is much more invigorating than moist. Closely allied to the question of humidity is that of fogs.

The air contains an infinite number of minute particles of solid dust, particles so minute as to be quite invisible to the naked eye. Fogs are caused by these minute particles becoming surrounded by watery envelopes on the air giving up its moisture. Town fogs are often caused, not so much by the moisture, as by the exceptional size or number of the dust particles. In the case of sea fogs the dust particles are really minute particles of salt given up from the spray.

Naturally, in selecting a situation for a house, one would choose a locality in which the death-rate is low, since a high death-rate is to be looked upon as a danger signal. Statistics as to death-rates require to be regarded with care, since crude statistics are liable to be misleading. Thus, in a small district, there may be a large hospital, or a manufactory in which processes prejudicial to life are carried on. Again, the district may be a watering-place largely favoured by invalids, or with a very fluctuating population. There is also the question of the age and sex distribution of the population, since it is a well-established fact that women, as a class, live longer than men. Lastly, density of population is another factor which must not be overlooked in investigating death-rates. Parts of a district may be densely populated, thus facilitating the spread of infection and other evils and causing a high death-rate while the district as a whole may be healthy.

We come next to the question of local sanitary administration. One would choose a district which was well provided for in this respect. Out in the open country this point has not much application, but in the case of a town there should be a public supply of good water, a good system of sewerage and sewage disposal; the scavenging should be properly dealt with, the refuse being cremated; the streets should be wide, well arranged so as to get good ventilation, and should be well lighted.

Artificial nuisances should of course be avoided. One would not, from choice, erect a house near a factory where an obnoxious trade was carried on, such as chemical works, tanneries, soap works, and such establishments; nor would one choose a site adjoining a fever hospital, disinfecting station, cemetery, or sewage disposal works. The methods for the disposal of sewage have made large advances in recent years, and one can safely say that with a thoroughly up-to-date installation there is no danger from such works, but, notwithstanding this, the best of schemes is likely to get out of gear at times, and nuisance, though possibly not danger, from smell might arise occasionally.

It is always desirable to get a good circulation of air around a house. It would therefore appear at first sight as though the best position would be on the top of a hill. This is not so, however, unless the house is protected from the winds by a belt of trees. Low lying districts should be avoided in all cases if possible, so also should any hollows or places lower than the surrounding land. They are apt to be damp and cold. The banks of rivers, unless many feet above the highest level of the stream, should also be avoided, owing to the risk of floods and dampness.

The side of a hill is often selected as the site of a house, on the ground that the slope facilitates the drainage. It is never wise to build a house close in to a hill, such a site being damp and unhealthy, in addition to the house being liable to serious damage by the rush of heavy rains. A spur or projection from the side of a hill affords a good site, and is not open to the objections just stated. While, generally speaking, sloping land affords, with the reservations just made, a good site, it is necessary to point out that one must consider also the aspect of the slope. Thus a slope facing south is infinitely to be preferred to one facing north. Of course a house should not be too exposed to the glare of the sun, but I think there is little risk of that in this country.

Down below the surface of the ground, at very varying depths, is a large sheet of water, termed the ground water. In some places its surface is only a foot or so below the ground, while in others it may be as much as hundreds of feet down. The depth of this ground water can be noted approximately by inspecting the water level of any shallow wells in the neighbourhood, and the same method of inspection will disclose the fact that the level of the ground water fluctuates, rising or falling with the presence or absence of heavy rainfall. As the water rises, it forces up through the ground the air previously filling the pores of the soil above it, known as ground air, and takes the place of such air. On falling again, the interstices of the soil are left charged with moisture, termed ground moisture. Ground moisture is also due to the ground water rising by capillary attraction, or being soaked up, so to speak, by the soil, and to the evaporation of the water.

It will be seen that if the level of the ground water is near the surface, the site will be damp; therefore one should not adopt a site, if avoidable, in which the highest level of the ground water is less than 10 feet below the surface. Both ground air and ground water are constantly moving and therefore require careful consideration. If one house be built at a lower level than another on a hill-side, for example, there is a risk of soil pollution, the underground water being polluted in its course by leaky drains, cesspools, and such things. The air forced upwards out of the soil may also be polluted from the same causes. Every care must be taken to see that the subsoil is free from pollution, since not only must the house itself be protected from the possibility of danger to health (which can be accomplished by means of an impervious layer over its site), but also the ground immediately adjoining the house.

Should the level of the ground water be rather high, the site may be greatly improved in value by the drainage of its subsoil. The judicious planting of trees and shrubs will also help matters, since they tend to dry the soil. The value of vegetation in this direction is not sufficiently recognized, but one must also not lose sight of the fact that excessive vegetation is not beneficial to a site. Grass acts very beneficially on a somewhat polluted soil, by using up the organic matter therein. It has been pointed out that the common sunflower is a good cleanser and drier of the soil.

Let us next consider the situation of the house with regard to the question of soil. One may divide this into surface soil and subsoil. The former is of shallow depth, generally formed by the decayed upper surface of the rocks below, mixed with the remains of animal and vegetable matter and often a quantity of alluvial deposit brought to it by running water. This surface soil is generally very absorbent, being disintegrated by worms, ants, and other things, and so readily letting air down to the subsoil below. The subsoil should be of a porous nature, and capable of readily absorbing and retaining heat. Moist soils, such as clay, absorb heat slowly and lose it rapidly. One may put the principal soils in the following order of preference from a hygienic point of view: gravel, sand, limestone, sandstone, chalk, clay, or loam. It is of very great importance that there should be a fairly thick stratum of one of these materials before an impermeable layer is reached, otherwise the subsoil will act as a sponge, soaking up and largely retaining the ground water and thus making the site a damp one. Trial holes or borings should be made to determine this point in any important case.

Sites of former gravel pits, clay workings, and such features often become tips for house refuse and miscellaneous rubbish of all sorts, forming what is known as "made" soil. Made soils are very undesirable from a building point of view, being highly charged with organic matter and other impurities. After long exposure to the sun and air they become considerably purified, but they should not, in any case, be built upon for at least five years after the land has ceased to be a rubbish tip, as it still remains an undesirable soil. Alluvial soils, or arable land, should also be avoided as a building site; so also should land which has been reclaimed at the mouth of a river, or any similar case.

The greater the amount of open space around a building the healthier will it be. In the open country there is generally no difficulty on this point. In the towns, where land is more valuable, developers of land have, in the past, shown no great generosity in forming wide roads and laying them out on lines beneficial to the community at large. The Public Health Acts empower local authorities to make by-laws regulating the widths of new streets, among many other things. For the guidance of the authorities the Local Government Board issued a Model Code of By-Laws, forming what are generally known as the Model By-Laws. In these, the width of new streets is fixed at a minimum of 36 feet. It is open to any urban authority to prescribe a greater width than this as a minimum, subject to confirmation by the Local Government Board, and many authorities in the Provinces have done so, the minimum being as high as 50 feet in some few cases. Generally speaking, London does not come within the purview of the Public Health Acts as to sanitary matters, and this question of the width of streets is covered by the provisions of the London Building Acts, which fix a minimum of 40 feet. Both in London and in the Provinces the local authority may require the road to be of greater width in certain cases. The provisions of the Housing, Town Planning, etc., Acts, should go far to abolish the old haphazard method of developing building estates and should make it possible to get wide, through streets so as to ensure the efficient circulation of air.

Both in London and the Provinces also there are statutory requirements in reference to the amount of open space to be provided in the rear of domestic buildings. A minimum area is provided, but a further provision makes this area dependent on the height of the building. Provisions are also made in this matter in regard to special sites, such as those at the corners of streets, those in which the depth of the plot does not permit of the required area been given at the back of the premises, or sites which taper towards the back.

It will have been seen from the foregoing that some types of house are better than others; thus, a detached house is the best, since one can get fresh air on all four sides of it; a semi-detached house can be placed second in order of preference, air being obtainable on three sides. A terrace house is not so good since air is only obtainable at front and back. With good planning, however, a through current of air can be ensured. Cottages in a row would at first sight appear to be on just the same footing as the terrace houses, but in most cases economic considerations in planning appear to prevent the provision of a through current of air, and the streets on which cottages abut are usually as narrow as the regulations permit.

Flats, generally speaking, are planned so that there is no possibility of a through current, the flat often fronting one street only. Back-to-back houses are often met with in Yorkshire and Lancashire. These are a particularly insanitary type of dwelling, and are of course limited to small property. The principal objections to this class of building are, the lack of through ventilation, making it very difficult to thoroughly change the air throughout; the fact that the death-rate in such dwellings has been shown to be higher than in those with through ventilation; and the lack of privacy in the privy accommodation, it being usual to group the privies together in the land appurtenant to the buildings. The Housing, Town Planning, etc., Act, 1909, prohibits the erection of this type of dwelling in future, unless the Medical Officer of Health certifies their construction and arrangement to be satisfactory.

Cellar dwellings were at one time largely used, but a cellar may not now be newly utilized as a dwelling. The reasons for this are fairly obvious, and the point has been dealt with by various legislative measures.

CHAPTER II

THE BUILDING—ITS PLANNING AND CONSTRUCTION, PREVENTION OF DAMPNESS, ETC.

GIVEN a site of sufficient area to permit of the erection of a detached house, it should be possible to design such a house in a manner free from any hygienic or sanitary objections. There are certain broad principles to be kept in mind in preparing such a design. The rooms containing sanitary fittings should be grouped together, floor over floor, in order to simplify the drainage of the house by collecting its waste pipes at one side as much as possible. If this point is kept in mind a far better system of drainage will be possible than would otherwise be the case, as well as a more economical system. Rooms containing sanitary fittings should be isolated from the other rooms. In the case of a detached house it is possible to group the sanitary apartments into a small wing and to isolate them, on each floor, by means of a small lobby, well lighted and ventilated, so as to prevent any possibility of smell finding its way into the main building. In the case of a semi-detached or terrace house considerations of space usually prevent the formation of a sanitary wing, but the principle of isolation by lobbies should be carried out as far as possible.

The staircase should be fairly central and arranged so as to form a means of ventilation to the house as a whole. This point will be more fully dealt with later under the heading of ventilation.

The rooms should be of good size and fairly lofty, well lighted and ventilated, and all against an outside wall.

Windows of good size should be so placed that they give the greatest amount of light in the room; that is to say, they should not be in one corner, or at the end of a wall, but more nearly in the middle of the side of the room. They are also of the greatest efficiency when they extend nearly up to the ceiling, particularly when the wall in which they are placed is not far from another wall, since then the room will get a maximum of direct rays of light.

The building should be so planned that the natural light of any room is not prejudiced by extensive projecting "back additions" or wings, and, like the rooms, all lobbies and passages should have windows, or overhead lights, communicating directly with the outside air. The question of natural and artificial lighting will be dealt with more fully later on.

The placing of the building on the site is a matter of some importance, since certain rooms should have certain aspects. Thus, a morning-room should face south-east, to get the morning sun; a drawing-room should have a south-west aspect in order to get the benefit of the afternoon sun; a dining-room gets the greatest benefit of the evening light if facing north; the north side is also the best for the kitchen, larders, etc., as this will be the coolest side of the house. Care should also be taken to put the rooms containing sanitary fittings on the side on which they will get but little sun. This serves the double purpose of keeping them cool, and of keeping the waste pipes efficient, since the latter, being of metal, should not be exposed to the risk of expansion and contraction due to the heat which would be imparted to them by strong sunlight.

It will be obvious that the planning of a house cannot be rigidly standardized, owing to the exigencies of site and individual requirements as to accommodation, but the foregoing principles should be followed so far as practicable.

Let us next consider the construction of the house, so far as it comes under the heading of sanitation. It has been pointed out that it should be put on a dry, porous soil and subsoil. It may be that this is impossible. In such case the subsoil should be improved by drainage. A great deal can be done to lessen the evils of ground water. If the house is not a very large one, the best plan is to lay subsoil drains around the foundations of the outside walls, falling to one corner of the building. These drains should be of unglazed pipes, without sockets, laid with butt joints (i.e. just end to end), and covered over to a depth of about 1 foot with broken stone, the remainder of the trench being filled in with ordinary earth. If laid around the building in this way, the drains of two sides of the building will fall in one direction and those on the two other sides in an opposite direction, the two sets of drains meeting at a point from which they are continued onwards as one drain. There can be no hard and fast rule for the size of the drains, but those around the building can be in most cases of 3 inches in diameter, continuing onwards from the point of junction with a diameter of 3 or 4 inches as the case may be

If the soil is very wet, or the building of considerable size, subsoil drains are frequently formed *under* the site of the building, but drains of any kind should not be put under a building if it can be avoided. In such a case, however, a main drain of say 3 or 4 inches diameter can be laid diagonally across the site of the building, with branch drains of say 2 inches diameter leading to it, laid herring-bone fashion on plan at a distance of about 6 or 8 feet apart. It may be desirable to lay a subsoil drain around the building in addition. The subsoil drains should in all cases be below the level of the foundations of the walls.

Whichever of these two methods may be adopted, the drains should be continued, from the point at which they are collected together, to a ditch or other water-course if there is one on the property. Should there be no natural outfall of this kind, the main drain can discharge into the ordinary system of foul drainage provided that it is cut off, or intercepted, by a trap at the point of junction, in order to prevent the foul drains being ventilated into the soil through the subsoil drains.

Should there be a separate system of drainage taking rain water only, the subsoil drainage can be discharged into such systems without being intercepted in the manner just described.

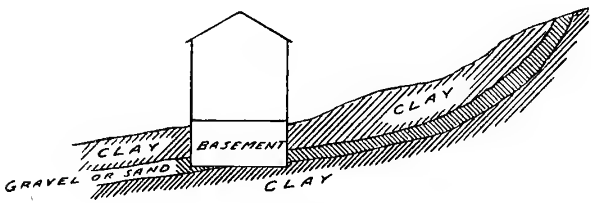


Fig. 1.

The subsoil water gravitates towards the broken stone over the unglazed pipes, percolating through them, and entering the drain through the open joints, thus rendering the site very much drier than it would naturally be.

It has already been pointed out that houses should not be built close to a hill-side. It is sometimes done, however, and in such a case the subsoil drainage requires very careful consideration. Trial holes should be sunk at various points around the site of the house, and the water level and nature of the subsoil carefully noted, the former being noted at various times owing to its fluctuation in the wet and dry periods.

Assume, for example, a case like that shown in Fig. 1 in which the basement of a house cuts through a bed of sand or gravel lying between an upper and lower stratum of clay. The bed of gravel is shown coming to the surface, or outcropping as it is termed, some distance up the hill behind the house. In times of heavy rainfall there would be a stream of underground water passing through the porous stratum of gravel or sand and washing round the outside of the basement. The rain falling on the land between the outcrop and the house would not soak into the clay, but would pass on to the walls of the house. The walls might be protected by a layer of

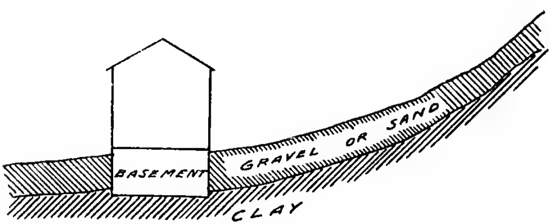


Fig. 2.

asphalt, but the interception of the water would be much better. Again, assume that the circumstances are as shown in Fig. 2 in which a bed of gravel or sand lies over a subsoil of clay. Here, also, there would be difficulty. The best method of dealing with either of these cases would be to (1) form an open area around the walls affected, carrying it down below the level of the basement floor and paving it, forming a gutter at the toe of the bank, with proper falls to gulleys, in order to carry the water off, and (2) to form, also, a deep subsoil drain some distance back from the house and carried down to a depth of about 2 feet below the level of the foundations of the walls, as shown in Fig. 3, the trench being filled in with broken stone. The dip of the strata around the house would have to be carefully noted, so that the water might be intercepted properly. Thus, assume

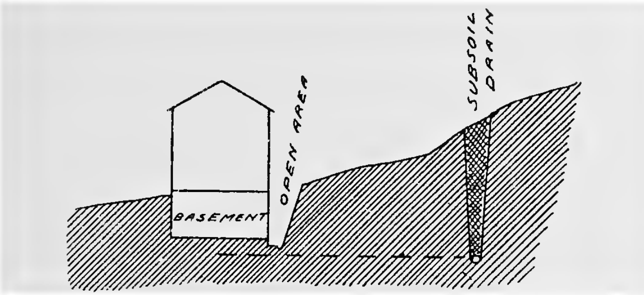


Fig. 3.

Fig. 4 to be a block plan of the site, showing the building, the arrowheads showing the dip of the strata. The subsoil drain would be given a slight fall from A to B and from the latter point it could be gradually brought out to the surface at some convenient point, or carried away to the nearest natural outfall, just according to the use to which the surrounding land was put. Figs. 3 and 4 are not drawn to scale, the size of the drains being exaggerated for the sake of clearness.

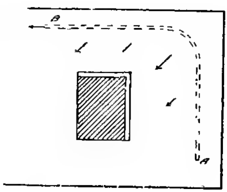


Fig. 4.

As has been pointed out, it may or may not be necessary to drain the subsoil of a building, but whether it be necessary or not, there are many other causes of dampness which it is necessary to guard against.

The principal causes of dampness are the following: (1) moisture rising from the ground; (2) rain beating on the faces of the walls; (3) rain soaking downwards through the walls; (4) waste pipes fixed close to the walls and becoming defective; (5) defective roofs and gutters, and (6) defective fittings or burst pipes.

Prevention is always better than cure, and the means of preventing dampness arising from each of these causes will therefore be dealt with fully.

1. Moisture Rising from the Ground.

Air, as it becomes warm, tends to rise; therefore there will always be an upward tendency on the part of the air in a building, since even though there be no warming of the air by heating or artificial lighting, yet it will be warmed and rendered lighter by mere contact with the occupants. Assume a house to be occupied, with all the external doors and lower windows closed; the air will be tending to rise and must be replaced from somewhere, or, if not replaced, will, in time, make the house very unhealthy. The house therefore tends to act as a sort of suction pump, and would draw air out of the soil—air possibly charged with organic impurities and moisture—if means were not taken to prevent it. It is therefore necessary to put a layer of cement concrete over the whole site of the building, of a thickness of not less than 6 inches, which effectively prevents the mischief if properly done. If badly done, moisture and air will find its way through. It is better, therefore, to cover the top of the concrete with a thin layer of cement, termed cement "rendering," or, if expense is no object, a thin layer of asphalt.

As a sort of second line of defence, if an ordinary wooden floor is used (that is, other than a wood block floor), a clear, well-ventilated air space should be left between the top of the concrete and the underside of the floor timbers. This space should be, if possible, 18 inches deep, and thoroughly ventilated by means of perforated or air bricks, or gratings, in order to protect the floor timbers from the possibility of dry rot, which would, otherwise, cause them to decay and crumble away in time, in the form of a brown, snuff-like powder. In the early stages of dry rot water exudes freely from the timber. This air space is of great value as a reserve precaution against the rise of ground air, though it is generally regarded only as a provision for the security of the timbers. There should be plenty of air bricks or gratings in the outer walls, and they should be carefully placed so as to ensure a through current of air. There are often too few of them. Care should be taken that they do not get obstructed by the formation of garden beds or rockeries in front of them. It is usual, in forming a ground floor where there are wooden joists, to make the joists of less depth than those of upper floors and to give them a proportionately shorter bearing. Accordingly, what are termed sleeper walls are provided to give intermediate support to the joists.

These walls, which are usually only a foot to 18 inches high, need not be more than a half brick thick, and should be built "honeycombed," that is, with spaces left as shown in Fig. 5. This provides for the free circulation of air under the floor. The sketch shows a longitudinal section of a honeycombed sleeper wall, the bricks being shown by hatched lines.

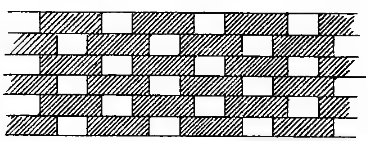


Fig. 5.

Notwithstanding the concrete over the site, and a thicker bed of concrete under the bases of all walls, moisture will rise into the walls by capillary attraction from contact with the soil. This must be prevented by the use of a horizontal damp-proof course placed in the wall about 6 inches above ground level and below the floor timbers.

There are a large number of materials used for this purpose. Perhaps the commonest is a mixture of pitch, tar, and sand, boiled together and laid on hot. A better form consists of two courses of stout slates set in cement, and laid breaking joint; that is, so that no two joints come one over the other.

In the case of unequal settlement of the building, a slate damp course is liable to fracture, leaving a way through. Sheet-bitumen is also largely used and is good if properly jointed—a precaution often overlooked. Sheet-lead is also sometimes used, but is unwarrantably expensive, and apt to become perforated by unequal settlement of the building. If used, it should have lapped and soldered joints. Sheet-lead between an upper and lower layer of good tarred felt is another example. One of the best forms of damp course consists of a layer of good mastic asphalt about a half-inch thick. It should not be of a greater thickness than this; not only is a greater thickness unnecessary, but in very hot weather asphalt is liable to soften, and an instance could be given of a house having, as a whole, slewed round on a thick asphalt damp course.

A really first-class form of damp course is provided by a layer of glazed stoneware ventilating slabs. These are from $1\frac{1}{2}$ to 2 inches thick and are perforated from edge to edge; they thus form an excellent substitute for the usual air bricks. Many varieties of this kind of damp course are obtainable, the upper and lower surfaces being generally corrugated, and the perforations being either circular or diamond shape in section. The slabs should be set in cement. Sometimes they are jointed, in cement, edge to edge, and in other cases they are intended to be set without such a vertical joint. One sometimes finds old houses with no damp courses. A good way to deal with them is to insert a damp course of blue bricks set in cement. This can readily be done in short lengths of about a yard each, the old course of bricks being cut out and replaced by the non-absorbent ones. There are also machines on the market now for inserting damp courses of other kinds in walls where none previously existed.

Where the house has no basement, therefore, the construction around the base of the wall would be as shown in Fig. 6, in which the thick line shows the damp course and AB the air bricks. The two could be combined as just described, and in any case they should both be below the floor timbers. A 6-inch layer of concrete is shown 18 inches below the floor timbers.

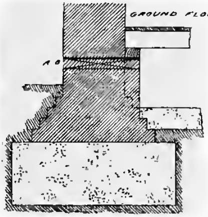


Fig. 6.

If, however, the house has a basement, additional precautions are necessary, owing to the earth abutting on the basement wall above the level of the floor. There are many methods of dealing with such a case, the use of the various methods being largely governed by considerations of economy and sentiment respectively.

Probably the best method of dealing with the basement is that of the open area, an example of which is shown in Fig. 7. It will be seen that an area is formed, wide enough

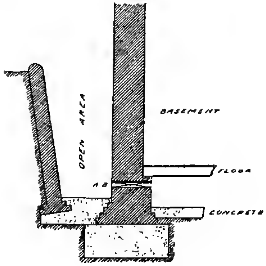


Fig. 7.

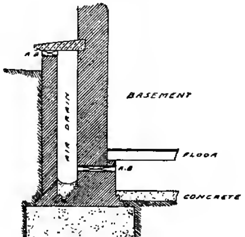


Fig. 8.

to walk round, paved with concrete rendered in cement and laid with falls to gulleys at intervals. The earth is kept up by a small retaining wall, either sloping as shown in the sketch, or vertical. If the retaining wall is vertical, it requires to be rather thicker near its base. The arrangement of the damp course and air bricks is as already described.

A second method is that shown in Fig. 8, which represents a covered "air drain," about 9 inches or a foot wide. It is often formed with a concrete bottom, but this is not indispensable. It is covered with stone slabs built into the main wall and sloped or "weathered" on the upper side to throw off the rain. A damp course and air bricks are provided under the floor, and a second damp course and series of air bricks just under the covering slabs as shown. This ensures adequate ventilation to the space under the floor timbers, provided, as already stated, an adequate number of air bricks is put in. The bottom of the air drain should be somewhat lower than the air bricks in the main wall, to allow of the accumulation of any dust without obstructing the air bricks. This method is not so unsightly as that of the open area, and it is cheaper, but the air drain cannot be cleaned out readily like an open area.

Another method is shown in Fig. 9. In this the base of the wall is built with just a narrow cavity about $2\frac{1}{4}$ inches wide, the thin portion of the wall being tied to the thicker portion by means of galvanized iron ties or glazed stoneware bonding bricks, there being numerous varieties of both. The stoneware bonding bricks are the better, owing to the possibility of the ultimate corrosion of the iron ties. At the top of the cavity a plinth is formed round the building by means of a course of cover stones, under which is placed a damp course and series of air bricks. In this case and the preceding one, the importance of not having large holes through the air bricks will be clearly seen, as they might lead to the entrance of vermin.

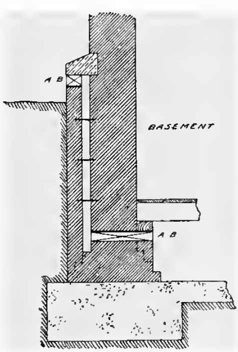


Fig. 9.

The simplest and cheapest method, and one that is quite efficient if the work is really well done, is given in the next sketch, Fig. 10. It shows the wall protected against the earth by a coating of mastic asphalt not less than ½ inch thick. At the base of the wall this coating joins the damp course, and at the top it is turned into a joint of the brickwork. It will be seen that this method, if carried out right round a building in the manner shown, would not provide for the ventilation of the space under the floor. In such a case, the wall should be carried down rather lower, and vertical iron tubes carried down in the thickness of the wall, with external gratings at the top and internal gratings at the bottom; an alternative course would be to put a wood block floor which needs no ventilation.

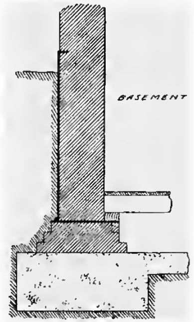


Fig. 10.

Cheaper substitutes for the asphalt are sometimes used, such as a mixture of pitch, tar, and sand, or a rendering of neat Portland cement about ¾ inch thick, but these are not so effectual as asphalt. Sometimes, also, the cavity shown in Fig. 9 is filled in with asphalt, but no useful purpose is served by this, and the ventilation of the space under the floor requires to be separately dealt with. Again, a vertical damp course is sometimes put up the middle of the wall, with a horizontal damp course at the foot and another just above ground.

2. Rain Beating on the Faces of the Walls.

This, in any ordinary unexposed position, is merely a question of materials. Good bricks are readily obtainable, and such bricks are not very absorptive. Continued heavy rain would not go right through a good brick wall of usual thickness, and the moisture would readily evaporate afterwards. The use of sea water or sea sand in building work would lead to dampness and should be avoided in all cases. Similar remarks apply to stone walls. A good building stone for external work should be only slightly absorptive. Good terra-cotta forms a non-absorptive wall facing, so also do glazed bricks, but the appearance of the latter prohibits their use in domestic work. A well-built ferro-concrete wall should also be impervious to moisture.

In a very exposed position additional precautions have to be taken. In cottage work one sometimes finds external walls rendered with tar or slated. In better class work walls are frequently hung with tiles. Cement rendering is also largely used, though its appearance is prohibitive in good domestic work. Another method is to build a cavity wall with the thin part outside to act as a weather screen and the thicker part inside to do the work of carrying the floors and roof. The two parts should be properly tied together with stoneware bonding bricks. Still another method is that of using a vertical damp course throughout the entire height of the wall.

3. Rain Soaking Downwards Through the Walls.

If a house is roofed with overhanging eaves, this question does not arise, except in so far as already dealt with, but in the case of parapet walls, means must be taken to prevent rain soaking downwards. The case is often met by forming the top course of non-absorbent bricks set and bedded in cement. Less unsightly, but also apt to be less efficient, is the formation of the top course of ordinary bricks set and bedded in cement. Other methods consist of (*a*) tile creasing with a course of bricks above as in Fig. 11; (*b*) a course of drip tiles as in Fig. 12, and (*c*) a proper coping of stone or terra-cotta. Tile

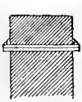


Fig. 11.

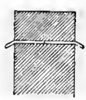


Fig. 12.

creasing is used, as a rule, under a course of bricks set in cement edgewise. The creasing consists of two courses of roofing tiles, laid breaking joint, and bedded and jointed in cement. Above the tiles, where they project, it is usual to put a triangular fillet of cement to throw the water off.

Drip tiles, as shown in Fig. 12, are laid in one course only, being set in cement, and usually having the course of bricks above, as in tile creasing. The downward slope of the projecting part of the tile causes the water to drip clear of the wall.

The best method of dealing with this case, however, is to use a proper coping, shaped at the top so as to throw the water off, and projecting on each side as shown in Fig. 13. The top of the section is often of segmental or other fancy shape, but that is merely a matter of detail, the exact outline being immaterial so long as it is such that the water is thrown off. The underside of the oversailing part should have a small groove, or throat, as shown in the sketch, to intercept the water which would otherwise travel along the underside to the face, and possibly, if the pointing of the brickwork were decayed, to the interior of the wall. Any such projections should be throated in this way, other examples being window sills and string courses. The groove need not be more than about half an inch wide but should not be less than three-eighths of an inch or it will be too small to be efficient.

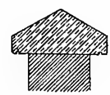


Fig. 13.

Parapet roofs are rather more liable to cause dampness than the ordinary eaves roof, owing to the gutter behind the parapet becoming defective.

4. Defective Waste Pipes Fixed Close to Wall.

This cause of dampness arises chiefly from rain-water pipes, though other waste pipes sometimes give trouble. Rain-water pipes should be jointed with red-lead putty, but are very frequently found unjointed. They are apt to get obstructed with rust and other things at the foot, and, in times of heavy rain, to fill up, causing leakage at the lower joints. With the usual practice of fixing them close to the wall, this leads to the formation of a damp patch of wall around the joint. The difficulty is overcome at once by properly jointing the pipes, and things can be made doubly safe by fixing them a short distance away from the wall, which also makes it possible to paint them all round. The use of very thin pipes sometimes leads to cracked pipes, and consequent leakage, by unequal settlement of the building. This can be obviated by the use of reasonably thick pipes, although, of course, rain-water pipes do not require to be so thick as those jointed by the consolidation of molten lead, such as iron soil pipes.

5. Defective Roofs and Gutters.

The smaller the pieces in which the roof covering is used, and the more irregular their shape, the steeper should be the slope of the roof. Thus, tiles are smaller than slates, and owing to slight warpings in the process of burning, they do not lie so closely together as slates. Consequently the pitch or slope of a tiled roof is made usually about 45° and that of a slated roof about 30°. On the other hand, materials which can be used in large pieces and which are capable of a fairly close joint can be laid to a very slight fall. Sheet-lead, for example, can be used in fairly large pieces, being very malleable so that adjoining edges can be dressed closely together with but little liability of the heat of the sun drawing them apart again. A lead-covered roof, therefore, needs only a slight fall, which should not be less than about 3 inches in 9 feet. Zinc is not so easily or perfectly jointed and is more susceptible to the action of the sun. It should therefore be given a greater fall than lead, say not less than 6 inches in 9 feet. Zinc should never be laid on roofs to which cats can obtain access as the material is not proof against the acids in the organic liquids given off by these animals.

If the roof covering is jointless, such as asphalt, the slope can be less than for lead. It need only be sufficient to ensure throwing the water off; say not less than $1\frac{1}{2}$ inches in 10 feet.

The slope of a roof is dependent on other points in addition to the foregoing. The architectural style of the building may call for a particular sort of roof. The liability to falls of snow is another point to be considered. In countries like Norway one finds roofs of very high pitch, whereas in Southern Europe one generally finds the flat roof.

Roofs with gutters behind parapet walls are more likely to give trouble than those with projecting eaves. A heavy fall of snow may cause such a blockage of a parapet gutter that water or moisture may enter the roof or walls above the gutter. With such roofs, therefore, a damp-proof course should be provided at the top of the wall below the roof.

Slated and tiled roofs can be rendered more secure against the elements by putting boarding and inodorous tarred felt under the covering. In common work it is usual to put battens only. The greater thickness of tiles, and the fact that they are not such good conductors of heat, make tiles the better of the two materials from the point of view of keeping a building warm in winter and cool in summer, this point being of some importance where rooms are formed in the roof.

The best-known slates are those from Wales, particularly those from the Penrhyn and other quarries in the neighbourhood of Bangor. Other good varieties are obtained in the Festiniog and Portmadoc districts of Wales, and in Westmoreland and Cumberland. In Scotland perhaps the best known is the Easdale, and in Ireland the Valencia slate. Delabole in Cornwall, furnishes a thick slate often used on account of its appearance.

Many slates are imported from Canada and Belgium. The Belgian slates sold in England are generally immature from a geological point of view and very liable to crumble and decay in time.

Slates are secured by means of zinc or composition nails, iron nails being unsuitable because they are liable to corrode. The slates are laid to a lap depending upon their size. They can be nailed either near the head of the slate, or near the centre, the former being often preferred as every nail is covered by two slates. On the other hand, the leverage on the heads of the nails is greater, and the expense is increased; consequently the centre nailing is more usual. The size most generally used is the Countess, which is 20 inches by 10, and laid to a lap of 3 inches. The tail, or lower edge, of each course overlaps the head, or upper edge, of the course next but one below it to an extent termed the lap as shown in Fig. 14, the distance from the tail of one course to the tail of the next course below being termed the gauge or margin. If the slating is nailed at the head, the lap is the distance from the nail hole in any course to the tail of the course next but one above it. At the top and bottom edges of the roof, double courses of slates must be put, in order to prevent water passing through the joints between the adjacent edges of the slates in the upper course at the bottom edge and of the under course at the top edge of the slope.

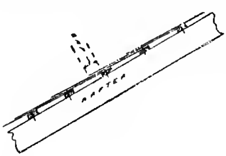


Fig. 14.

The ridge or summit formed by two adjacent and opposite slopes is made watertight by several methods. One is to use ridge tiles moulded to the shape of an inverted V and bedded on mortar. Another is to use a built-up ridge of slate. In this method two pieces are used as shown in Fig. 15. The under piece, marked A, is fastened by screws at its upper edge and the piece marked B fits over it, both pieces being bedded in mortar. The adjacent ends of the pieces marked B are connected by means of small pegs termed dowels. Still another method is that of forming the ridge of lead. In this case a wooden roll is put on top of the wooden ridge and sheet-lead dressed over from side to side, the section of the lead being the same as the uppermost edge of the slate ridge just shown.

Fig. 15.

Slopes intersect at other points than the ridge, forming what are termed hips and valleys, the former being the external angles and the latter internal. Thus, in Fig. 16 the ridges are marked R, the hips H, and the valley V. The hips are usually formed, in a slated roof, in the manner last described for dealing with the ridge, i.e. a wooden roll is fixed to the hip rafter and lead dressed over it on to both slopes. In the case of a valley, a lead gutter is formed in the angle as shown in section by Fig. 17, which shows the roof boarding carried by a valley rafter. Two small triangular fillets prevent the water getting under the slates. The lead is shown in section by a thick line.

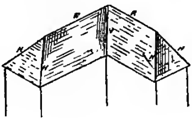


Fig. 16.

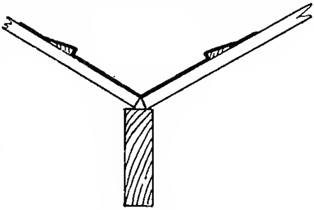


Fig. 17.

Tiles for roofing work are of many kinds, such as the plain tile, the pan tile (with a roll or wave in its width), the double roll tile (with two such waves), and many patented forms of self-locking tile. The best-known and ordinary form is, of course, the plain tile, $12\frac{1}{2}$ by $6\frac{1}{2}$ inches and about $\frac{1}{2}$ inch thick.

Tiles are laid in a similar way to slates, each course having a lap over the next but one course below it, with double courses at top and bottom of the roof. Tiles may be fixed by hanging them to laths by means of projecting nibs moulded on their under sides, by oak pegs driven through holes in them and hanging them to laths, or by means of zinc or composition nails as in the case of slates, the last-named method being the best and always adopted where boarding is used.

The ridges of tiled roofs are always finished with ridge tiles set in mortar, and, generally speaking, hip and valley tiles, specially moulded, are used for hips and valleys, although these features may be dealt with by means of sheet-lead as before described.

It is not within the province of this book to go very fully into the subject of general building construction, but the details of roof work, so far as they affect the prevention of damp, must be dealt with.

A gutter behind a parapet may be of either tapering or parallel form on plan. Fig. 18 shows an example of the former. All gutters must have a good fall, and in the case of such a gutter there should be a fall of not less than about 2 inches in 10 feet. The gutter is carried by bearers, fixed at varying heights, in order to give the fall, with the result that the gutter is of tapering form on plan. The least width should be 9 inches. It will be seen that the bearers carry gutter boards and that a small triangular fillet prevents the water from getting up under the slates. The lead is shown by means of a thick line and is in two pieces, (1) the main gutter, and (2) a flashing fixed into the joints of the brickwork or into a groove formed in the case of stonework. This flashing should lap well over the vertical

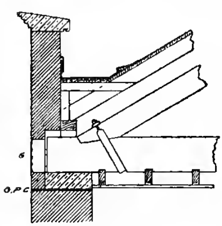


Fig. 18.

side of the gutter but should not be carried nearer than about 1½ inches to the bed of the gutter. The transverse joints of the gutter should be formed by means of steps or drips, details of which will be found later under the heading of lead flats. These should occur at intervals of not more than 9 feet. Where a long gutter falls for half its length in one direction and half in another, the joint at the summit should be formed by means of a roll, details of which will also be found later. The flashing should be secured by either cast-lead wedges, or small round pebbles. Iron wall hooks, or oak wedges, are often used but are open to objection; the former on the ground that they rust away and become loose, and the latter on the ground that they shrink.

Snow boards or grids should be provided to all such gutters and also to flat lead roofs, so that the snow does not impede the flow of water more than necessary. These should be kept well up off the lead.

A section through a parallel, trough, or box gutter is shown in Fig. 19. Such a gutter should be wide enough to enable one to walk along it, say 1 foot to 1 foot 3 inches. The construction will be obvious from the sketch after reading the foregoing description of Fig. 18. It will be seen that in Figs. 18 and 19 there would be a closed-in space between the ceiling and the underside of the roof boarding. This space should be ventilated by means of air gratings, for the preservation of the timbers. Such a grating is shown at G in each of the two cases. In order to prevent moisture finding its way downwards by the overflowing of the gutter, should it become obstructed, a damp-proof course (D.P.C.) should be put just below the roof. The outlet of the gutter should be provided

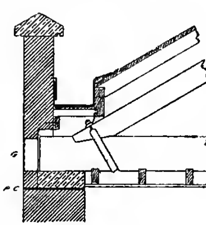


Fig. 19.

with a wire guard to prevent it becoming obstructed by leaves or birds' nests.

Gutters and flashings are often formed of zinc, but it is a very inferior substitute for lead and should be avoided wherever possible. The general arrangement, if zinc be used in the two cases just illustrated, is very similar but the flashings should be "beaded" at the lower edge to stiffen them. An example of a zinc flashing is given later under the heading of flat roofs.

Where a chimney, or similar feature, cuts through a roof, a small gutter, very similar to that shown in Fig. 18, must be provided, the only difference being that the gutter behind the chimney would be smaller.

On the lower side of a chimney or similar feature an "apron" of sheet-lead is provided, secured at its top edge in the same way as a flashing, and dressed over the slates or tiles as shown in Fig. 20. Similar construction should be provided where the top of a sloping roof abuts against a wall. In the case of a chimney the apron is generally in one piece, but in the case of a wall it should be of pieces not longer than about 10 feet and well lapped at the joints.

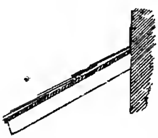


Fig. 20.

At the sides of a chimney, or where a slope abuts, at the end, against a wall, a flashing should be used. In the case of brickwork this is of the type known as "stepped". Fig. 21 shows an elevation of a stepped flashing against the side of a brick chimney stack. It consists of a piece of lead cut so that its upper edge is in steps, in order to enable it to be wedged into the horizontal joints of the brickwork. The fronts of the steps are cut so that they slope backwards in order to prevent rain driving in between the lead and the

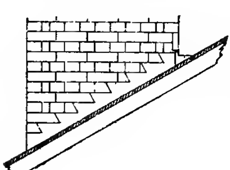


Fig. 21.

brickwork. If it were so cut that the fronts were vertical and in such a position that they could also be wedged into the vertical joints of the brickwork, the upper edge of the flashing would, it will be seen, be very irregular and unsightly. The lower end of the flashing is dressed round the corner over the apron, and the joint at the upper end is made, as shown, by dressing over the end of the gutter. The flashing to the gutter is also shown dressed round the corner to form a finish.

In the case of stonework, the upper edge is generally straight, and parallel to the slope of the roof, being turned into a groove, or raglet, cut in the stone, and, of course, wedged.

The lower edge of the flashing is usually dressed over the slates or tiles as shown in Fig. 22, the lead being shown by a thick line. A superior method of construction is that shown in Fig. 23. In this case the tilting fillet is fixed a little way off from the chimney or wall (about 2 inches), and the lead forms a small secret gutter.

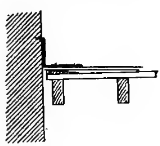


Fig. 22.

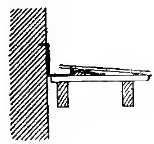


Fig. 23.

An alternative method of dealing with such a case is to use what are termed soakers, with a flashing over them. Soakers are relatively small pieces of lead bent to a right angle and built in with the slating as the roof is covered. The soakers lap well over one another, and either a stepped or a raking flashing covers their top edges. The number of lapped joints is the weak spot of this method, which is not to be preferred to the methods before described.

Corrugated iron sheets are often used for roofing sheds or large temporary buildings. They should be of good quality and well galvanized or they will soon rust through. The sheets are well lapped on all sides and secured by galvanized screws and washers set in white lead. Such a covering should be given a slope of not less than 1 in 10. On the decay of any part of the coating, a galvanic action is set up which rapidly destroys the iron covering.

Lead flats form a good roof if well constructed. The sheets must not be too large, owing to the expansion and contraction of the metal with changes of temperature. The edges of the sheets should be jointed by means of "rolls". These are usually formed by dressing the lead over wooden rolls, but sometimes by forming hollow rolls with the lead only. The latter is a more expensive method and has nothing much to recommend it over the usual method. The rolls should not be at greater intervals than 2 feet 6 inches centre to centre. The usual method of construction in the South of England is that shown in Fig. 24, in which the edge of one sheet is dressed nearly round one roll, and the edge of the adjoining sheet is dressed right over and on to the flat for 2 or 3 inches on the opposite side. The edge of the sheet is rather liable to turn up in time and facilitates the drawing up of water by capillary attraction. The method has nothing to commend it, and is really an unprofitable employment of material. A much better system is that generally adopted in the North of England, and illustrated by Fig. 25. The only difference is that the edge of the sheet is not continued down on to the flat, but stopped about $\frac{3}{4}$ of an inch above it. The wooden rolls are about 2 inches in diameter. The rolls are often formed of the section shown by

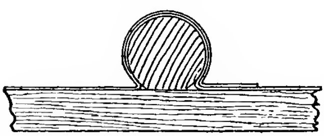


Fig. 24.

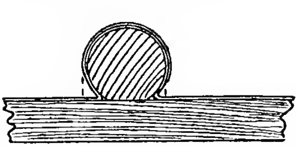


Fig. 25.

dotted lines in Fig. 25, but such a method gives a less satisfactory grip for the lead.

The joints across the fall of the flat are formed by means of drips, which should be not more than 8 feet apart. They are really steps and should be not less than $2\frac{1}{2}$ or 3 inches deep. Fig. 26 shows the usual method in the South of England and is on the same lines as the roll, so far as the carrying of the upper piece on to the flat is concerned. The lead is let into a rebate or sinking on the edge of the upper boards, so as not to cause a ridge at the point A, since traffic over the flat might cause the lead to wear through at that point. Fig. 27 shows the North of England method, which is a better one for the reasons just given. The rolls and drips just given are applicable to gutters also. A lead flat should have a fall of about 3 inches in 10 feet. The boards should be laid in the direction of the slope, as otherwise their edges might in time curl up and form hollows which would tend to check the flow of the water. With lead flats parallel gutters are used, very similar in construction to that shown in Fig. 19, but with the difference that no tilting fillet is needed. The side of the gutter where it adjoins the flat is best constructed on the lines shown in Fig. 27. The ends of the rolls are protected by the lead being dressed over them. Where the flat abuts on a wall, the lead should be turned up against the wall about 6 inches, and covered by a flashing. The slope is, of course, insufficient to call for a stepped flashing, so its

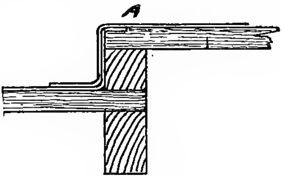


Fig. 26.

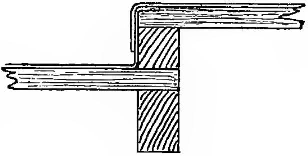


Fig. 27.

top edge is always horizontal for each length from drip to drip.

Sheet-lead is obtainable in two forms, cast and milled. The former is of little value, being liable to flaws and sand holes. Milled lead should always be used for flats and gutters. It is obtained by first casting a sheet 6 or 7 feet long, about 5 feet wide, and about 6 inches thick, and then passing it through a rolling mill, the rollers being heated to facilitate the reducing process. Milled lead is obtainable in sheets up to about 35 feet in length by 9 feet in width, and is made of varying weights per foot superficial. It is described in this way, being known as 3, 4, 5, 6, 7, and 8 lb. lead respectively, such description implying the weight per square foot.

For flats and gutters 7 or 8 lb. lead should be used; for hips, ridges, and valley gutters 6 or 7 lb. lead, and for flashings 5 lb. lead.

As has already been stated, zinc is used sometimes as a cheap substitute for lead. The details of a zinc flat are quite different from those of a lead flat, except in so far that rolls and drips are used. The rolls should not be further apart than 2 feet 10½ inches, centre to centre, and the drips should be at intervals of about 8 feet. The fall should be, if possible, about 6 inches in 10 feet, as the joints cannot be so perfectly made. Zinc is not described by its weight, but by its gauge, the gauge used being the Vielle Montaigne, or Belgian, zinc gauge. For flats the gauge should not be less than No. 16, and for flashings No. 10.

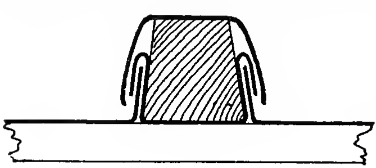


Fig. 28.

Fig. 28 shows a section of a zinc roll. It will be seen that the shape of the wood roll differs from that used with lead, owing to the fact that zinc cannot be so readily dressed round a curved surface as lead. The edges of the sheets are turned up against the side of the roll and held down by clips, or tingles, which are strips about 1½ inches wide placed about 3 feet apart. The roll is covered by a capping, which is secured to the tingles by clips soldered to its underside. The ends of the rolls are protected by shaped pieces soldered on.

There are various patented systems in which soldered joints are avoided, such as that known as Braby's system, in which the ends of the cappings are turned up or down in such a way as to make a watertight joint without solder. Such systems are good as they overcome the rigidity of the soldered connexions.

The shape of the drip, too, is different from that used with lead. Fig. 29 shows the construction. Instead of being turned over into a rebate or sinking, as with lead, the top edge of the lower sheet is bent forward, and the edge of the upper sheet bent to a roll or bead. Where the zinc flat abuts on a wall, the sheet is carried up the wall about 6 inches, and protected by a flashing with a beaded lower edge as shown, the bead checking the tendency, which would otherwise exist, for the lower edge to curl outwards. The details of gutters in zinc can be seen from Figs. 29 and 30, the former showing one edge of the gutter and the latter the edge against the wall.

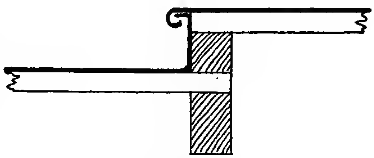


Fig. 29.

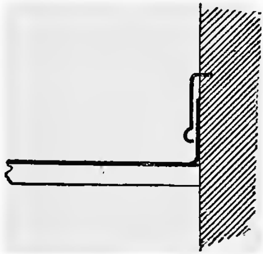


Fig. 30.

6. Defective Fittings and Burst Pipes.

These are an occasional cause of dampness, but one which is always avoidable. Well-designed and properly fixed fittings, together with pipes fixed against internal walls need never be a cause of dampness. Where pipes are fixed against external walls, the danger of damage from frost is much greater, but there are many methods of protection in the way of casing them with non-conducting materials, such as hair felt, slag wool, and similar things.

Let us next consider the construction and equipment of the building from other standpoints of a sanitary or hygienic nature.

If walls are plastered, the plaster should be carried down behind the skirting board to prevent the entrance of vermin. The old-fashioned lath and plaster partition with its timber posts or studs should not be used. It takes up more room than a partition of fire-resisting slabs and affords a refuge for vermin. There are many types of slab partition, made up of thin, strong slabs, readily finished with plaster on either face. They have, however, the drawback that they are difficult to fix to, and are apt to readily transmit sound.

There should be as few surfaces as possible on which dust can collect. Elaborate mouldings, cornices, high-relief lincrusta or anaglypta, should be avoided on this ground. In hospitals, where absolutely sanitary conditions are a *sine quâ non*, internal angles are avoided entirely, all angles, including those between walls and floors, being rounded.

Walls should be plastered in order to give a smooth surface on which but little dust can collect. The wall surface can be finished with paint, distemper, or paper. The first named is generally out of the question on the ground of appearance, but effectually prevents the absorption of impurities by the plaster. Washable distemper, having a dull surface, is more pleasing in appearance and can be readily cleansed. Washable distemper is a thoroughly sanitary material, most varieties containing a disinfectant in their composition.

Ordinary distemper is not so good, being mixed with size (animal matter), which is liable to decompose and putrefy. The size, too, often smells in hot weather. The tendency to smell and to putrefy can be arrested by the addition of a small quantity of turpentine, or of carbolic acid, but the ordinary distemper still has the disadvantage of not being washable.

Paper, unless it is of the variety known as "sanitary" wall-paper, has a rough surface which readily collects and retains dust. The appearance of sanitary wall-paper, with its slight glaze, prevents its extensive use in houses of good class. Whenever wall-paper is renewed, the old paper should be entirely removed from the walls, as it will have absorbed dirt and possibly not be free from germs, while behind it will be decomposed paste in most cases. The walls should be well washed down with water containing a disinfectant before re-papering.

For such rooms as sculleries, bathrooms, housemaids' closets, and water-closets, a glazed surface is desirable for the walls. For sculleries, tiles or glazed bricks are the best, failing which the walls should be painted and varnished. For bathrooms and housemaids' closets, enamelled walls, or a lining of low-relief lincrusta or an anaglypta finished with enamel are good if tiling is objected to. A lining of enamelled zinc, forming imitation tiling, is also quite sanitary. If expense prevents either of these alternatives, varnished paper may be used, but ordinary unvarnished paper is quite unsuitable. Non-absorbent wall surfaces have the drawback that they encourage the condensation of moisture, but their sanitary advantages outweigh this consideration.

For closets, it is a good plan to tile the walls, or, at any rate, to put a tiled dado, with enamelled walls, or low-relief lincrusta finished with enamel above. Here, again, if it is a matter of strict economy, paint, or varnished paper, may be allowed as a cheap substitute.

Where papers, or other materials such as lincrusta or anaglypta are used, the paste used to hang them is liable to ferment unless means are taken to prevent it. This can be done by the addition of a small quantity of alum or oil of cloves.

In dwelling-houses it is usual, for ordinary rooms, to provide a boarded floor, made up of narrow boards with square abutting edges, carried on wooden joists. The boards are cramped up tightly at the start, but soon shrink, leaving openings through which dust can pass to the space between the underside of the boards and the upper part of the ceiling below. When such floors are washed, dirty soapy water finds its way through the crevices and lies decomposing below. Solid floors are therefore much more sanitary, though generally prohibitive from an economical standpoint. A boarded floor with a thin parquet floor over it, well laid, is good, but a solid floor, such as one of ferro-concrete, with well-seasoned wood blocks as a surface, is better. Failing this, the best thing to do is to stain and varnish the boards all over, keeping all cracks stopped up as they from time to time appear. For better-class work, hard woods, with the surface wax polished, can be used.

For sculleries, housemaids' closets, and water-closets a non-absorbent floor is essential. Tiles set on concrete furnish the best method of dealing with such cases. For high-class bathrooms, marble slabs or terrazzo paving may be used, on the ground of their better appearance, while for servants' closets or closets in factories, concrete with a cement-rendered surface will meet the case cheaply and well.

For ordinary rooms, if a carpet is used it should not entirely cover the floor, but leave a margin round the room. Fixed carpets do not provide a really sanitary floor covering. Easily removable rugs are much better, as they can be taken up and shaken daily. Generally speaking, carpets are only taken up, and cleaned or beaten, once a year on the occasion of the so-called spring cleaning. During the remainder of the year the pile of the carpet readily collects dust, which is, from day to day, brushed up into the air of the room, some finding its way into the dust pan, but a large part finding its way back into the pile of the carpet, through which, in time, it works to the underside, as evidenced by the necessity of taking up and beating the underfelt.

It is only fair to point out, on the other hand, that if carpets *are* preferred, it is possible by the daily use of a good make of portable vacuum cleaner, to keep them entirely free from dust. They cannot be so kept by any other means.

Lastly, a word or two with regard to ceilings. Panelled or painted ceilings are the best, being non-absorbent. If ordinary distempered ceilings are used, it is imperative that the plaster should be of the best, made of thoroughly clean sand and lime, sand free from any trace of organic matter which may and will work its way through to the surface in time. The organic nature of the size in the distemper should be killed by the use of turpentine or carbolic acid.

I well appreciate that the foregoing notes may be termed counsels of perfection, but that is as it should be in all sanitary matters. The principles laid down should be followed as nearly as circumstances will permit under the conditions of each case, economical and otherwise.

CHAPTER III

THE BUILDING—ITS VENTILATION.

THE necessity for ventilation has, of course, always existed, though the means and degree have varied according to the knowledge and ideas of refinement of the inhabitants. Even the mud hut had its opening in the roof to let the smoke out and the air in. Probably the two earliest official pronouncements in the way of ventilation were in the form of proclamations by James I and Charles I respectively. Realizing the difficulties of the circulation of air in narrow streets with buildings having upper stories which projected considerably beyond those below, James I, in 1619, ordered the walls of all new buildings to be carried straight up, while in 1631 Charles I, by proclamation, fixed the minimum heights of rooms and proportions of windows " for the benefit of ventilation ".

Local authorities of the present day possess large statutory powers in this direction under Building Acts, Public Health Acts, and by-laws framed under such Acts. Much has been done by legislation in the provision of sufficient air space around buildings, the prevention of overcrowding, and so on. An honest attempt seems to have been made in the form of the Housing, Town Planning, etc., Acts, 1909 and 1919, to ensure the more skilful planning of towns and development of building estates. Notwithstanding all this, however, one still finds vast numbers of existing buildings ill planned and badly ventilated.

There are few subjects in a more unsatisfactory state than that of ventilation, or the removal and dilution of the products of respiration and combustion, though a large amount of experimental work has been done in recent years. Nature helps to purify air through the medium of wind, rain, oxidation, and diffusion, and man can do much to check its pollution by insisting on cleanliness and absence of dust in rooms, and on the rooms being well lighted.

Let us first consider the composition of pure air and the things which subsequently render it impure.

Approximately, pure air consists of nitrogen and oxygen in the proportion of about four to one, but more definitely it can be stated as, by volume :—

Oxygen . . .	20·94 per cent.
Nitrogen . . .	79·02 ,, ,,
Carbonic Acid Gas (or Carbon Dioxide)	·04 ,, ,,

Oxygen is an element which combines with nearly everything. It is found in the soil, and it is also the principal constituent of water, of which it forms 89 per cent. by weight. The quantity left in the air is, practically, what is left over after it has combined with everything possible.

In the pure air of mountain tops, or near the sea, one finds just a trace of ozone, which is a concentrated form of oxygen produced principally by electric discharges during thunder-storms, silent discharges from thunder-clouds, the evaporation of sea-water, and the action of some vegetable products on the air. It is also produced artificially by means of electrical discharges through air, a fact that is taken advantage of in the practice of ventilation. Ozone possesses both positive and negative properties. Thus, it renders the air healthful and invigorating, while on the other hand it acts as a disinfectant, killing harmful germs. It possesses a distinct smell, which makes the air of an open, seaside place quite distinctive from the air of ordinary towns.

The nitrogen in the air acts as a diluting influence on the oxygen. Human beings could not live long in pure oxygen, though it would mean a short life and a merry one. Oxygen is absolutely necessary to life, its removal from the air, or even a substantial lessening of its proportion, causing death. It is necessary for the processes of combustion, and also for the production of artificial light, except in the case of electric light.

Carbonic acid gas, or carbon dioxide, though so small in proportion to the quantities of the oxygen and nitrogen in the air, is only second in importance to the oxygen. On its presence depends the existence of all vegetable life. It is a compound of oxygen and carbon, and is formed at the expense of the oxygen in the air and of carbon derived from various sources, chiefly animal respiration and the combustion of carbonaceous matter. It is also given off as a product of fermentation and putrefaction. An eminent scientist calculated that volcanoes give off ten times as much carbon dioxide as is derived from all other sources. It is vital to the life of plants, forming their largest food factor. Under the influence of sunlight, they absorb and decompose it, retaining the carbon and giving off the oxygen again, but at night the process stops. While so vital to plant life, however, it is detrimental to animal life, and 3 per cent of it in the air is fatal.

There are also always in the air myriads of micro-organisms, or as they are popularly termed, microbes. These organisms are very minute, it being possible to get a number equal to one hundred times the population of London on 1 square inch. They reproduce very rapidly, it having been stated by eminent bacteriologists that a single microbe gives rise to a progeny equal to about four times the population of London in twenty-four hours. They are not necessarily harmful, but, the greater the number in any sample of air, the greater the likelihood of the presence of pathogenic or disease-bearing organisms. For all the processes of agriculture they are essential. Their presence in the soil is necessary for the growth of crops, and without their aid the farmer could not ripen his cheese or make his butter. They are necessary, in fact, in the soil, in the manure heaps, in the barn, and in the dairy.

A certain quantity of watery vapour is also almost always present in the air. The question of humidity has already been referred to, but the fact of watery vapour being present in the air of a warm room can be easily verified by a simple experiment. If a glass of cold water be taken into such a room it will chill the air just adjacent to it and cause the deposit of the vapour in the form of minute dewdrops on the glass.

Minute particles of dust are also almost always present in the air. If one places oneself in a dark room and makes just a pinhole through which a ray of sunlight can pass, one can see these fine particles floating about in the streak of light. To give an idea of their minuteness, one ingenious investigator has stated that the average smoker gives off 4,000,000,000 of such particles into the air at each puff of smoke from a cigarette.

Among the impurities found in air, in addition to dust, are organic matter, various acids, suspended matters, and marsh gas.

The organic matter may be either in the form of vapour, or in the form of minute particles of solid matter. The bad effects of foul air are largely due to this impurity.

The air of manufacturing districts is frequently charged with sulphuric and hydrochloric acids due to the waste products of manufacturing processes. Ammonia compounds are also often found, due to decaying organic matter.

Among the suspended matters found in the air are particles of fine sand, dried mud, carbon from smoke, iron rust, and other inorganic items, as well as organic impurities, such as fragments of horse litter, hairs, spiders' webs, spores of fungi, pollen, etc.

In the neighbourhood of low-lying land marsh gas, otherwise known as carburetted hydrogen, or methane, is often found.

In the process of respiration, air is inhaled into the lungs, the oxygen being brought into contact with the blood. A large part of the oxygen is converted into carbon dioxide. In the course of twenty-four hours the average man gives off a quantity of carbon dioxide containing as much as a half pound of carbon. Moisture is also given off to the extent of from about 6 to 27 ounces in twenty-four hours. Organic matter and minute quantities of ammonia are also given off.

In the processes of combustion and artificial lighting, among the impurities given off are carbon dioxide and moisture, unconsumed carbon; carbon monoxide, due to imperfect combustion, particularly from coal gas and coke fires; also sulphuric acid and sulphuretted hydrogen from gas which has not been properly purified. It is these last two impurities which are answerable for spoiling pictures and the bindings of books.

In dealing with the question of ventilation it is necessary to consider standards of permissible impurity. The principal impurities found in the air of rooms are organic matter and carbon dioxide. The former cannot be accurately or easily estimated, but is known to bear a fairly constant ratio to the latter, which is therefore adopted as a basis. The proportion of carbon dioxide in the air of a room should not exceed ·6 cubic feet in 1000 cubic feet of air. The ordinary air of towns contains about ·4 cubic feet in 1000 cubic feet, and the average adult is said to give off about ·6 cubic feet of the gas in one hour. At this rate, he will, in twenty minutes, raise to the allowable limit of impurity 1000 cubic feet of air, and so should be provided with about 3000 cubic feet of air per hour. This fact is often put another way, to the effect that he should be given 1000 cubic feet of space and the air be changed three times an hour.

It is not wise to put it in this way, as the change of air is more important than the space occupied, and it has been shown that apartments with a large amount of cubic space per head and slow change of air, are less healthy than those with less space and more frequent change. In calculating the quantity of air required, each gas jet can be regarded as equal to one human being in its effect on the purity of the air.

In calculating the cubic space, the height of the room requires careful consideration, and must be limited so far as the calculation goes. Arithmetically, a very small space, and very lofty room, might fulfil the conditions, but it would not be satisfactory from a ventilation point of view. Above a height of 12 feet the air space can be ignored in all cases. Suppose, for example, the space required for any particular room, from a ventilation point of view, is 7200 cubic feet. Determine its floor space, assuming the room is to be 14 feet high. The cubic space will be the floor area multiplied by the height. The *usable* height will be 12 feet, therefore the area will equal $\frac{7200}{12}$ or 600 square feet. A room 30 feet by 20 feet will therefore meet the case.

The following figures will give an idea of the customary allowances of cubic space per head: Common lodging houses 300-350 cubic feet; Metropolitan Police quarters 450; Army barracks 600; and for hospitals, adults 2000, and children 1500 cubic feet respectively.

There are certain conditions which any really satisfactory system of ventilation should fulfil. They may be stated briefly as follows:—

1. Fresh air must be admitted or injected, and the vitiated air allowed to escape, be extracted, or expelled.

2. The quantity of air supplied, and the velocity of its admission should be under control.

3. The change of air should be thorough, no stagnant corners being left.

4. There should be no draughts.

5. The incoming air should be clean and humid, and not scorched or deprived of its moisture by defective methods of warming it before admission.

6. The temperature of the air should be uniform and under control.

I may say, at the outset, that I know of no system which absolutely fulfils all these conditions at all times, but the principal systems in use and their respective advantages and disadvantages will be fully described.

Air, as it becomes warm and vitiated, tends to rise, and the air currents from the body also tend upwards. It is essential that the vitiated air be extracted while warm, as the carbon dioxide, when cooled, is heavier than air, and falls to the floor to be re-breathed. The tendency of warm air to rise is an assistance to upward ventilation, but an obstacle to downward, necessitating, in the latter case, the introduction of about three times as much air as is needed, in order to dilute the vitiated air which is sent down to be re-breathed. Again, gas jets and other means of artificial lighting are difficult to deal with in downward systems, as are also halls with galleries.

Systems of ventilation can also be classified under the headings of (*a*) natural, and (*b*) artificial or mechanical, though the two systems are often combined. In a natural system, inlets are provided through which the fresh air enters without assistance, and outlets through which the vitiated air will escape without assistance, but it may be found desirable to let the fresh air in *naturally*, and to assist the egress of the vitiated air by some *artificial* means, such as warming the outlet shaft, providing it with a cowl, or by some other method. Again, the fresh air may be forced in mechanically, the vitiated air being left to find its own way out through the outlets. A *complete* mechanical system provides for mechanically injecting the fresh air and mechanically extracting the vitiated air.

The objections to the natural systems are (1) the source of supply of fresh air is not under control; (2) the incoming air is not so readily cleansed and humidified; (3) the volume, temperature, and velocity of incoming air are not under control; and (4) it is a draughty system.

On the other hand, it is simple and inexpensive, costing very little for maintenance, and doors and windows may be freely opened without disorganizing the system.

The Plenum system is the principal of the mechanical methods. In it fresh air is propelled into the building and admitted to the room at a fairly high velocity, usually well above the heads of the occupants, the vitiated air being extracted just above floor level. The objections to this system are as follows: (1) it is opposed to natural laws and necessitates vitiated air being re-breathed; (2) the flues and ducts are very difficult to keep clean, and become foul from dust and germs; (3) the air is apt to be delivered overheated, causing great discomfort about the head, while the extraction of vitiated air near the floor level is apt to cause coldness to the feet; (4) the incoming air is liable to be fouled by the roasting of dust on the heating batteries; (5) the doors and windows must be kept closed; and (6) the system requires skilled supervision.

On the other hand, the system is under control as to quantity of air supplied, its temperature, and its humidity; it is claimed to keep out fog and to keep rooms more free from dust than the natural system, though it is doubtful if this claim can be fully substantiated. It is argued that pure air is conducted down to the nostrils, and so to the lungs, before passing over contaminating bodies, but this is also a matter of serious contention owing to the natural tendency of warmed vitiated air to rise.

Having dealt broadly with the principles of the systems, let us next consider fully their details. In doing so, it will be well to have regard first to the ordinary dwelling-house, in which there should be three essential considerations: (1) the rooms containing sanitary fittings should be grouped together floor over floor and isolated from the rest of the house, so far as possible, by approaching them through a ventilated lobby. If circumstances permit, this lobby should have a good window on each of two opposite sides so as to ensure its through ventilation; failing this, one large window should be provided. The grouping together of the sanitary fittings in this way also greatly simplifies the drainage. (2) The building should be ventilated as a whole by providing a staircase as central as possible. If there be a fire-place in the hall, the upward current will be assisted. The outlet at the top may be in either of the following forms: (*a*) a lantern light having side lights to open, (*b*) an opening skylight, or (*c*) a good sized window. The inlets on the ground floor may be in the form of fanlights hung at the lower edge as shown in Fig. 31, and with quadrant stays and opening gear. The sketch also serves to show the principle of the hopper sash such as is frequently used in schools and in hospitals. In such cases the fan-shaped openings at the ends are often closed. The principle of the hopper sash was first introduced in 1785, in connexion with the ventilation of St. Thomas's Hospital by one Whitehurst. (3) Each room should also be ventilated as a separate unit.

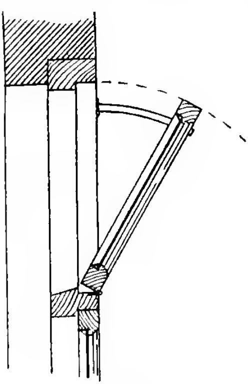


Fig. 31.

Nature helps to purify air through the medium of wind, rain, oxidation, and diffusion. In a natural system of ventilation no mechanical appliances are used. Outlets for the vitiated air are put as high as possible and inlets for fresh air reasonably low, though not so low as to cause discomfort by draught or by the diffusion of the incoming air with that of the room. The incoming air is often filtered and warmed.

The forms of inlet are not very numerous. The windows may be either authorized or unauthorized inlets, it matters not which in a *natural* system. There is a distinct advantage in being able to open a window without fear of disorganizing the system of ventilation. The tops of windows should be as near the ceiling as possible, to assist in letting out the vitiated air.

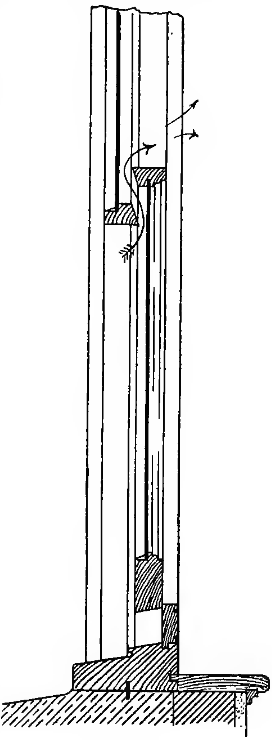


Fig. 32.

The ordinary sash window can be made to form a good fresh-air inlet by having a draught-board about 3 inches wide on the inside of the bottom rail of the lower sash, as shown in Fig. 32. This enables the lower sash to be raised so as to admit air in an upward direction between the meeting rails of the two sashes, without the liability to draught lower down. In the sketch the glass is shown in section by thick lines and the course of the incoming air indicated by arrows. This is the most convenient type of inlet for a dwelling-house or ordinary office. This principle was introduced in the eighteenth century by Whitehurst, before referred to, but the subject of ventilation was not then considered so important and it fell into disuse. Nearly a century later a somewhat similar system was introduced by Dr. Hinckes-Bird. This, however, was more clumsy, consisting of placing a wooden block under the lower sash in order to raise it. The intention is the same as with the use of the draught-board system, which, therefore, is often termed the Hinckes-Bird system.

Another form of inlet is the Sheringham valve, shown in section by Fig. 33. It consists of a small iron flap with fan-shaped ends, and is hinged at the lower edge A; it can be opened or closed to varying extents by means of cords and pulleys and is so shaped that the incoming air is given an upward direction. The outer face of the opening through the wall is protected by a grating. This form of inlet is often found in use in bedrooms.

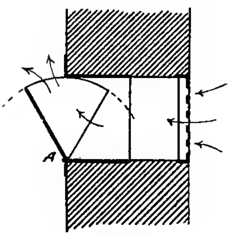


Fig. 33.

What is termed a "hit and miss" ventilator is sometimes used as an inlet. Fig. 34 shows a circular form, in which a series of openings is shown by firm and dotted lines respectively. Those shown by firm lines are cut in a circular piece of glass fixed at its centre so that it can be made to rotate in the direction shown by the arrowhead. The openings shown by dotted lines are formed in the window pane. On rotating the circular disc the openings can be made to partially or entirely coincide, thus providing a less or greater amount of air inlet. Fig. 35 shows a straight ventilator of the same type, capable of being opened or closed by

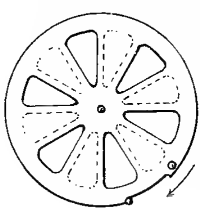


Fig. 34.

means of cords and pulleys. "Hit and miss" ventilators are almost always found over the doors of railway carriages, though there, of course, they are of wood.

Fig. 35.

Another form of window inlet is the "louvred" pane; that is to say, an arrangement of strips of glass working like a Venetian blind and capable of being opened or closed. Still another is the hopper sash already referred to.

A form of inlet found more often in a public building than in a private house, though sometimes met with in billiard rooms, is that known as the Tobin tube. It is of various forms and constructed of various materials. Thus it can extend from the floor level to a height of about 5 feet 6 inches or 6 feet above the floor, or it may be of a bracket form not reaching to the floor. Again, it may have a filter, a regulator, and a lid or it may have neither of these accessories. Further, it can be of zinc or sheet-iron, or of one of these materials cased in woodwork, or of woodwork principally. Fig. 36 shows a vertical section through one of full height. An opening is formed through the wall and a tube carried up inside the room to a height of say 6 feet. The opening should slope downwards to the outside face of the wall and be partially closed there

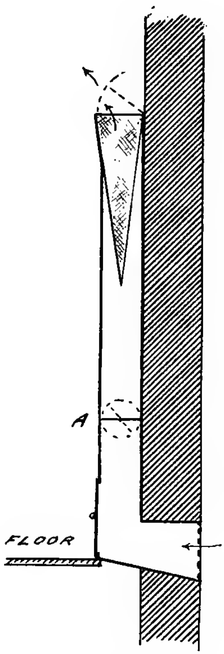


Fig. 36.

by a grating. The object of tapering the inlet in this way is to allow for the fact that the sum of the areas of the holes in the grating should be equal to the sectional area of the tube. All gratings in such positions should be either hinged or screwed on to a frame so that they can be readily removed for cleaning out the opening. If not made in this way, the alternative is a small door, closely fitting, just above the floor. At A is a regulator, consisting of a flat piece of zinc, equal in size to the sectional area of the tube and pivoted at its ends so that it will rotate as shown by the dotted lines; it is capable of being turned by a handle outside the tube and so of regulating the amount of velocity of the incoming air. At the top of the figure is shown a muslin bag filter. Sometimes an inclined sheet of tightly drawn muslin is used instead. The object in either case is to obtain a large area of filtering material; a piece of muslin across the top of the tube would be speedily clogged up owing to its affording such a small filtering surface.

Fig. 37 shows an alternative for the bottom of the tube. It is constructed with a small bath of water at its base, with baffle plates to deflect the incoming air on to the water surface as shown by the arrowheads. The effect of this is that the particles of dust and grit in the air are caught by the water. The intention is that this shall act as a substitute for the filter, but the arrangement is not to be commended, for the reasons that (1) there is no provision for readily removing the grit which will accumulate in the bath of water, and (2) the water is apt to evaporate and not be

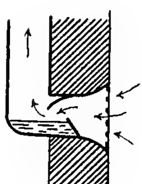


Fig. 37.

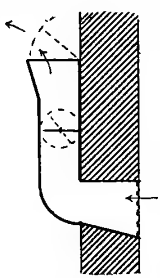


Fig. 38.

replenished by reason of the position being out of sight and out of mind.

Fig. 38 shows a "bracket" form of Tobin tube, coming through the wall about 4 feet from the floor and similar to that just described in most respects. It will be seen that it is too small to permit of a filter, but like the full-size tube it has a hinged lid to enable it to be closed, if need be, in very cold weather. Care should be exercised in the use of Tobin tubes, as, if used in schools, they are apt to become receptacles for waste paper, nut shells, and such refuse; in fact, veritable dust boxes.

A form of inlet sometimes adopted for private houses, but more often for schools and public buildings, is that obtained by casing in a hot-water or steam radiator. Wooden casings are undesirable. Fig. 39 shows an ordinary iron radiator, cased in by two iron baffle plates (shown by thick lines), so that the incoming air has to rise up between and around the pillars forming the radiator. This method is usually found very efficient, but it is wise to provide means for shutting off the cold air supply if need be. This can easily be done by a valve on the inside of the wall. Radiators, built up in sections, are now made of such a form that when put together they obviate the use of the baffle plates, but the construction shown indicates how an ordinary radiator can be adapted as a ventilating radiator.

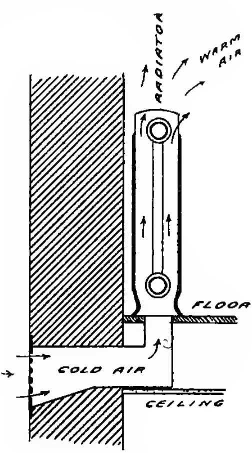


Fig. 39.

Another excellent fresh-air inlet is provided by the ventilating grate or stove. These date back to the early seventeenth century, but space will not permit of a detailed investigation of their gradual development. The ventilating grate, designed for the old War Office, in Pall Mall, by the late Sir Douglas Galton, is an excellent example. Fig. 40 shows a vertical section of this grate. Cold air enters through a grating at the outside face of the wall and circulates in an air-warming chamber behind the fire. It then passes upwards and around the smoke flue, and is admitted into the room by means of two louvred openings at the side of the mantel.

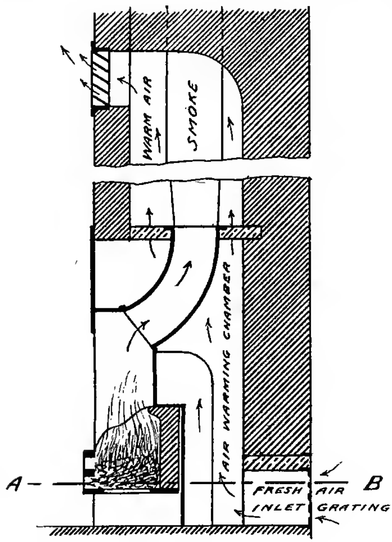


Fig. 40.

The section given in Fig. 40 should be compared with the plan on the line A-B which is shown in Fig. 41. It will be seen that the fresh air enters through a grating at hearth level, and that the iron back of the fire-place has projecting gills, GG, projecting into the hot-air chamber in order to increase the warming power. There have been many other

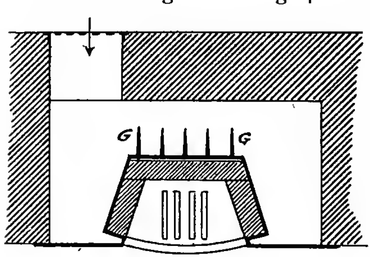


Fig. 41.

similar grates to this, but with most of them there is some difficulty in regard to the sweeping of the chimney flue. They do not call for detailed comment, the object of this work being to deal with *types* rather than variations of detail in examples of such types.

The air inlets must be well distributed in order to prevent stagnation of the air in any part of the room. The judicious placing of inlets and outlets is a matter of the very greatest importance in all schemes of ventilation. A common rule for the sectional area of inlet ventilators is that they shall, all told, equal 24 square inches per person, the outlets being made slightly larger.

The outlets in the natural system should be placed as high as possible. There are many forms, some being applicable for one case and some for another. For an ordinary dwelling-house, a good form is shown in Fig. 42. It consists of a valve leading into either a smoke flue or, better, a separate ventilating flue carried up alongside a chimney flue so as to ensure its being kept warm and so induce an upward current through it. It should be placed as high as possible. If a smoke flue is used a flap valve, like that shown, is the best. It consists of a grating with valves behind it, marked VV in the sketch. They are very light and hinged at the top edge. Talc is often used but has the disadvantage of rattling, and thick silk is therefore better as flaps of such material are noiseless. The dotted lines indicate their movements.

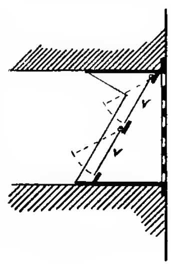


Fig. 42.

Another form of outlet is that put in the ceiling, preferably over a gas or electric light pendant, and leading to a flue by means of a tube between the floor and the ceiling under it, a valve being put at the junction with the flue if it is one from a fire-place. Sometimes outlets from different rooms are collected into one central vent shaft, but this has the disadvantage that vitiated air from one room may beat down into another room.

A ventilating flue may be closed at the top and have a side outlet, or it may be finished with an extract ventilator such as that shown in Figs. 43 and 44 either as shown, or enclosed in an ornamental ventilating turret. Fig. 43 shows an elevation, and Fig. 44 a horizontal section of it on the line A-B. In the centre is a ventilating tube, VT, and around it two sets of baffle plates, so arranged that the openings between those forming one set do not coincide with those of the other set. Its action is as follows: Assume the wind to be blowing from the right-hand side, as shown by the arrowhead. It will pass through the opening between the outer plates and strike against the inner baffle marked B, which splits up the current into two different directions as shown by arrowheads. In rushing past the openings xx air will be drawn out from the space between VT and the inner baffle plates, tending to cause a partial vacuum in the tube VT, which is not carried right up to the top. As nature abhors a vacuum, air will be drawn out of the ventilating tube. This series of events occurs no matter which side the wind may be blowing from. It is unwise to terminate an outlet shaft with a mechanical cowl, which is a very uncertain quantity in ventilating, and generally a nuisance.

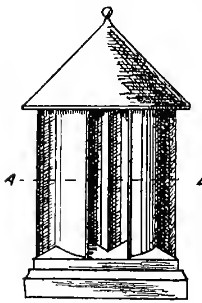


Fig. 43.

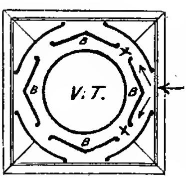


Fig. 44.

A chimney-breast ventilating valve should never be put in the flue of a smoky chimney, or it will make it worse. There are numerous varieties of outlet ventilator, some of them more or less hidden or secret in nature, but it is sufficient to say that the simpler they are in design the more efficient, generally speaking, will they be.

The value of a fire-place in a room lies not only in its warming capacity but also in the fact that it necessitates a flue. The heat of the fire warms the air passing over it and causes an up draught, making the flue a valuable air outlet.

The details of any elaborate scheme of ventilation are best left to experts practising in this particular branch of engineering, but a few notes may be given here in reference to the movement of air in tubes and flues.

The quantity of air discharged by an inlet or outlet ventilator will equal its sectional area multiplied by the velocity of flow, or

$$Q = AV$$

in which

Q = quantity of air in cubic feet per second.
A = sectional area of inlet or outlet in square feet.
V = velocity of the air in feet per second.

The formula for velocity is based on that for the velocity of falling bodies ($v = \sqrt{2gh}$), but has to be modified to allow for the difference in temperature between the air in the tube and the outer air; also for the fact that air expands $\frac{1}{491}$, or ·002, of its volume for each degree Fahrenheit, and for *friction*.

The formula therefore becomes

$$V = c\sqrt{2gCHT}$$

in which

V = velocity in feet per second.
c = coefficient of friction = ·5 to ·75 according to the sectional form and smoothness of the tube, and the number of bends in it.
g = the gravitation unit = 32·2.

C = coefficient of expansion = $\cdot 002$ or $\frac{1}{491}$.

H = height in feet from the inlet to the outlet of tube or flue.

T = difference in temperature, in degrees Fahrenheit, between air in tube and the outer air.

Therefore $V = c\sqrt{2 \times 32{\cdot}2 \times {\cdot}002 \times H \times T}$
or simplifying :—

$$V = c\sqrt{{\cdot}129\ HT}.$$

The rougher the surface of the tube or flue, the lower the value of "*c*". Again, angles tend to lower its value, therefore the best type of tube or flue is one of circular section with easy curves for changes of direction. Right angles seriously check the velocity ; one right angle in the length would reduce V to ·5 V and two right angles would reduce it to ·25 V.

So far, we have only been dealing with the ventilation of ordinary dwelling-houses by the natural system. Let us next consider the application of the system to other buildings.

Take first, for example, a public hall. In such a case the best form of inlets would be either Tobin tubes or ventilating radiators, and the best form of outlet a ventilating turret over the centre of the hall, or two if need be. From the ceiling a wood-lined shaft could be formed, leading up to a turret formed above the roof, with small doors to close the shaft at ceiling level by means of cords and pulleys. The turret might be formed with louvred sides ; or it might contain an extract ventilator such as that illustrated in Figs. 43 and 44.

Buildings of one story are much more easily ventilated than those of several stories. Thus, schools are better dealt with if arranged on the pavilion plan, that is to say, in a series of one story rectangular buildings connected by corridors after the manner of an infectious diseases hospital. Such a case might be dealt with by using Tobin tubes or hopper sashes as inlets, with extract ventilators at roof level.

In the case of hospitals the ventilating stove is largely used. Fig. 45 shows a section of one of the best-known types, known as the Manchester stove. The cold air supply is conducted to the stove by a duct formed in the floor. It then rises up around the back of the fire and passes through tubes, shown in section by circles, placed in such a position as to get the full heat of the fire. Thence it passes upwards through a grating formed in the top of the stove as shown by the sketch.

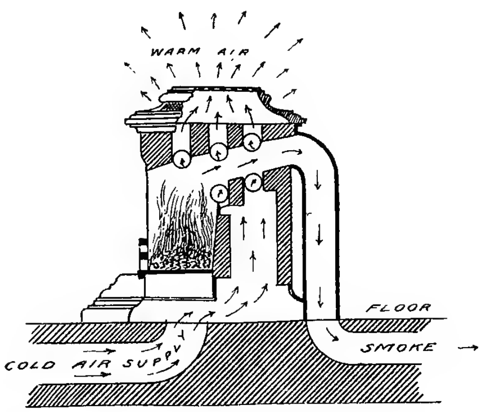


Fig. 45.

The smoke from the fire escapes by a descending flue to a duct formed in the floor and leading to a chimney. While it is desirable to have a room warmed to a reasonable temperature, care must be taken to prevent the air being unduly warmed, too high a temperature causing its partial decomposition, and robbing it of its humidity. Additional inlet ventilators can be provided low down, between or under the beds, and they may take the form of openings through the wall guarded by gratings on the outside face and by "hit and miss" plates on the inside so as to regulate the supply of air. Ventilating radiators and hopper sashes are also often used for such buildings. In the case of single story buildings, exhaust ventilators can be put in the roof, and, in the case of buildings of more than one story, the outlets can be collected to proper ventilating flues.

In the case of stables and similar buildings, it is undesirable to have any projecting features. Air inlets can be formed in the thickness of the wall as shown in Fig. 46. The "kink" in the inlet breaks the inrush of the air, and the inlet can be controlled on the inside by "hit and miss" plates. The inlets in such buildings are fairly low down. For commoner work air bricks are often provided as inlets and in such case a special form of brick is desirable. One of the best forms has conical holes with the larger ends at the inside of the buildings, so as to reduce the velocity of the incoming air.

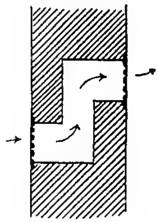


Fig. 46.

One of the very best forms of air inlet for high-class stable work is a modification of the Tobin tube introduced into the stall partitions. This idea was, I believe, introduced by the late Sir Alfred Waterhouse, R.A. Fig. 47 shows a sectional elevation, and Fig. 48 a horizontal section on the line AB, of such an arrangement. It will be seen that the air inlet is virtually a Tobin tube of about 2 feet to 2 feet 6 inches projection and about 4 inches width, the inlet being also high and narrow. As with all other external gratings, the inlet grating should be readily removable for the purpose of cleaning out the base of the tube. An alternative form of air inlet, though not nearly so efficient, consists of a hollow heel post at P. This, however, necessitates a long and somewhat inaccessible duct leading under the floor to the foot of the heel post.

An excellent form of ventilator for such buildings can be provided by louvres in the roof. Fig. 49 shows, to a small

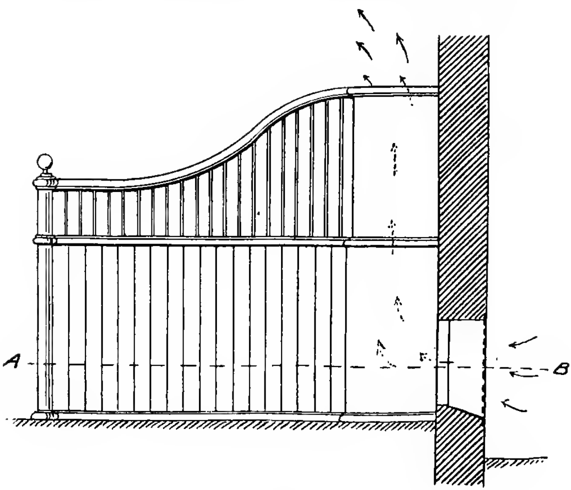


Fig. 47.

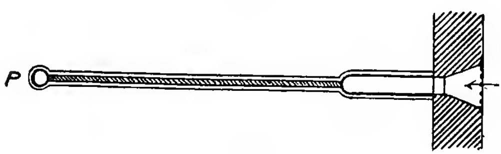


Fig. 48.

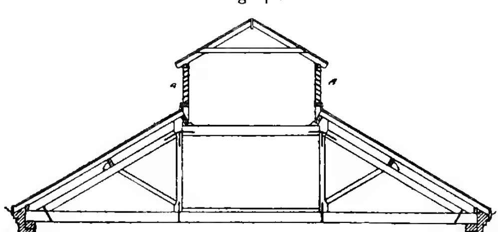


Fig. 49.

scale, a cross section of such a roof, louvred openings being shown at A and A1. The louvred openings can extend the whole length of the building, or they may be discontinuous; that is to say, they may extend for 10 or 12 feet and then stop for a space of about the same length, furnishing louvred ventilators about 10 or 12 feet long at intervals of about 10 or 12 feet apart. The louvres are formed of narrow boards as shown in Fig. 50 which shows a larger section of the part adjacent to A in Fig. 49. From the latter fig. it will be seen that one can obtain a good through current of air from side to side of the roof. It is wise to arrange similar louvred openings at the ends of the roof in order to ensure ventilation, no matter in what direction the wind may be blowing. The louvres are generally fixed but sometimes pivoted at the ends so as to be capable of opening or closing the opening. In such a case the gearing should be arranged so that it is impossible to have both sides closed at once.

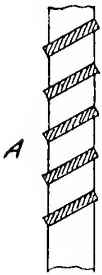


Fig. 50.

An alternative to the foregoing is the provision of extract ventilators similar to Figs. 43 and 44, or louvred turrets at intervals, or opening sashes.

In ordinary workshops, such as a builder's or decorator's, no elaborate provision is made for ventilation. In ordinary buildings, the spaces between the ends of the rafters, where they rest on the walls, are bricked up. It is a common practice to leave them open in the case of workshops, and this makes some provision for ventilation. In the absence of anything of a mechanical nature, other alternatives are the provision of a reasonable number of air bricks or gratings around the walls, or louvres in the roof.

Laundries present especial difficulties, and cannot be ventilated adequately without mechanical aid.

It should be noted that any system of natural ventilation is always somewhat at the mercy of atmospheric conditions and cannot be regarded as constant or uniform in action, even though it may be the best system available for the particular case in question.

So far, we have been dealing only with natural ventilation; that is to say, with ventilation systems involving nothing of a mechanical nature. We now come to artificial or mechanical ventilation, the simplest form of which is that in which the inlets are of the forms already described, while the outlets receive mechanical assistance. One of the best-known mechanical outlets is the cowl. There are innumerable varieties of cowl and they are comparatively inexpensive. Unless of good quality they are apt to get out of order and become a nuisance. With this reservation, they are both simple and effective outlets.

Outlet shafts are also often aided by means of gas, steam or water jets inside them, or hot water or steam coils are put in the shafts to increase the current of air through them. The value of heat for inducing a current in this way has long been recognized, a seventeenth-century example of its use being on record.

Fans, also, are used as extract ventilators in conjunction with natural inlets. The use of the fan in conjunction with schemes of ventilation is generally regarded as quite a modern idea, but this is not so. Their value was known to the Romans, for Agricola describes the injection of fresh air into mines by means of rotary fans. It is equally certain that their use was unknown for very many centuries in England, and the manner of introduction of the fan into this country for ventilating purposes is of some interest.

Sir Christopher Wren having been unsuccessful in ventilating the old Houses of Parliament satisfactorily, the matter was entrusted to a Dr. Desaguliers, a Frenchman, who had lived in

England from his childhood. He made many experiments, and in 1734 installed a ventilating fan over the ceiling of the House. It was of wood, about 7 feet in diameter by 1 foot thick, and had twelve straight blades reaching from the circumference to within about 1 foot of the axle. It was placed upright, with the inlet at the centre of its side, and the outlet at the top, and was rotated by a man turning a handle. This fan was so successful that it remained in use for over three-quarters of a century.

Rotary fans are in universal use now for ventilating purposes, but they are always of metal. It is interesting to note that one of the best-known types is of very similar construction to that just referred to. Fig. 51 shows a section of what is termed a fan wheel. It is similar in form to a paddle wheel. The thick lines show the blades in section, and they are connected at their sides to flat rims, one of which is shown by the two circles in the sketch. The wheel is housed in a casing of steel, one or both sides being partly open to admit the air, and the outlet or inlet can be horizontal, as shown in the sketch, or vertical, or at any angle of elevation. The dotted lines show the housing. Such a fan is often termed a blower, and is only used in large ventilating schemes.

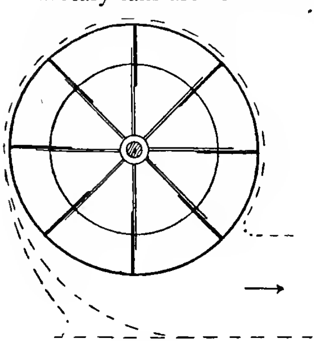


Fig. 51.

There are various other types of ventilating fan. For example, Fig. 52 shows one form of what is known as an air propeller. There is a circular rim of the section shown at B in the small sketch, and the blades are of curved section, with a fairly large area. Other examples of this type have blades of less area, and do not so completely obstruct the view through them when stationary. Each blade is straight at one edge and curved at the other. The small sketch gives a section on the line AB.

Another type is that shown in Fig. 53, and termed a disc wheel. It has flat adjustable blades set at an angle to the face of the frame. The small sketch shows a section through one blade, on the line AB, the blade being shown in section by a thick line.

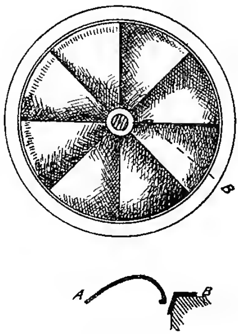


Fig. 52.

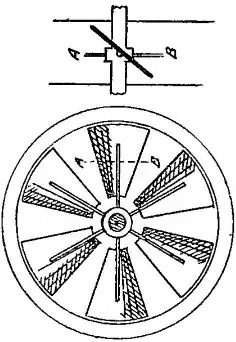


Fig. 53.

Various types of portable or table "fan" are in use, but these are mere air agitators, and are often termed rotary punkahs, a name which expresses their action more correctly. In some cases they are attached to ozonisers, small instruments for the production of ozone by means of electrical discharges.

A somewhat similar device is the fixed, overhead punkah with arms or blades rotated by electricity. They are often seen in restaurants, and provide a means of agitating the air and preventing stagnation.

The large types of fan are driven by either steam, gas, or oil engines, by electric motors, or occasionally by means of water-power.

Some forms of artificial ventilation provide for both propulsion and extraction by mechanical means. Thus a very usual method of ventilating a laundry is by means of a powerful fan at each end, well overhead.

The principal mechanical system is, as already stated, that now well known as the "plenum". The great point about this system is that the air in the room is intended to be always under pressure, so that any leakages must be outward, thus intending to guard against draughts. For this reason the outlets are slightly less powerful than the inlets, the reverse of the arrangement in the natural system. Another respect in which, generally speaking, the plenum is the reverse of the natural system, is that of the relative position of the inlets and outlets, the inlet being usually, in the case of plenum installations, fairly high up, with the outlet at floor level.

It is claimed to be essential to the success of the system that windows and doors must be kept closed, which is contrary to one's natural inclinations at certain seasons of the year. The use of the system in schools is greatly to be deprecated, accustoming, as it does, the young minds to permanently closed windows.

To be at all successful, such an installation should provide for definite mechanical extraction as well as propulsion. The system, as usually carried out therefore, provides for propelling into the building by mechanical means, tempered, filtered, humidified air, which passes along large horizontal ducts and through vertical flues into the rooms, the vitiated air being extracted through other vertical flues leading to a main trunk outlet. The design of such an installation is a matter calling for very great skill, and is essentially one for a specialist. The plenum system has been adopted in many large public buildings, and too often the result has been far from satisfactory.

Briefly, the system is arranged as follows. The fresh air is drawn, by means of a powerful fan, through a humidifying screen or filter, into a large main duct situated in the basement, at the entrance to which is usually a heating battery. From the main duct, flues lead up to the various rooms controlled by dampers or valves. Usually the ducts are in duplicate, one for cold air and one for warm, arrangements being provided for mixing the air from the two. Let us consider more fully the details of the system.

The fresh air supply can be taken in at any desired distance from, or height above the building. It then passes through one of many varieties of humidifying filter, which serves the double purpose of moistening the air and filtering it. The general experience goes to show, however, that only the larger and heavier impurities are intercepted. Wherever air is forced rapidly through a screen, it is almost bound to carry the finer particles of dust with it.

The use of screens kept moist by sprays in one form or another is by no means new, one having been installed at the Houses of Parliament in 1835.

Among the forms of screen in use are the following: The roughest form consists of a sheet of coarse canvas stretched on a frame, with or without perforated pipes spraying water on it to moisten it. It is a difficult screen to keep clean and not much used.

A somewhat similar arrangement of coarse fibre, plaited at intervals with perforated, or sparge, pipes discharging on to it is another form. It, also, is difficult to keep clean.

Another form consists of an upright iron case about 6 inches thick, covered with wire netting on each side, and packed with broken coke which is kept wet by water discharged through a sparge pipe at the top. It is not a very satisfactory form, as if the coke is packed closely so as to efficiently intercept the impurities, it is difficult for the fan to draw sufficient air through it.

A better form is a revolving screen of fibre. It consists of an endless band of plaited fibre, passing over horizontal rollers at top and bottom, the bottom roller being in a shallow trough of water. The band revolves very slowly and is always kept wet by means of the water trough. The air has to pass through the two upright parts of the band, thus giving double filtration, but here again it is somewhat difficult for the fan to draw sufficient air through.

Another form of fibre screen consists of a large inclined drum, covered all round, and at one end, with fibre. The open end leads into the main duct, the covered lower end dipping into a water trough in such a manner as to keep all the fibre constantly wet. In all these cases the water in the troughs is being constantly changed so as to wash away the impurities, but notwithstanding this, the types of screen just described have the common disadvantage that the material to some extent harbours impurities. A type, therefore, which has not this drawback is to be preferred.

There are various forms of mist screens agreeing in their general principle though varying in their details. The principle is as follows: In the vertical intake shaft an arrangement of water jets is provided, these being so arranged as to finely divide the water and thoroughly distribute it over the horizontal area. Below the water jets a number of sheets of galvanized corrugated iron are put, the width of the sheets being vertical and the length either horizontal or inclined.

The sheets are about 1 inch apart, right across the shaft. The air is drawn through the spray formed by the jets and so humidified. It then passes between the wet corrugated sheets, the corrugations ensuring its continued contact with the wet sides which thus further arrest the impurities. The base of the shaft is arranged so as to readily drain off the water as it falls.

The spray or mist is, in some cases, formed by a series of jets discharging upwards into the air, but this arrangement hardly gives such good conditions as the following: A vertical water pipe is terminated by a four-armed fixed sprinkler, the outlets pointing downwards at an angle and discharging on to a loose revolving propeller. The effect is to cause the propeller to revolve at a high velocity, thereby dividing the water into a very fine mist.

In such screens there is a liability for the jets to get frozen in winter, but this is avoided by putting a heating battery, of fairly large pipes, round the shaft just above the jets.

In some cases the fans discharge into a large brick or concrete single duct, rendered in cement, with the floor laid to falls, and stand pipes for the purpose of washing out the duct. From the main duct, which should be well lighted, subsidiary single ducts go vertically to supply the various rooms. In such a single duct system the bases of the subsidiary ducts are provided with heating batteries fixed opposite the upper half of the inlet, the lower part being free to pass cold air. Dampers are provided to regulate the temperature. Thus, if the damper is down, all the air passes through the heater. If it is up, no air passing into the duct is warmed; if partly up or down, it will be seen that some air will be warmed and some not, making it possible to regulate the quantity of each and so control the temperature. In this case, the arrangement of the inlet to the room is very simple, as shown in Fig. 54. There should be no sharp angles in the length of the duct, and its entrance to

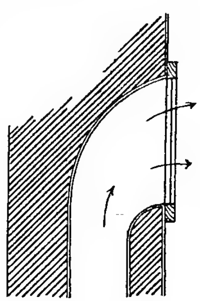


Fig. 54.

the room should form an easy curve. The sketch shows the duct plastered to make it smooth, and shows the inlet to the room marked by a frame with a very open and readily removable grating, often of brass-wire netting. The heaters are often of ordinary wrought-iron pipes, but in order to get greater radiating surface they are frequently of what are termed gilled pipes, having a section similar to that shown in Fig. 55. In summer, the warmth of the air can be tempered by passing it through large crates filled with broken ice.

Fig. 55.

On the other hand, if the double duct system is used, as is now more usual, the main duct is divided horizontally, the upper duct taking cold air and the lower warm. Similarly double subsidiary ducts are used. In this case the usual method of heating is by a battery of steam pipes adjacent to the fan or blower, the heater at the foot of each minor duct being unnecessary. The temperature is kept under control by mixing dampers placed near the inlet to the room as a rule. These are of various types, but a form in very general use is shown diagrammatically by Fig. 56, which is an outline section through the heads of two subsidiary ducts. The damper D is in the form of a metal cylinder, loosely hinged to the division between the ducts. It can be raised or lowered till it occupies either of the positions shown by the two dotted circles. Thus, when in the position of the upper circle, the cold air is entirely shut off and vice versa. It can be regulated to admit any proportion of hot and cold air respectively.

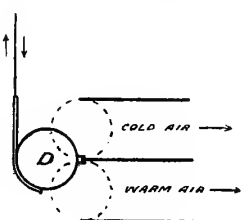


Fig. 56.

The sectional area of the main duct should far exceed the combined sectional areas of the minor ones, so that it may form a sort of storage reservoir for filtered air. There should be no obstructions on the floor and all angles should be rounded to facilitate cleansing. It is often the case that the main duct is not kept clean, and dust allowed to accumulate on the heating batteries. The high temperature of the latter roasts the dust, causing an unpleasant odour in the air. The heating batteries, too, are often at such a high temperature that the air is robbed of the humidity which such pains have been taken to give it. Of course, on the other hand, if air is too humid, there is a feeling of oppression, caused by the checking of evaporation of moisture from the skin.

The power used should be as far as possible from the rooms to be ventilated, as the ducts are powerful conductors of sound.

The automatic regulation of temperature is often adopted in such schemes of ventilation. This is accomplished by the use of thermostats. There are many types of thermostat. One consists of two thin corrugated metal plates, fastened together at the edges to form a hollow disc, which is filled with a volatile liquid capable of boiling at a very low temperature (58° or 60° F.), creating a pressure which expands the disc and so causes it to exert force. At 70° F. a pressure of 6 lb. per square inch is given, and this is enough to operate the mechanism of the dampers. Other types of thermostat are actuated by the expansion or contraction of various metals, vulcanized rubber, etc.

The positions of the inlets and outlets for the air is a matter of very great importance in order to avoid dead or stagnant corners to the room.

Both inlets and outlets are usually put in the same wall, an internal one for preference. They are used at both ends of the room to prevent short circuiting. The centre of the inlet is usually put at about three-fifths of the height from floor to ceiling. It should take the form of a detachable grating about one-third larger in area than the sectional area of the duct, the current being directed somewhat upwards as shown in Fig. 54.

The outlets are made less powerful than the inlets, thus putting the air of the room under slight pressure. The outlet gratings, however, are usually about one and a half times the size of those forming the inlets. If gas is used in the room, an outlet should also be put in or near the ceiling, to carry the products of combustion to the extract flue.

As a general rule, the velocity of the incoming air, in the case of the plenum system, is about 4 to 6 feet per second, and the air is changed about ten to twelve times an hour. The main extract shaft should be covered and have side outlets, a propeller being provided near the outlet to assist the extraction. It is important that this propeller should not be too powerful, or it will short-circuit the circulation of air in the rooms.

From the foregoing it will be seen that the system is one which, if used at all, should be installed when the building is erected. It is, however, sometimes applied to an existing building, in which case the ducts are usually of light galvanized iron sheeting. The best form of section for such ducts is circular, this giving the least frictional resistance. All bends should be of large radius and all junctions of easy curvature.

In the case of factory buildings, it is often applied in this way, a main duct running the length of the building, overhead and down the centre. From this, branches are taken at intervals towards the side-walls, but going only about halfway towards them and then bending slightly downwards. In some cases such a system is adopted merely for warming, the building getting its air by a natural system. In such a case, a fan or blower wheel is installed, open at the sides for entrance of the air of the building which is then blown through a heating battery.

It will be seen that the plenum system is complicated and costly. It is very liable to disorganization by breakdowns, which makes it desirable to put in the whole of the plant in duplicate. It is of the greatest importance that the instructions given for the management of the installation should be very carefully followed, many an installation having been, I understand, greatly increased in efficiency by changes in the supervising staff. It is obvious that so complicated a system cannot be entrusted to any odd man, but must be put in the charge of a skilled mechanic, thoroughly conversant with all its details.

The system has been adopted to some extent in hospitals, but it seems singularly inappropriate for this purpose, with its closed doors and windows, when one considers the fact that for convalescence, as well as for the treatment of some diseases, as much "open air" as possible is desirable. There is a great difference between what is known as plenum air and the open air. The plenum system has also been extensively adopted for schools, but here again I venture to suggest that an abundance of fresh, untreated air, so vital to convalescents and consumptives, is also very desirable for school children, while the practice of accustoming them to closed windows is one the advisability of which is seriously open to question.

Several novel features are possessed by a mechanical system of fairly recent introduction by Dr. Glover Lyon. It provides for more or less separate ventilation of each room. The inlet and outlet ducts are fairly high, but shallow from front to back. They can be arranged along opposite sides of a room, forming a frieze, but having fronts which are readily removable for cleansing. No filters are used, and the air is both drawn in and extracted by means of fans. The fact that the velocity decreases as the distance from the fan is increased is taken advantage of, and regulated spaces are pierced in the inlet ducts, the quantity and velocity of the incoming air, as well as the uniformity of its distribution, being thus kept well under control. The further from the fan, the larger the pierced opening, the same principle being adopted with the outlet. Openings of various sizes would of course look unsightly, but the system provides for this by masking the variation in size by appropriate architectural treatment. The incoming air can be warmed by means of electric radiating lamps enclosed in the inlet duct, and the temperature is thus under perfect control, while there is the further advantage that doors and windows can be freely opened. The system is one that can be readily installed in an existing building without elaborate structural alterations.

Reference has already been made to the question of humidity, but it may be well to mention the way in which the degree of humidity is determined. This is done by means of an instrument termed a hygrometer, which is a sort of double thermometer. Two thermometers are placed side by side, and the bulb of one, which is wrapped in silk, cotton, or wick, goes down into a small water reservoir. As evaporation causes loss of heat, the wet bulb thermometer will read the lower. If the air is quite saturated, both thermometers will read alike, but ordinarily the wet bulb will read the lower. Between the two thermometers is a scale giving the percentage of humidity, absolute saturation being, of course, 100.

In connexion with ventilation there are, naturally, a host of patents, but the intention has been to deal with broad principles involved in the principal systems.

In testing the ventilation of any building, one cannot do better than follow the advice of Dr. Parkes, the eminent writer on hygiene. His advice on this point is as follows:—

1. Find the amount of cubic space and floor space per person.

2. Find the number of cubic feet of air per person per hour.

3. Test the air by the senses, and by chemical, mechanical, and biological methods.

The first item is merely a matter of measurement. The second is found by multiplying the total sectional area of the inlet openings by the velocity of the incoming air, the latter being measured by a small instrument termed an anemometer. In addition to testing the air by the senses, a rough test can be applied to determine the percentage of carbonic acid gas which is a good index of impurity. A sample of the air is taken as follows: Get a clean transparent glass bottle of about 10½ oz. capacity and cram into it a clean, dry linen cloth. Take the bottle into the room the air of which is to be tested, and pull out the cloth; the air will rush in to take its place. Put into the bottle ½ oz. (or a tablespoonful) of clear lime water, and shake it up; if the lime water becomes milky, there is an excess of carbonic acid gas present. This rough test was introduced many years ago by Dr. Angus Smith, a well-known authority on sanitary matters.

A more exhaustive examination is, of course, a matter for the chemist and biologist.

In comparing the cost of systems of ventilation, it is necessary to capitalize the cost of maintenance and add to it the initial cost, as the system which seems the more economical may possibly prove the more expensive.

Nearly a century ago, an essayist on this subject, Bernan, delivered himself of some sage remarks which, in concluding this section, are worth repetition. He said: "Ventilation is a process so simple in itself, yet withal so delicate, as to be easily impeded or destroyed even by seemingly skilful arrangements to promote it; and more attempts have failed by aiming to produce the effects wholly by comparatively complex artificial means, than by relying on a simple modification of the natural process, which would have served the purpose as effectually".

CHAPTER IV

THE BUILDING—ITS WARMING AND LIGHTING.

As an introduction to this part of the subject, a brief historical note may be of interest.

Philosophers have pointed out the influence of scarcity or plenitude of fuel. The athletic stature of the Swede has been attributed to his nation's abundance of fuel. It may be merely a coincidence, but in England, where fuel is abundant, the average height is 5 feet 9 inches; in the Netherlands, where less abundant, it is 5 feet 6½ inches; and in France, where comparatively scarce, only 5 feet 4 inches.

The origin of fire is about as uncertain as the date of discovery of coal as a fuel. Innumerable other kinds of fuel have been used in ancient and modern times. For centuries, wood, peat, and turf were the staple fuels of Great Britain, but the consequent denuding the land of timber led to a proclamation by Queen Elizabeth to the effect that no oak, ash, or beech tree that was 1 foot through at the stub and growing within 14 miles of the sea or of a navigable river, should be used as fuel for smelting iron.

It is believed that coal was known before Roman times, coal cinders having been found under Roman foundations in England. The word coal, also, is British—that is to say, of earlier than Anglo-Saxon date. In 1239 Henry III granted a charter to the inhabitants of Newcastle, permitting them to dig for coal, and at the end of that century it was imported into London. The smoke produced by burning it in improperly constructed grates caused such a prejudice against its use that in 1306 an Act was passed making it a capital offence to burn coal in the city of London, and there are records of execution for the offence.

Probably the first composite fuel used was that introduced by Sir Hugh Platt, an eminent sixteenth-century lawyer, who says, "to speake trulie of it, coal and cowdunge maketh a sweete and pleasing fier," a statement which seems open to question.

The methods of warming buildings are almost as numerous as the varieties of fuel. A favourite primitive method was a sort of stove or oven inside the room, and stoked from the outside, this structure serving as couch by day and bed by night, the whole family often sleeping on the top of it. Examples are to be seen to-day among the poor of Russia, and the method has been used as far afield as Egypt and China.

According to Homer, the Greeks used fires in hearths for both warmth and light; they also used charcoal brasiers. The Romans used hypocausts consisting of a sort of hollow floor with a space about 2 feet high, in which a fire was made, with pipes or flues up the walls to spread the heat, the openings into the rooms being in the form of lions' heads, and this method was used in Roman villas in England.

The forms of chimney, hearth, and fire-place have gone through great changes before reaching their present character.

In British houses, the hearth was put in the middle of the hall so that as many as possible could get round it, and this practice was followed till as late as the fifteenth century, though at the time of the Norman Conquest the hearth was often placed against the wall, with a sort of pyramidal flue terminating in a hole in the outer face of it. Generally speaking, from the Conquest to the time of Henry VIII, fire-places were put on outside walls, but the Elizabethan architects put them on inside walls opposite the windows. Huge fire-places were used, with large flues often put one behind the other instead of side by side as nowadays.

Fires were at one time a great luxury in the house, the right to use the fire being sometimes bequeathed. Thus the will of one Richard Byrchett (1516) reads: "I will yt the sayd Nell my wyfe shal have ye chamber she lyes in and lyberte at ye fyer in the house; all yese things shal she have so long as she ys wido".

The modern methods of warming include the use of open fires, close fires or stoves, hot water, steam, hot air, gas, and electricity.

Mention of iron grates for burning coal occurs in inventories of the early sixteenth century, and at the end of that century we know that the depth and width of the hearth recess was much reduced and the mouth of the flue contracted. An Italian architect, Scammozzi, writing at that time also says that, in England, a door of iron is used to close the flue after the fire is well lighted, this being the first mention of the register plate.

About 1624 a French architect, Savot, further reduced the height and width of the fire-place opening, and introduced the iron back and coverings, together with the perforated base plate of the ordinary grates still in use. About 1738 came the use of fixed canopies, adjustable registers, and the insulation of the grate by means of air spaces behind it. In the same century the well-known Bath fire-place was in vogue, consisting of a hobbed grate with an iron plate front, having an arched opening in it. It had great draught-creating powers, carrying off all the air in the vicinity. An old English writer, in commenting on it, says, "whoever, impelled by the merciless severity of the frost, comes near the grate, will find his front fried and his rear frozen".

At the beginning of the nineteenth century, Count Rumford, a versatile American, at various times shop boy, soldier, diplomatist, financier, scientist, and founder of the Royal Institution in our own country, did more to improve the fire-place than any one up to that time. He it was who brought the fire grate forward, the mantel lower, emphasized the importance of forming a "throat" to the flue, and introduced the diverging sides and covings, to obtain greater radiation of the heat into the room. He pointed out that the bars should not be too far apart, ensuring brightness of the exposed surface of the fuel, and increasing the radiation of the heat, and also showed that dull, rough, iron covings were better radiators of heat than polished surfaces.

Later in the nineteenth century, valuable experimental work was done in connexion with the improvement of fire-places, by Dr. Teale, F.R.S., who embodied his conclusions in a paper read before the Royal Institution in 1886, on "The Economy of Fuel in House Fires". The chief conclusion obtained by Dr. Teale was that slow and efficient combustion depends on there being no current of air up through the grate, and he accordingly introduced what is known as the economizer, shutting in the space below the grate. He also laid down a series of rules for the design of fire-places, the principal of which are:—

1. Use as little iron as possible, making both back and sides of fire-brick.

2. The fire-brick back should lean over the fire; and

3. The greatest efficiency is obtained from the covings when they are inclined at an angle of 60° to one another.

Later investigators have held that it is important that the air should not pass through the face of the fire, and so have designed fire-places of what is known as the well type, with raised hearths in front, and ventilating fenders communicating with a hot air chamber below the grating at the base of the fire, practically the whole thing being formed of fire-brick. In some examples the base of the grate is formed with reinforced fire-clay bars to prevent the absorption of heat by the iron, which is supposed to be an appreciable amount in types having iron gratings.

Other experts hold that there is no necessity to supply air to the lower side of the fire and that a grated base with an ash-pit under is a superfluity. It has been fairly well demonstrated that a good fire can be obtained without any air supply other than that passing over the top of the fire; that more perfect combustion is thereby attained with economy of fuel; and that much less draught is caused in the room owing to the demand for air being far less than in the older types of grate.

It should be pointed out, however, that, in almost all types, ashes will accumulate and require removal. The grated base allows for the removal of the ashes without letting out the fire, which is a point not to be overlooked in the case of a sick-room where a fire is constantly required.

Such fire-places as those just dealt with, however, must only be put into existing buildings after the closest inspection for hidden timbers under the old hearth, as they have been said to be the cause of many accidental fires.

The chief drawbacks to the use of open fires are the unequal distribution of the heat and the lack of economy, but the cheerful appearance and the fact that the flue assists the ventilation of the room will no doubt always keep the open fires first favourite with the English people as a means of warming the rooms of dwelling-houses. In large public and office buildings, the labour attendant on their use has caused them to fall largely into disfavour.

No apology is needed for dealing with this question of open fire-places in the foregoing manner. It shows clearly the lines upon which improvement has taken place, and in which direction improvement is tending. As Carlyle says: "There is precious instruction in finding we were wrong; it is, at bottom, the condition on which all men have to cultivate themselves".

Before leaving the question of open fires, reference must be made to the gas fire. It is becoming increasingly popular for rooms in which a fire is not constantly required, such as bedrooms. If in continuous use it is far less economical than the coal fire, but for occasional use it has the advantage that it can be brought to its full heating power in a few minutes and that the expense of the fuel can be shut off immediately the fire becomes unnecessary. A good type of gas fire should be formed largely of fire-brick and asbestos, as little iron as possible being used in its construction. All gas fires should communicate with a flue, and a good type materially assists the ventilation of the room by creating a slight draught towards the fire. On the other hand, inferior types give off the products of imperfect combustion, appear to dry the air, and cause a feeling of oppression.

There is considerable prejudice against the use of closed fires or stoves, as people want to *see* the fire. The commoner forms are apt to get very hot and they then roast and burn the organic matters in the air, and give off unpleasant odours. They are liable to decompose the air, and they certainly deprive it of much of its moisture. A close stove, also, if of ordinary form, cannot be looked upon as any material aid to ventilation. The following extract from the works of an old writer, Jeremy Bentham, is an amusing commentary on the manners of his time: "A bad smell often arises in consequence of people spitting on the stove to try if it be hot, but this nasty, unmannerly practice should be reckoned to the discredit of the spitter, and not as an objection to the spittee". Were he living to-day, he might have extended his observations to cover a worse practice, somewhat prevalent in America, I believe, where closed stoves are in very common use, of sitting round the stove and spitting on the *floor*.

With closed stoves there is also the risk of the escape of carbon monoxide if the joints are not perfectly made, as is often the case. Wrought iron is better for their construction than cast, if well riveted at the joints. They are economical but not so healthy as open fires.

There are, however, many good types of slow combustion stove now obtainable, burning anthracite coal, or patent fuel. They are usually lined with fire-brick and cased with vitreous enamelled iron, and are fixed on an ordinary hearth, the flue pipe being taken into the chimney and the wall made good around it. To make the appearance more cheerful, red mica panels are usually put in the front fire door. A good stove of this type is best charged with anthracite coal broken to the size of walnuts. It will keep in day and night and only require recharging with fuel once in twelve to twenty-four hours. They are smokeless and very cleanly in use, and require a minimum of attention. Whereas with an open fire three-fourths of the heat passes up the chimney, with a good type of slow combustion anthracite stove, the bulk of the heat is available for warming the room. The supply of air to the fire is regulated and the heat thereby controlled. The fire can be raked without nuisance, even when out, as this can be done by a handle outside, without opening the fire door. The dust therefore passes up the flue instead of into the room. Such stoves are charged, when once lighted, from a stoking door near the top, the fuel entering a sort of reservoir from which it automatically works down as required. Stoves of this kind are very economical.

The imperfect ventilation obtainable by the closed stove of ordinary form can be overcome, in the case of a large hall, by the use of a ventilating stove. An open stove of this variety has already been shown in Fig. 45, with a descending smoke flue passing under the floor to the walls. Fig. 57 gives a diagrammatic section of the Musgrave stove, which is closed in. The sketch shows it with a back outlet for smoke, but the descending flue can be used as in Fig. 45. The stove is lined with fire-brick, shown by hatched lines, and the iron work is shown throughout by thick lines, the dotted lines indicating grating outlets for warm air.

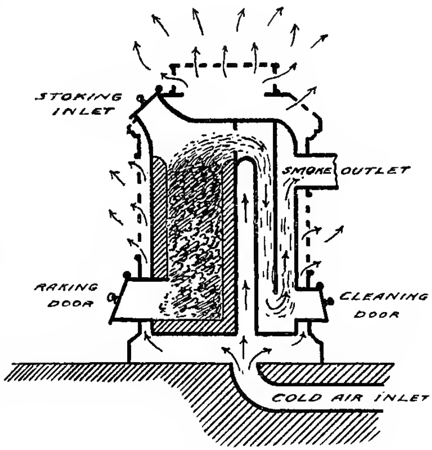


Fig. 57.

Ventilating gas stoves are also obtainable on somewhat similar lines, but they are very far from economical. In the problem of warming a building one may note that there are three methods of transferring heat, namely, radiation, conduction, and convection. The open fire-place furnishes a good example of radiant heat. From each particle of fuel, and from the fire-brick sides and back, the heat is radiated in straight lines. The rays diverge and affect objects at a greater distance to a less degree; the air is not warmed but the heat is radiated to individuals and objects, being re-radiated from the latter to a certain extent. Let us consider the phenomena illustrated in Fig. 58. The black dot represents a particle of incandescent fuel and the diverging lines show the diverging rays of heat. At A is a small screen which receives all the heat from that particular particle of fuel. If A be removed, and a screen be placed at B, it will have to be of a larger size to receive the same total amount of heat as would be received by A, therefore receiving less heat per unit of area. Similarly, if there be no screen at either A or B, a screen placed between the same rays at C would have still less heat per unit of area. Putting it another way, the heat decreases as the distance increases, and in a ratio of the square of the distance. Thus, compare a surface 1 square inch in area at a distance of 1 foot, with a similar surface at a distance of 10 feet. The latter will only receive one-hundredth of the heat that would be received by the particle 1 foot away.

Again, suppose a screen to be placed at C, there being

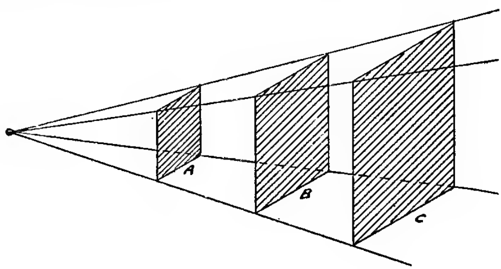


Fig. 58.

none at A and B; if the small screen A be placed in the position shown, it will shut off all the radiant heat from C. A practical example of such a case is the use of a fire screen.

It is not strictly correct to say that with open fire-places the room is entirely warmed by radiant heat. The walls, furniture, etc., become warmed by the radiated heat, and warm the air in contact with them by what is more strictly termed convection, which is really a warming by air or water currents.

The best example of convection is the hot-water service, in which the warmed particles, becoming lighter, rise, being replaced by colder, thus setting up a circulation. An example of conducted heat is a poker placed with one end in the fire.

The heat is gradually conducted to the other end, which, in time, becomes too hot to hold.

Radiant heat, then, does not warm the air; this can only be done by bringing the air in contact with heated surfaces.

In systems of warming by means of hot-water pipes, radiators, etc., the air is warmed partly by one method and partly by another. Powers of radiation and absorption of heat are about equal; that is to say, a substance that will absorb heat readily will just as readily part with it again. Iron fulfils the condition about as well as any material and is therefore used for pipes and radiators.

The installation of hot-water or steam systems for large buildings is entirely a matter for an expert who devotes his attention only to such work, but the following notes are intended to give a general idea of the construction and arrangement of such systems.

The heating engineer uses, as a means of measuring heat, what is termed the British Thermal Unit. This is generally defined as the amount of heat needed to raise 1 lb. of water 1° F., though it is more correct to define it as the amount of heat necessary to raise 1 lb. of water from 39° to 40° F. In most continental countries the unit is the Calorie, which is roughly equal to four British Thermal Units.

For the warming of buildings by hot water there are two main systems available, the low pressure and high pressure respectively. In the former, a system of circulation is set up, the water being heated in a boiler supplied by a cold-water cistern placed in a position above the highest point to be supplied with hot water. The water becomes lighter as its temperature is increased, and rises, being replaced by the heavier cold water. The water expands to the extent of $\frac{1}{24}$ to $\frac{1}{25}$ of its bulk in the process of heating, and provision must be made to permit of this expansion.

In the high pressure system the arrangement is somewhat similar, but differs in that the whole system of pipes is sealed, whereas in the low pressure system there is a free communication with the atmosphere. The effect of sealing the system is that a much higher temperature can be obtained.

The low pressure system is largely used and may be dealt with first. Its advantages are that it is economical both in first cost and maintenance, gives an agreeably mild heat, and if well arranged prevents draughts. On the other hand, it has the disadvantage that, if used intermittently, there is the danger of freezing, leading to burst pipes and possible danger of flooding. The system is a much older one than the high pressure, having been introduced about the beginning of the eighteenth century by a Norwegian for the purpose of warming his greenhouse. It was developed in France for incubator work and was introduced into England by a Frenchman, named Bonnemain, for domestic warming.

Before dealing further with the general disposition of the system, let us consider its component parts.

There are many varieties of boiler, some set in brickwork and some quite independent. Of the latter, some are practically in one piece, while others are built up in sections, either vertically or horizontally, being known as sectional boilers. The independent boiler is rapidly superseding the older, brick enclosed type, and the sectional form gives a splendid provision for readily increasing the size of the boiler without trouble. Further, a sectional boiler is very portable, the sections being capable of passing through any ordinary doorway. Boilers are made of cast iron, wrought iron, steel, and copper. Cast iron is largely used on the ground that there is less corrosion than with wrought. A boiler should not be too high, or it will restrict the fall available for the pipes; it should have a manhole for access; its flues should be readily accessible for cleaning. Its efficiency will depend on many factors, the principal of which are, the ratio of fire grate area to the boiler surface, its size in relation to the system as a whole, the size and height of the chimney, the regulation of the draught, the rate of firing, and the condition of the flues. All boilers should have safety valves. By boiler surface in this connexion one means the surface in contact with water.

The pipes used in heating work are usually of either cast iron, wrought iron, or copper. Their expansion and contraction under changes of temperature is a matter which has to be seriously reckoned with. Expansion joints are largely used, but on long lengths of pipe it is better to put an expansion bend in the form of a loop. This should be of copper, as it is much less rigid in nature than iron. The bend should lie horizontally or it will form a dip or trap and so obstruct the circulation of the water. Similarly, in connecting the pipes to the boiler or to radiators, a double bend should be used, to permit of a little elasticity in the system.

There are various methods of jointing the pipes. Those of wrought iron and copper are generally jointed by means of screw threads only. Cast-iron pipes are either socketed or flanged. In the former case, the joint between the spigot (or plain end) and the socket may be made in various ways, as follows: (1) A few strands of tarred hemp may be well rammed in, and the socket then filled up with rust cement, a mixture of iron shavings and chemicals which ensure rapid consolidation by the oxidation or rusting of such shavings; (2) a few strands of spun yarn dipped in a mixture of red and white lead, followed by a few strands of tarred hemp, and then rust cement; or (3) as last, but no rust cement, using instead a mixture of red and white lead with chopped hemp, a small quantity of gold size being added to hasten the setting of the joint.

If flanged joints are used, the abutting flanges are bolted together, with various packings between. For low pressure hot-water work, the packing between the flanges may be either asbestos or india-rubber; for low pressure steam asbestos; and for high pressure steam, corrugated brass rings smeared with red and white lead.

If expansion bends are not used, expansion joints must be. There are very many forms, but two examples will suffice to show the general idea. Fig. 59 shows the "Jones" joint, which is formed as follows. The pipes have no sockets, and are butted end to end at a little distance apart to allow for expansion. Around the abutting ends is a flat iron ring, and on either side of this a rubber ring, shown by fine dots in the section. These three rings are secured by two collars, bolted together as shown. The great advantage of this joint is that plain tubular pipes can be utilized, and its disadvantage that it is only suited to low pressures and temperatures, owing to the use of rubber rings.

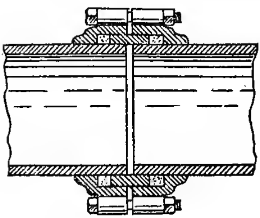


Fig. 59.

A better form of joint is that shown in Fig. 60, in which no rubber rings are used; the joint consists of an inner and outer tube (I.T. and O.T.) sliding one within the other. At A is a packing of hemp treated in various ways, the screwing up of a cap B making the joint thoroughly watertight by the compression of the packing.

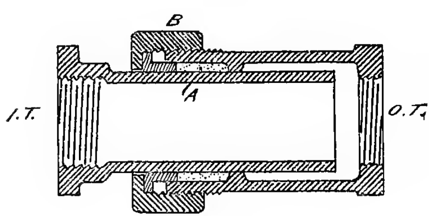


Fig. 60.

The pipes are fixed in various ways. They must be free to move with the expansion and contraction, and may in the case of long pipes be supported on rollers, either one over the other or side by side. With shorter pipes the rollers are unnecessary, but the pipes should be supported in clips or links so that a small longitudinal movement is possible. The clips or links are in two or more pieces, bolted or screwed together after the pipe is placed in them, forming a circular support rather larger in internal diameter than the outside diameter of the pipe.

The next point to consider is the provision for radiation. This can take various forms. Thus, the simplest is to use fairly large pipes, of say 3 to 4 inches in diameter, placed round the walls. This method, though suitable for a greenhouse, is of no use in a dwelling-house. Not only would the pipes be an eyesore, but they would readily collect dust. In small public halls the method is, however, often used. One thing that cannot be too strongly condemned is the placing of hot water or steam pipes in a trough formed in the floor and covered by a grating. Dust gets swept through the grating, and is often roasted by the heat, causing serious nuisance. An alternative method is to put the pipes in a chase formed in the face of the wall, with a vertical grating in front of them. Here also there is the difficulty of the accumulation of dust in an inaccessible position, which should always be avoided.

Another method is the formation of a coil of pipes to act as a radiator. This, also, is unsightly, and tends to accumulation of dust. Sometimes the coils are cased in by means of gratings, which improve the appearance, but the dust nuisance remains.

The best method is that of using upright radiators, built up in sections, a system of American origin. One may divide the radiators under three different headings: the direct, the indirect, and the direct-indirect.

The direct is the ordinary type, placed about 6 inches from the wall. They should be placed against outside walls, preferably under windows, to check the cooling action of the window on the air of the room. They usually extend down to within a few inches of the floor, and the space below and behind is apt to become a receptacle for dust in the absence of good supervision. In hospital work, they do not extend to the floor and are hinged at one end so that they can be swung round in order to keep the wall and floor free from dust.

They vary in height from about 2 feet 6 inches to 3 feet. For hot-water work the units are connected at top and bottom so as to permit of a thorough circulation through the radiator. The most efficient type is one made up of single columns placed a reasonable distance apart, such columns having about 3 to 3½ square feet of radiating surface each. The radiating surface is the external measurement. Radiators with surfaces very close together are not so efficient as those with them further apart; those with flat surfaces are more efficient than those with a lot of raised ornament. Cast-iron radiators will radiate much less heat when enamelled than when painted with bronze or a mineral paint. Oil paint should not be used.

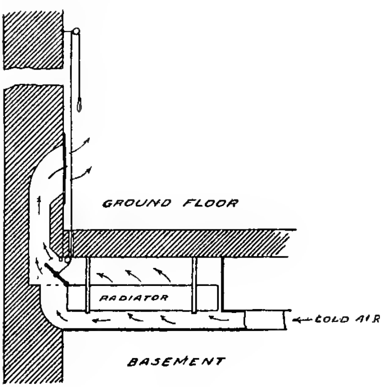


Fig. 61.

The indirect radiator is of an entirely different type. It consists of a group, or battery, of heating units, placed below a floor so that air can pass through the battery and into the room through gratings in the walls. Fig. 61 shows such an arrangement diagrammatically. The radiator is made up of a series of gilled pipes, similar to that shown in section in Fig. 55, or else of tubes of rectangular section with projecting pins or studs to give greater radiating surface. It is held up to the floor by means of iron straps. Leading to it, from an external wall grating, is a cold-air tube. This tube joins a vertical shaft formed in the wall, and a hinged damper or regulator is put at the point of junction, and controlled by a cord and pulleys as shown, so that the temperature may be regulated by the proportioning of the cold and warm air admitted to the room through a grating just above the floor. It will be seen that the heating battery and air tube take up room and are unsightly; this restricts the use of the system to ground floor rooms, the apparatus being put in the basement. The system is a good one for one-story buildings and gives the basis of a warming and ventilation scheme together.

The direct-indirect radiator is really a ventilating radiator also. One form is shown in Fig. 39, under the heading of ventilation, and consisting of a radiator with baffle plates at front and back. A better example, however, is that shown in Fig. 62. The radiator has no baffle plates, and consists of hollow vertical sections through which the hot water circulates. It is covered by a grating at the top, has an air inlet at floor level, with a combined damper and "hit and miss" ventilator at its base. Thus, if the "hit and miss" valve is open the damper is shut, and only the air of the room is warmed by the radiator. If the "hit and miss" is closed the damper is automatically opened, and the incoming air is warmed.

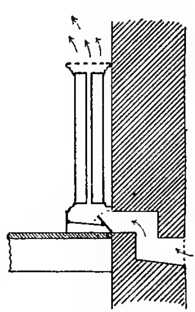


Fig. 62.

It will be seen, therefore, that the direct-indirect radiator warms the air of the room *directly*, and by means of the air inlet it also warms the air *indirectly*, hence its name.

The direct form warms only the air in the room, and the indirect warms only the incoming air, which in turn, by diffusion, warms the room.

The direct and direct-indirect forms should be against external walls, and the indirect should be below gratings, on the less-exposed walls for preference.

It has already been pointed out that the installation of a large heating system is a matter for an expert, but an idea may be given of the method of finding the quantity of radiating surface. Thus, where pipes only are used, Molesworth's rule for hot-water heating is as follows:—

$$L = \frac{\cdot 018C(P - t)(T - t)}{D(P - T)}$$

in which—

L = length of pipe in feet.
C = cubic feet of air to be warmed per minute.
P = temperature of pipes (F.).
t = " " external air (F.).
T = " " building (F.).
D = diameter of pipes in inches.

This must be regarded as an approximate rule only, the exact disposition of the pipes governing every case.

There are numerous rules for finding the amount of radiating surface to be provided in the heating units, but the following is one which is extensively used, both in this country and in America:—

$$S = 1 \cdot 25 \frac{(T - t)}{(t' - T)}$$

in which—

S = square feet of radiator surface to each square foot of glass or its equivalent, 10 square feet of wall, ceiling, etc., equalling 1 square foot of glass in its cooling effect on the air.

T = temperature to be maintained in room (F.).

t = ordinary lowest temperature of the outside air, say 30° F. in England.

t' = temperature of pipes, say 160°-180° for low, to 250°-300° for high pressure hot water, and 180°-220°, and 250°-400° for low and high pressure steam respectively.

It is obvious that the quantity so found will have to be increased if the building is very exposed, or if it is only heated intermittently, as in the case of a church or assembly hall.

Stop valves must be provided at the inlet of each radiator in order to permit of the regulation of the temperature. Where there are several branch services, valves are also necessary on them, in order to regulate the uniformity of the circulation of the water. There are many varieties of such valve, and it will be sufficient just to give an idea of their construction and desirable points. Whether they are placed on a straight length of pipe or at a bend (or elbow) they should be of such a form that when fully opened they permit of a full-way flow through them. Fig. 63 shows a section of one suitable for a straight length of pipe, and termed a "gate" valve. The handle should be of wood and is connected to a vertical shaft having a screw thread on it.

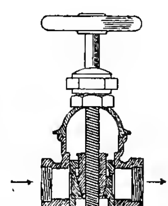


Fig. 63.

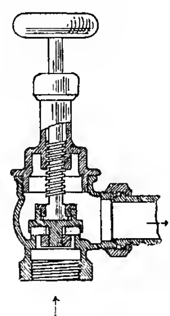


Fig. 64.

A few turns of the handle raises the gate and leaves a clear way through the pipe. It can, of course, be only partially opened if desired. Fig. 64 shows a section through a valve at an elbow. Here also a few turns of the handle raises the valve from its seating in order to leave a clear way through. The inlet pipe to the radiator is shown on the right and the socket to receive the supply pipes is at the bottom. The wooden handles are desirable as opposed to handles of iron, as the former do not get hot.

Air valves must be provided at the side of the radiators, just near the top, to allow of the escape of air. They only need to be opened occasionally, say every three or four weeks, to release any accumulation of air. They can be either operated by hand in this way or be automatic in action. The more usual form in domestic work is that operated by hand, and illustrated in Fig. 65. The automatic forms are often used on large installations, but they are somewhat liable to get out of order and should only be used where there is an engineer handy to attend to them if required.

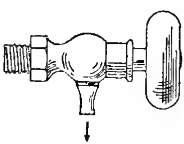


Fig. 65.

There is another position in which a valve is required; that is, on the return pipe near the boiler, so that the pipes can be emptied if desired. For this purpose an ordinary draw-off cock or valve is used.

To complete this brief description of the units which go to make up the complete system, one may mention that automatic means is often adopted to regulate the temperature, either by thermostats (already described) and leverage, or by electric devices involving a motor near the boiler and a thermometer in the room.

Where pipes pass through rooms not requiring to be warmed, a non-conducting covering is generally used; there are many forms of covering, some applied as a sort of plaster, and others in the form of a strip of material wound spirally round the pipe.

We are now in a position to consider the ways in which the pipes are arranged in the low pressure hot-water system. There are three principal methods, termed respectively, the one-pipe, two-pipe, and the drop or overhead system.

In the one-pipe system the inlet and outlet of each radiator joins the same pipe. Fig. 66 shows, diagrammatically, the arrangement of the connexions in this system where the pipe serving the radiator is approximately horizontal, and Fig. 67 where it is vertical. The outlet in Fig. 67 is taken down a little way before joining the main pipe, as this method gives better results than taking it straight across as shown for the inlet. The inlet valve is lettered I.V. and the air valve A.V. It will be noticed that there is no air valve in Fig. 65, the reason being that it is unnecessary with that method of connexion since the air can escape through the inlet pipe.

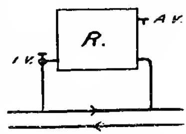


Fig. 66.

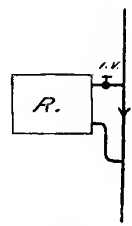


Fig. 67.

There are varieties of the one-pipe system. Thus, in a building of one story only, the main circuit of piping is taken vertically up from the boiler to as high a point in the basement as possible and then passes round the building, falling all the way back to the boiler, to which it is connected low down at the side. The rising pipe is termed the flow, and the falling pipe the return. The pipes should have a fall of not less than 1 inch in 10 feet, and short branches should have a fall of not less than 1 inch in 5 feet.

With a building of two stories it is possible to arrange the pipes in a similar way, taking the shortest route to the highest point for the flow pipe, circuiting round the upper floor, then vertically down to the lower floor and circuiting round that and on to the boiler as before. The disadvantage of a single circuit is the inequality in temperature, the radiators farthest from the flow pipe being of lower temperature than those near it. Therefore two separate circuits are often provided, one for each floor. The one-pipe system is not well adapted to a building of several floors.

A third method of running the one-pipe system is to run a single circuit round the basement, and to provide secondary circuits in the form of two pipes in each case, rising vertically on either side of radiators placed one over the other on plan, one of the vertical pipes supplying the radiators and the other returning the circulation to the main circuit. The secondary circuits are of smaller diameter than the main. From the highest point on each circuit, an air pipe of small diameter (about $\frac{3}{4}$ inch) must be provided, and carried up to discharge above the cistern supplying the whole system, which must of course be placed a few feet above the highest point to be supplied with hot water.

It is sometimes necessary to dip the pipes to pass under doorways and similar features, rising again on the far side of the obstruction. Such dips form traps and obstruct the circulation; they should therefore be avoided wherever possible. If unavoidable, the best place for them is on the return pipe, near the boiler.

The cold supply should be taken either direct into the boiler or connected to the return pipe just before the boiler is reached, the supply pipe having a dip or trap at the point of connexion to prevent the hot water circulating up it to the feed cistern. An expansion pipe should be carried up as nearly over the boiler as possible, in the form of a continuation of the vertical flow pipe, and should have its upper end bent over the feed cistern. This allows for the expansion of the water in heating, and also for any discharge that may occur from it to occur in a place of safety.

In the case of the one-pipe system the flow connexion to the radiator should be taken from the top side of the pipe, as the water is hottest there, and the return connexion should be made into the side of the pipe where the temperature is a trifle lower. This obviates any cooling in the system.

The amount of radiator surface, if the radiator is on the return pipe, must always be a little more liberal than if it is on the flow pipe, as the temperature is rather lower.

Each system of arranging the pipes has its advantages and disadvantages, and those of the one-pipe system are as follows: The advantages are economy, and the fact that there is no liability to short circuiting; i.e. no radiator can escape being supplied. On the other hand, it is not so suitable as other systems for a building of several floors.

In the two-pipe system the pipes are arranged to flow and return as before, but in a different way, the flow and return following the same course. In this system, if radiators are used, the supply to the radiator is taken from the flow pipe, and the outlet is taken to the return pipe. Figs. 68 and 69 show this, and should be compared with Fig. 66. An inspection of Figs. 68 and 69 will show that they give different positions for

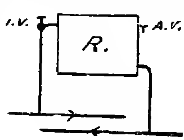


Fig. 68.

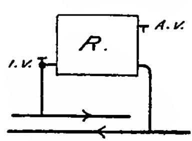


Fig. 69.

the inlet in the two cases. The top inlet shown in Fig. 68 is the most efficient, but the bottom inlet shown in Fig. 69 is the neatest in appearance, being only a little above the floor. The two-pipe system is more generally used when pipes are utilized for the radiation, and is not often used for radiator schemes. It is better than the one-pipe system for a building of several floors, but is more expensive to instal than the former. The chief advantage lies in the fact that the cooled water from the radiator is taken into the return pipe and does not therefore cool that in the flow.

In the overhead or drop system the flow pipe is taken to the highest point straight away, and then split up into several vertical returns, which are collected together at the bottom into one main return. The radiators are connected by inlet and outlet to the same vertical pipe as shown in Fig. 67. The system is particularly suitable for a high building, if the radiators are arranged one over the other on the various floors. The advantages beyond this are that the large amount of vertical piping ensures a rapid circulation, and permits the use of smaller pipes. No air valves are needed, as explained in referring to Fig. 67.

Where several detached buildings have to be heated, such as a hospital, it is unusual to instal a boiler in each building in the manner already described. Instead of this arrangement, an apparatus known as a calorifier is provided in each building to heat the water. In its commonest form it consists of a cylindrical vessel, containing a coiled pipe through which steam passes. It is not worth generating steam especially for this purpose, but in such a building there is generally a boiler house from which steam under pressure can be obtained. To save waste, provision is made for shutting off the steam when the desired temperature is obtained.

In the low pressure system the temperature of the radiators is not high since the water can never do more than boil, which, when open to the atmosphere, it does at about 212° F. Therefore the temperature of the radiators does not often rise above 150° F. The system is largely used because it is free from danger and can be economically installed. Any hot-water system is, however, liable to damage by frost if not used continuously through the cold weather.

The high pressure system of hot-water heating was invented early in the nineteenth century by a Mr. Perkins, and was known by his name for many years. The method of installing the system has varied but little since it was first introduced. Whereas the low pressure system is open to the atmosphere, through the medium of the expansion and air pipes, the high pressure system is hermetically sealed. Broadly speaking, it consists of an endless pipe partly filled with water, a coil of the pipe being placed in a furnace to act as a boiler.

It is a well-known fact that water boils at different temperatures when subjected to different pressures. Thus, at sea level, it boils at about 212° F., but at the top of a high mountain, where the pressure of the atmosphere is less, it would boil at a lower temperature. Similarly, at the bottom of a very deep mine, it would not boil until it reached a much higher temperature than 212°, because the pressure is greater. This phenomenon is utilized in the determination of heights, the science of determining heights by the relative boiling-point of water being termed hypsometry.

The object of the high pressure system is to remove this governing influence of the air, it being possible to get a much greater pressure in a closed apparatus and therefore a higher temperature. In the ordinary forms of high pressure apparatus the pipes reach a temperature of about 250° to 300° F., and in any good installation valves are used to prevent a higher temperature being reached, since as high as 600° F. is quite a possibility. The pressure referred to above is obtained entirely by natural means, the expansion of the relatively incompressible water compressing the air.

Let us consider the details of the system. The component units are the coil or coils forming the boiler, the pipes and joints, the expansion chamber, and the filling pipe. No stop valves are needed in this system, neither are air valves used, as the air is dislodged when the apparatus is first charged with water, while that which is given out from the water during the heating accumulates in the expansion chamber. No branch services are needed, nor are radiators used as a rule.

The boiler is usually formed of a coil or coils of the same pipe as is used for radiation of the heat into the rooms. The total length of the coiled pipe is about $\frac{1}{5}$ of the whole length of pipe used apart from the boiler. It can be in a single coil, but, in a system of any size, several intercoiled sets are used, the flow of one set joining the return of another, thus making one entire unit instead of several distinct units, each of which would require its own expansion chamber. This method of arranging the coils gives several distinct pairs of flows and returns and so ensures a high temperature throughout.

The pipes are of strong welded wrought iron, $\frac{7}{8}$ inch in internal diameter and about $\frac{1}{4}$ inch thick. They are usually tested to a pressure of 3000 lb. per square inch and to a temperature of 2000° F. These tubes are threaded at both ends with right and left-handed threads respectively, the joint being made by means of loose collars as shown in Fig. 70. No jointing material is used, but one end of each pipe is shaped as shown, so as to give a tight "metal to metal" joint when the socket is fully screwed up.

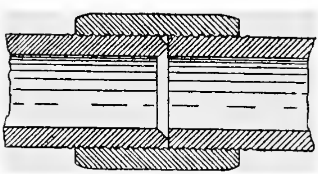


Fig. 70.

The expansion chamber usually takes the form of a pipe 3 or 4 inches in diameter, fixed vertically or nearly so, with a screw cap at the top. It may, however, take the form of a coil.

The apparatus is charged, in the first instance, through a plug near the boiler, but a recharging plug is provided just below the expansion chamber, for adding water as from time to time required.

The flow pipe should go to its highest point by the most direct route, in order to ensure a good circulation. Dips or traps in the pipes are not so difficult to deal with in this system, as the circulation is much more rapid than in the low pressure method. The pipes should be fixed at least 3 inches from any woodwork. They can be exposed in the room, or, if this is objected to on the ground of appearance, they can be put behind a grating where the skirting of the room would ordinarily be.

Radiators are not ordinarily used in this system, but if one or two are desired on the system they can be effectively provided in the manner shown in Fig. 71. Below each radiator a large pipe is put, of say 3 to 4 inches diameter, to the ends of which the ordinary small pipe is connected. From the larger pipe a flow is taken to the radiator, a return being taken from the opposite end. The method of connecting the flow and return has already been described, and should be again noted in Fig. 71, the flow going from the top of the pipe and the return being connected to its side.

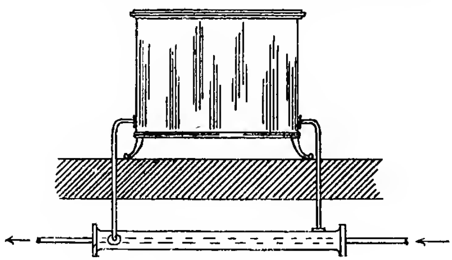


Fig. 71.

Instead of the expansion chamber, a valve may be used, fixed in a water tank. This valve can be adjusted to limit the pressure and the temperature to any desired figure. Fig. 72 shows a section through one form of such a valve, known as the Stainton valve. At the top, shown by hatched lines, is a weight, connected to a vertical spindle which has a conical lower end. The cone rests on a seating, and when the pressure gets beyond the predetermined figure it automatically rises and lets the water out into the tank. On the pressure falling below its normal amount, another small valve, at the bottom of the Fig., automatically rises and lets more water in. The spindle of this valve is not of circular but of cruciform section, so that a very slight rise of the spindle will let water in.

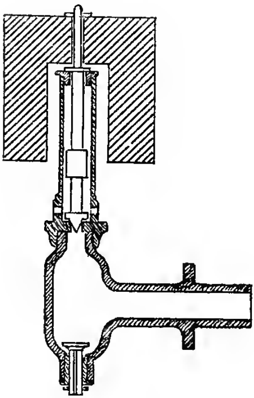


Fig. 72.

As has been pointed out, any water system is liable to be interfered with by frost, but it is only right to point out that frost-defying liquids can be obtained and added to the water to prevent freezing. Such liquids, however, are not in very general use.

In concluding the description of the high pressure system its advantages and disadvantages may be briefly set forth. Its first cost is not great, unless the pipes are encased; the pipes may be quickly raised to the desired temperature; a high temperature may be obtained, which is particularly desirable for some purposes, such as the drying-rooms of laundries and other businesses; and only a small quantity of water is used. On the other hand, there is danger of explosion if the system is not well designed; the temperature may become too high if a valve is not used with the result that the adjacent air will be scorched; if care is not used in proportioning the system, the heat may be unequally distributed, the upper rooms becoming too hot and the lower ones not warm enough; the appearance of the pipes is sometimes an objection, and if they are enclosed by gratings dust accumulates behind the grating and is decomposed by the heat.

We come next to steam heating, which was proposed as far back as the sixteenth century, for we find Sir Hugh Platt, before referred to, writes: "For the keeping of any flowers abroad, as also seeds sown within doors . . . in a temperate heat with small charge, you may perform the same by hanging a cover of tin or other metal over the vessel wherein you boil youre beefe or drive youre buck, which, having a pipe in the top, and being made in the fashion of a funnel, may be conveyed into whatever place you shall think meete".

It was not, however, until the early part of the nineteenth century that a workable system was installed on very much the same lines as at present adopted. In modern systems the steam circulates through strong wrought-iron pipes, having expansion joints, and laid so that the condensation water can drain back to the boiler. The principle of warming by steam is the rapid condensation of steam into water on coming in contact with cooling surfaces, the latent heat being given out at the moment of condensation. The quantity of radiating surface depends on the system of ventilation, the area of cooling surfaces, the accuracy of fitting of doors, windows, etc., and the desired temperature.

Steam is, of course, water turned into gas by expansion due to heating it to a temperature above boiling-point. There are several methods of steam heating, such as low and high pressure, atmospheric pressure, exhaust steam, and vacuum heating, which will be briefly dealt with in the order given.

Greater care and skill is needed in designing a system of steam heating than with one for hot water, owing to the difficulty of disposing of the condensation water without annoyance from vibration or "water hammer". In steam work the pipes must be given a greater fall than is usual for hot water and care must be taken to avoid obstruction to the return of the water to the boiler. In the case of dips or traps, for example, a draining pipe must be carried down from the dip to the return pipe to carry away the water which would otherwise fill up the dip and lead to noise and obstruction of the flow of steam. As another example of the necessity of care in this respect, what are termed eccentric fittings should be used. Thus the ordinary form of junction shown in Fig. 73 will do all right for hot-water work, but might collect water in steam work, therefore the "eccentric" form shown in Fig. 74 should be used for the latter case, since it gives no possibility of obstruction. The principle involved applies to all steam work.

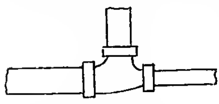


Fig. 73.

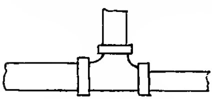


Fig. 74.

In the low pressure system, boilers similar to those used for low pressure hot water are used, the water supply being furnished by a feed tank near the boiler. A flow or distributing pipe goes from the boiler to supply the radiators, the water of condensation being taken back to the boiler by a return main as with hot-water systems. Sometimes the return is connected to the boiler above the level of the water in it and sometimes below, the former being termed a dry and the latter a wet return. Sometimes the condense water is pumped back, but in the low pressure it generally returns by gravitation, giving what is termed a gravity return. Air must not be allowed to accumulate in the pipes and the air valves fixed on the radiators are generally of the automatic type.

The expansion and contraction of the pipes is much greater than in the case of hot-water systems, and the changes of temperature are more rapid. Ample provision must be made for this, the difficulty being overcome by using expansion joints on the straight lengths, and plenty of bends where junctions and connexions occur.

It is unusual to fix radiators at a lower level than the boiler, but if this is done a steam trap must be provided in order to prevent waste of steam and take the water of condensation.

Sometimes the steam is taken from a boiler which is principally used for generating steam at high pressure for the driving of machinery. In such a case a special valve is used on the system in order to reduce the pressure from high to low.

The methods of arranging the pipes and connexions to radiators in steam work are similar to those described for low pressure hot water, i.e. the one-pipe, two-pipe, or drop systems. In the one-pipe system a single connexion is used for each radiator instead of two, the branch pipe conveying the steam *to* the radiator and the condensation water *from* it. In the two-pipe system the steam is conveyed by the flow pipe and the water carried back by the return, whereas with the one-pipe system the single pipe conveys both steam and condense water. In the two-pipe system, each radiator has therefore both a flow and a return connexion, with a valve on each. In the case of the drop system, there is usually only one connexion to each radiator, but if any radiators are served by the main flow pipe, they should have two. The system works better, however, if no radiators are connected to the flow pipe.

No matter which system is used each radiator should have an air valve, which should be fixed much lower down than is the case with hot water.

In the low pressure system the pressure of the steam is usually from 2 to 5 lb. per square inch, but in the high pressure it is above 10 lb. The arrangement of the units in the latter system is similar to that just described, but a different type of boiler is used, such as the Cornish, Lancashire, water-tube, or multitubular boilers. This system is, as a rule, only adopted where steam at high pressure is used in the same building for other purposes than heating.

. A system known as atmospheric steam heating is largely used on the Continent, but is not extensively used in this country. The boiler pressure is usually from 1 to 3 lb. per square inch. The pipes are arranged similarly to those in the low pressure steam system, but a pipe is carried up from the upper end of each return pipe and left open to the atmosphere at the top. The lower ends of the return pipes are collected together and taken into an enclosed tank, and thence into the boiler. The system is said to entirely overcome the difficulty of water hammer.

Exhaust steam, or steam which has been partly used in the cylinders of engines, is also used for heating. Such exhaust steam has about 90 per cent of its original energy on leaving the engine and can well be utilized for such a purpose. As it leaves the engine, however, it contains oily, greasy matter taken up from the lubrication of the cylinders, and this matter must be removed by special apparatus before admitting it to the heating system, or it will lower the efficiency of the radiators. The drop system is the usual method of arranging the piping, the water of condensation being collected into a tank and pumped back to the boiler, it being usually heated before reaching the boiler either by an "economizer" as used in con junction with the supply of water to large steam boilers, or by some other method. The system can be arranged so that both exhaust and live steam are available for heating, but this complicates the arrangement and greatly increases its cost. Special combined air and vacuum valves are fitted to the radiators. The cost of running an exhaust system is low, by reason of using steam which would otherwise be wasted, but the system is a rather expensive one to instal, owing to the fittings and apparatus required.

The system known as vacuum steam heating is one which provides for increasing the efficiency of the radiators by extracting the air from them and thus accelerating the circulation

The return pipes are always in a state of partial vacuum, being in direct communication with an exhaust pump which extracts the air and returns the water of condensation. In a vacuum, water will boil at a lower temperature than otherwise. Automatic valves are provided on both inlets and outlets of the radiators and at certain points on the pipes. In a system of this kind the temperature is much more under control than is the case with other steam systems. In a variation of this system termed the "Nuvacuumette," no valves are provided on the outlets of the radiators, which has the effect of causing a partial vacuum in both radiators and return pipes. The chief advantages claimed for the vacuum systems of heating are the following: The difficulties with regard to dips are easily overcome, a less amount of radiating surface is required, there is economy of fuel compared with other steam systems and with hot water, there is no danger from frost or leaks, and the cost of the installation is not high.

There are certain advantages incidental to steam heating as compared with hot water, the principal of which is that the radiators are quickly raised to their full temperature and also soon cool down again if desired. On the other hand, a steam installation is more costly than one for hot water, both as regards first cost and annual maintenance, and the heat is apt to be dry and fierce, tending to scorch the air.

There is also a system involving the use of both steam and hot water. It is rather a complicated system, but the mixture of the steam and hot water greatly increases the velocity of the circulation in the system, and the heat can be better transmitted for long distances.

The warming of buildings by the admission of warmed air is really a combination of warming and ventilation, and is fully covered by a study of the indirect and direct-indirect radiators already illustrated (Figs. 61 and 39 and 62).

Gas heated steam radiators, with or without flues, are also now largely used for special cases, such as small offices. Some have automatic gas valves, controlled by the steam, giving a means of regulating the temperature. Gas heated hot-water radiators can also be obtained suitable for a small garage or a greenhouse, the boiler and gas burners being on the outside of the building. Another type of gas radiator is known as the steamless. It has internal steel tubes of special form and warms the room merely by the medium of hot air, without the use of any liquid.

In recent years electricity has become more popular as a means of warming, but it is an expensive method. Probably the best form of electric radiator is that containing long bulb lamps. The filament is heated to an orange red, in which state it gives out most heat. The glass cases of the lamps are frosted or ground, to enable them to retain some heat rays and so assist in warming the air by convection as well as by radiation. Another type of electric radiator is the Prometheus, in which a metallic filament is deposited on thin mica sheets, enclosed in a casing. The use of radiators involves the necessity of duplicate systems of wiring the building so that the current consumed may be charged on the "power" scale. The system is not to be compared with fires as regards cost, but it is far cleaner, more sanitary, under perfect control, and portable.

To be sanitary in the fullest sense of the word, a building must not only be well warmed; it must also be well lighted, both naturally and artificially. Even in olden times this fact was recognized, for one finds the following in the writings of Lucar, who lived in Elizabeth's time: "For Heaven's sake make all the rooms of youre house lightsome, of a convenient height and of a laudable largenesse. Beware you do not sleepe in a close place."

In the very earliest times of which we have details, glazed windows were unknown, the ancients providing wide, low openings to their one-story houses, just under the eaves of the roof, high enough up in the walls to ensure privacy, the openings serving for both light and ventilation. This arrangement influenced the whole of their architecture. The ancient Egyptians used similar openings with gratings. One often finds windows referred to in the Bible, but there are seven words in the original writings which have all been translated "window". The windows in the ark of Noah were, according to correct translation, translucent, and are believed to have been filled with an arrangement of polished oyster shells. In the Book of Judges, windows with movable lattices are definitely referred to. The use of glass for glazing windows was known to the Romans, though talc was more largely used by them, while they also used sheets of oiled linen and thin plates of horn. One reads of the Emperor Caligula neglecting the duties of state to supervise the reconstruction of his windows with sheets of glass instead of sheets of talc. The excavations at Pompeii have brought to light the fact that glass windows were used in the better houses, while the Baths had windows glazed with plate glass ground or obscured on one side to prevent people seeing through.

Various materials have been used for covering window openings. Thus, the Greenlander of to-day fills them with the maws of halibuts. The Saxon used oiled linen, panels of horn, and lattices of wicker work or thinly cleft oak. The Romans, during their occupation, do not seem to have introduced the use of glass for this purpose in Britain, and the earliest mention of glass windows in England is in respect of the glazing of the windows of a church in York in 627 A.D. By the time of Chaucer (14th century) its use was more general, and in his "Dreme" he thus describes his bedroom:—

> With glas
> Were alle the windowes well yglazed.

His poems also show that the casement window was in use then. Till the time of Henry VIII, however, the use of glass did not become very general, and one reads, in the records of Alnwick Castle, that the glazed windows were taken out and put in a place of safety while the family were away!

The sash window was introduced about the time of the Great Fire of London, the upper one being fixed and the lower one raisable, being kept up by a system of notches and catches. The sash window with the sashes hung by means of cords and weights, as now used, is believed to be a Dutch invention, and was certainly introduced into this country with the arrival of William of Orange.

Natural lighting is, nowadays, furnished by means of glazed windows, lantern lights, skylights, fanlights, and glazed doors. Every habitable room should have a window, opening into the external air, the other items just enumerated being looked upon as quite supplementary to windows and in no way as substitutes for them.

By-laws and building regulations make various provisions as to the minimum window area allowable, some taking the height of the room into account and others not. Thus, two examples may be given:—

Window area to equal not less than $\frac{1}{10}$ the floor area.

Window area to equal not less than 1 square foot per 100 cubic feet of space.

While a minimum provision is desirable, there is another side to the question. If there is too much window space it is very difficult to warm a room by ordinary means. It is a good plan therefore to fix a maximum also, and say that the window area should not exceed 1 square foot per 70 cubic feet of space.

A further usual provision is that not less than one-half the area of the window shall be made to open. Windows should be very carefully placed in designing a house. They should extend as nearly to the ceiling as possible, and should be in the middle of a wall. If placed at one end of a wall, the room will not be nearly so well lighted as if the window is in the middle of the same wall.

Most windows are glazed with ordinary sheet glass, but for large sheets and first-class work plate glass must be used. Where the glass need not be transparent it is possible to get increased light by using a highly refractive glass such as muranese or prismatic. Both have a raised pattern on one side of the sheet, and this should be on the inside of the room. In the case of prismatic glass the pattern takes the form of straight V-shaped grooves over the whole surface; these should be placed horizontally in order to refract the light and divert it into the room instead of letting it fall on to the floor just inside the window. This sort of glass is often used for increasing the light in dark offices, but it is little used in domestic buildings on the ground of appearance. For offices in narrow streets, outside reflectors are frequently used, but these are not very suitable to domestic work.

If the window opens on to a small enclosed yard, or there is a wall opposite and not far from it, the light may be increased by facing the wall with white glazed tiles, or by whitewashing it. White glazed surfaces, when used externally, rapidly collect dirt, and unless kept clean are no more efficient than whitewash. Wherever the latter is used it should be renewed annually, and the former should only be used where it can be readily cleaned. Where there is a basement to a house with a forecourt, the area in front of the basement windows is often too narrow. The light may be increased by sloping back the area wall, in a direction away from the window, and lining it with tiles or whitewashing it. Where there is no forecourt, areas in the front of basement windows are covered with gratings. These should be made up of narrow, deep bars, placed at right angles to the face of the building.

If placed in a direction parallel to the face of the building, they obstruct far more light.

We now come to the consideration of the means of providing artificial light, which may be summarized as candles, lamps, gas, and electricity.

Candles are almost obsolete as a means of providing the sole light for a room. They are used to increase light locally in the case of say a piano or a writing table, and are also used, largely from a decorative point of view, in the arrangement of dining tables. One does not notice much vitiation of the air if they are used in this casual way, but if a room were lighted with exactly the same *quantity* of light by each of the various methods, the comparative vitiation of the air would be as follows: Candles, 1; oil lamps, ·7; ordinary gas burners, ·45; incandescent gas burners, ·27; and electricity, 0.

Oil lamps are still largely used where gas is not available. To be of the greatest efficiency they should be of good construction and carefully attended to. To get complete combustion and freedom from smell, there should be proper means of regulating the air supply to the flame, and a chimney of proper height. The receptacle for oil should never be allowed to get quite empty, or an explosive mixture of air and oil vapour may be formed, and possibly set on fire by the smouldering wick. On the other hand, the receptacle should never be filled too full, or the oil may run out and be set alight. The oils chiefly used are paraffin and petroleum, which are cheap and have a high illuminating power. Colza oil is safer, but it is thicker in nature and needs a lamp of special form owing to the difficulty of soaking the oil up into the wick. In using oil lamps, the impurities given off are carbon dioxide and water vapour.

Ordinary coal gas is perhaps the most largely used means of illumination. It is produced by the destructive distillation of coal, free from the access of air, the resulting gas being afterwards purified by various processes. The gas can be said to consist of three classes of constituent: the illuminants, the diluents, and the impurities. The power of illumination is derived from unsaturated hydrocarbons, which would cause smoke in the absence of diluents such as hydrogen, saturated hydrocarbons such as methane, and carbon monoxide, etc. The impurities consist of small percentages of carbon dioxide, sulphur compounds not effectively removed in the process of purification, etc.

Water gas is produced by passing steam through incandescent coke or anthracite coal, vaporized mineral oil being added to the resulting product. The fittings and pipes should be thoroughly gas-tight if this gas is used, as it contains a large proportion of carbon monoxide, a very dangerous gas to breathe.

Generally speaking, the impurities given off by the combustion of gas include carbon dioxide and monoxide, ammonia and sulphur compounds, and water vapour.

Gas is consumed by various kinds of burners. Thus, there is the circular or Argand burner in the form of a circular ring with fine holes at the upper side, and the flat flame burners such as the fish-tail and the bat's-wing. In the former the burner has an approximately flat top, the gas issuing through two fine ducts meeting at an angle of 90°, whereas in the case of the bat's-wing burner the top is rounded and has a slit from side to side. The top part of the burner should be of pottery, and the better classes have regulating devices inside to ensure more complete combustion than would otherwise be obtainable.

The brightness of the light in the case of ordinary gas is due to the burning, in the flame, of minute particles of carbon. The higher the temperature the more incandescent will they be, and the brighter the light.

The old-fashioned burners are now becoming somewhat obsolete, being superseded by one or other of the various incandescent burners, which have nearly perfected the combustion of gas. Their general principle is similar to that of the Bunsen burner, a controllable quantity of air being admitted to the burner so that it is a mixture of gas and air that is consumed. The result is that there are practically no unconsumed particles of carbon or other matter escaping into the air, which is further safeguarded by the use of the mantle or covering of fine asbestos gauze, the incandescence of which gives the familiar bright light. The inverted incandescent burner is a still further improvement in gas supply, burning less gas than the other form, and like it, leading to far less vitiation of the air; only about one-half the vitiation caused by the old-fashioned fish-tail or bat's-wing burners.

Acetylene gas is produced by the action of water on carbide of calcium. It gives a very brilliant light, making the mantle a superfluity. It is not, however, likely to come into very general use for domestic lighting owing to the extreme care required. All pipes and fittings must be thoroughly gas-tight, as a mixture of a very small proportion of this gas and the air is explosive.

Opposite in nature to that just described is what is known as air gas, in reference to which it is claimed that a burner might be turned on all night, unlighted, in a bedroom without danger. It consists of a mixture of air and petrol vapour, a very small percentage of the latter being needed to produce an illuminant. Small plants on this system are obtainable for country houses, but the system has not been applied yet, I believe, on a large scale.

Lastly, we come to the electric light, of which there are two principal varieties, involving the use of the incandescent bulbs and arc lights respectively.

The former furnishes the most sanitary method of lighting at present known. The globes or bulbs are hermetically sealed, so that no impurity can be given off into the air, and the light is derived from the incandescence of either a carbon or a metal filament. The lamps containing metal filaments require very careful handling as the filament is easily broken, but they give a better light than those with carbon filaments. The system involving the use of arc lights is more suitable for large exhibition halls, railway stations, and streets, though it is used also in factories and shops. The globes are not sealed as in the previous case and the light is produced between the points of a pair of carbon "needles," a small percentage of nitric acid being given off. The proportion is, however, so small that this method can still be placed far in front of those in which gas, oil, or candles are used.

CHAPTER V

THE BUILDING—ITS WATER SUPPLY.

WATER is a chemical compound of hydrogen and oxygen consisting of two atoms of the former to one of the latter; by weight it consists approximately of oxygen 89 per cent and hydrogen 11 per cent. As found in nature, it is almost impossible to obtain water free from impurities, which take the following forms: dissolved and suspended inorganic and organic matters, and micro-organisms.

The amount of dissolved inorganic matter in a sample of water depends very largely on the nature of the soil through which it has passed. The chief mineral impurities are lime salts, chiefly the carbonates and sulphates of lime; others are carbonate and sulphate of magnesium, chloride of sodium, iron salts, and silica. The salts of poisonous metals are also found, chiefly those of lead and copper, the commonest being the first named. The presence of lead in water is generally due to its being taken up by soft water in passing through lead pipes or when stored in lead-lined cisterns. Water containing the smallest quantity of lead should be avoided for domestic purposes, so small a proportion as 1 part in 700,000, or ·1 grain per gallon, being sufficient to set up lead poisoning in the system of a person who is in such a state as to be readily affected. The hardness of water is due to lime and magnesia, but a moderate hardness is not harmful. Exceedingly hard water is not good for a weak digestion.

The suspended inorganic matters are chiefly brought into the water in the form of impurities washed from the air by rain, or taken up in its passage over or through the soil. Examples are minute particles of sand, chalk, marl, oxide of iron, etc., all of which will settle and form a sediment when the water is at rest. They frequently cause colour but are not necessarily harmful to it.

Dissolved organic matters may be of either vegetable or animal origin. The former are not necessarily harmful, but the latter, consisting of ammonia compounds, and matters arising from putrefaction, are always dangerous. Thus water from a peaty soil may be quite wholesome, but the presence of animal organic matter often indicates sewage pollution, and any water containing traces of it should be rejected.

Water containing suspended organic matter is also always suspicious, as it may be accompanied by the presence of disease germs. Examples of suspended vegetable organic matter are woody fibre, pollen, starch cells, and fungi, and of animal matter, hairs and scales from the skin of diseased persons.

Micro-organisms may be of either a harmless or a hurtful type. They are so minute that their classification is a matter of difficulty, but it is known that polluted waters abound in germ life, and therefore the chances are that the greater the numbers of bacteria present, the more suspicious the water is.

A good water for domestic purposes should fulfil the following conditions: It should be practically colourless and clear, free from sediment, and sparkling and pleasant to the taste. It should have no smell, be soft to the touch, dissolve soap easily, and be sufficiently aerated, containing about 10 cubic inches of oxygen and 6 cubic inches of carbon dioxide to the gallon.

It will be obvious that the quantity of water required per head of population per day depends on a variety of circumstances. Thus, in a village, it is often limited to that needed for cooking, drinking, clothes washing, and house cleaning, plus a small amount for waste. The use of water-closets is not general in villages, earth-closets and privies being used instead. Bathrooms, also, are not general, unfortunately, in country cottages, and so there is not a great demand for water on that score. Similarly, the question of flushing drains and sewers has not usually to be considered, nor are there any public conveniences to be automatically flushed, nor manufactories to be supplied with water for conversion into steam or used in trade processes. It would appear reasonable therefore to suggest the following figures: for a village, about 12 to 15 gallons per head per day; for a large residential town, about 20 to 25 gallons; and for a large manufacturing town about 35 to 40 gallons per head per day. These figures can, in fact, be taken as reasonable. Thus, for example, the consumption at Bath is about 20 gallons per head, at Scarborough about 24, London 35, and Bradford 40 gallons per head per day. It is true, however, that one can quote other examples which clash with the above. Thus, at Torquay the consumption is as high as 30, and at Birmingham as low as 25 gallons, the former being a purely residential and the latter principally a manufacturing centre. Again, at Glasgow, it is as high a figure as 54 gallons per head per day. There is always danger, however, in dealing with crude statistics, and an investigation would probably lead to a simple explanation of the apparent discrepancy.

The original source of all available water is the rainfall. Part sinks into the ground to form underground supplies, part flows off the surface to form streams, and part evaporates. The amount of rainfall varies greatly in different places; thus on the East coast of England it averages about 17 inches per annum, on the South coast about 30 inches, and in the Lake District as high as about 200 inches per annum. The amount of rainfall is measured by means of rain gauges of various patterns.

The sketch, Fig. 75, shows a vertical section through a common form. It is constructed principally of copper, and consists of (1) a cylindrical body; (2) an inlet, fitting into a groove round the top of the body, and being cylindrical at the top, with a bevelled edge, and in the form of a funnel at the bottom, terminating in a tube; (3) a bottle or other similar reservoir; and (4) a separate measuring glass graduated to read inches of rainfall, and applicable only to the gauge with which it is supplied. The instrument is secured to the ground with small oak stakes

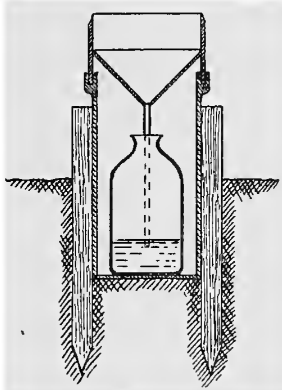


Fig. 75.

and is fixed with its mouth about a foot above the ground to prevent water splashing in. It is made of various diameters, but that in most general use has a diameter of 8 inches at the mouth. Rain gauges must be fixed in an open space, clear of any obstructions such as trees or anything likely to prevent the direct access of rain. In dealing with a large area a series of gauges would be used, scattered about the district; thus in the huge water supply scheme of the Derwent Valley Water Board, for the supply of Leicester, Derby, Sheffield, and Nottingham, the watershed area of which scheme is nearly 50 square miles, fifty rain gauges were used, or approximately one per square mile, in order to deduce a sound average.

One frequently refers to a water as being either hard or soft, and it will be well to deal with this matter before going further into the question of supply. Water is said to be hard if it makes a curdy precipitate when in contact with soap, instead of readily forming a lather, and its hardness is measured by its soap-destroying capacity. Hardness is chiefly due to the presence of bicarbonates and sulphates of lime and magnesia, but also, sometimes, to nitrates, nitrites, and chlorides. It may take either a temporary or a permanent form, temporary hardness being chiefly due to bicarbonates, and permanent chiefly to sulphates. As the two names would imply, the temporary may be removed, while the permanent cannot be entirely got rid of. Hard waters lead to the furring up of boilers and hot-water pipes, and are also wasteful in laundry work. Both hard and soft waters have their uses, however. Thus, a very hard water is needed by the brewer for making pale ale, while for the darker beers a soft water is desirable. Soft water is also desirable for cooking purposes, a hard water making vegetables and meat, if cooked with it, harder and less palatable. Rain water is about the softest obtainable, therefore, the rainfall being the original source of all water supply, the hardness, if any, in any particular water is due to impurities taken up by the water in its passage over or through the soil.

Hardness is measured in degrees, and a sample is said to have 1° of hardness when its soap-destroying power is equal to the effect of 1 grain of carbonate of lime in a gallon of water. Each degree of hardness in 1 gallon of water wastes from 8 to 9 grains of soap. A water having not more than 5° of hardness is classed as a soft water, and one containing anything above 5° as a hard water. Temporary hardness can be removed by boiling, which precipitates the carbonates, but boiling will not affect the permanent hardness ; this can, however, be somewhat lessened by the addition of soda. It will be seen from the foregoing that the goodness of water for domestic purposes depends on the amount of its permanent rather than its temporary hardness. Generally speaking, surface waters are soft and subterranean waters hard, but it depends a great deal on the nature of the strata with which the water has come in contact; for example, from calcareous strata a hard water would result and from igneous a soft one.

The effect of soft water on lead has already been referred to, and it should be noted that hard water has no such action. Water may, if too hard, require to be softened; similarly, if too soft to be palatable, it may be hardened, and it is necessary to consider how this may be done. It has been seen that the hardness may be reduced by boiling, but such a method is of course inapplicable to the case of a town's supply.

Perfectly pure water is incapable of dissolving chalk (or carbonate of lime), and the large quantities of carbonate of lime found in certain waters are therefore held up by some other agent, which is the carbon dioxide absorbed by the water during its passage through the air or the soil. Boiling drives off the carbonic acid gas, or carbon dioxide, with the result that the carbonate of lime, held in solution by it, is precipitated, giving the deposit termed "fur".

In the case of a town's supply, the same effect is obtained by other means. Strange though it may seem, the carbonate of lime is precipitated by the addition of lime, but the phenomenon is easily explained. When water dissolves carbonate of lime, it does so by reason of the carbonic acid gas it contains, the former being converted into a bicarbonate, or salt of lime in which carbonic acid predominates. If lime water, uncombined with any acid, is added to water containing bicarbonates, it converts the latter into carbonates by combining with the excess of carbonic acid they contain, and the carbonates, being insoluble, are precipitated. One oz. of quicklime per 1000 gallons of water is sufficient to reduce the temporary hardness by 1°; therefore for a reduction of, say, 6°, 6 oz. would be required. This process, which is carried out in large tanks, not only reduces the temporary hardness, but also considerably lessens the amount of organic matter present, if any. The carbonate of lime precipitates rather slowly, and the process, as originally carried out, has been modified in many ways. The precipitation can be either intermittent, a good example of which is to be found at Purley, or continuous, as carried out at Southampton. In the former case, the softened water is allowed to remain at rest for from twelve to eighteen hours, and in the latter, special filters are used to remove the precipitate. At Southampton, where the supply is drawn from deep wells in the chalk, the lime, or Clark process, is carried out with modifications under the Haines' patents. Lime water is made in large steel cylinders by mixing cream of lime with softened water, mechanical agitators preventing the lime from settling. The hard water enters a reservoir or softening tank upwards through a large pipe, terminating in a "bell mouth," and falls over the rounded edge as shown in Fig. 76. Over the centre of the bell mouth of the inlet pipe is a circular basin, fed by another pipe with lime water. The sketch shows how the lime water falls over the edge and becomes intimately mixed with the water to be softened. The quantity of lime water supplied is automatically regulated. Each pumping engine has an auxiliary pump coupled to it and working in union with the main pump, the auxiliary pump passing the water through the lime water cylinders and the main pump lifting the water from the well. The auxiliary pump is so proportioned to the main pump that the amount of lime water supplied is just sufficient to make the required reduction in hardness.

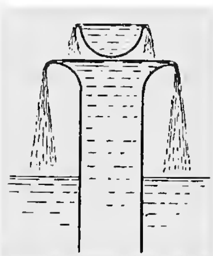


Fig. 76.

The water flows slowly through the softening tank, in which are baffle walls, and over a weir into a channel leading to the filters. These consist of steel tanks, each containing twenty flat rectangular plates made up as follows: A frame of galvanized iron is covered on each side with thick perforated zinc and the whole plate is then encased in cotton cloth. The water passes through the cloth, leaving the precipitated carbonate of lime on the face of it, and out through special openings into an outlet pipe leading to a filtered water storage tank. The water is reduced in hardness by nearly 20° at a cost of about $\frac{3}{16}$ pence per 1000 gallons.

Various methods of softening water by the use of other chemicals are adopted, but for domestic purposes great care is needed. A slight overdose of lime does no harm, but an overdose of a foreign chemical might be a serious matter.

There are many patented forms of water softener in which lime water and soda solutions are used in varying proportions; in some systems, such as the "Criton" and the "Reisert," the apparatus is automatic in its working, and in others, such as the "Archbutt-Deeley," the chemicals are added by an attendant. Such systems are compact, but more suited for industrial undertakings than the more extensive system applicable to a town.

It is not often that it is necessary to *increase* the hardness of water, but it is occasionally done, particularly with water from peat districts, the peat making the water very soft and acid leading to trouble with lead pipes. An example of hardening may be taken from Bradford, where part of the supply is so treated. The water is heavily charged with peat and deficient in lime salts, therefore lime is added to it. Chalk is specially prepared and then converted into milk of lime by machinery, the milk of lime being brought into contact with the water to be treated, in a mixing trough, the water being then passed on to sand filters. The installation at Bradford is said to require practically no attention, and has been working continuously, day and night, for about twenty years.

The quality of a sample of water is a matter calling for very careful investigation, and, in any case of doubt, is a matter for the chemist and bacteriologist. There are, however, certain conditions that should be fulfilled by a good water, and, if these are lacking, there is no need to incur expense in analysis; in fact a distinctly polluted water is not difficult to detect. To be fit for domestic purposes, water should be palatable and free from smell, and to be above suspicion it should be colourless. Palatability is purely a matter of tasting. Smell is also a matter for the senses, but one must go further. Take a stoppered glass bottle of large size, such as that known as the "Winchester quart," and holding about half a gallon. Wash it out with a weak solution of sulphuric or hydrochloric acid and rinse it out repeatedly with the water to be tested. Immerse the bottle in the water and allow it to fill to within about two inches of the neck and securely stopper it. Expose it to light and warmth for not less than twenty-four hours, to see if vegetation is set up or putrefaction occurs. On removing the stopper, this will be discernible by smell, and water not bearing this test should be rejected at once.

If water is tinged with colour, it is generally due to dissolved organic matter, though it may occasionally be due to iron or peat, in which case it is not necessarily a bad water, although one to be avoided if possible. The colour cannot as a rule be judged merely from filling a tumbler. One should use two glass tubes, each about 24 inches high and 2 inches in diameter. One should be filled with distilled water and the other with the water to be examined. If they are placed on a sheet of white paper, a comparison of colour can easily be made. If found to be tinged with colour, a rough test can be made in order to see if the cause is organic matter. Add a drop of Condy's fluid to a glass of the water, which should thereby be turned pink. If the pink colour remains, all is well as regards this point, but if the colour be bleached, the presence of organic pollution is indicated. The presence of chlorine may be detected by adding a small quantity of nitrate of silver and dilute nitric acid. Small tabloids are obtainable for this purpose. If chlorine is present, the fact will be indicated by a haziness or by more or less white precipitate, 1 grain per gallon giving a haziness, and as much as 10 grains per gallon a considerable precipitate. A small quantity of the water may be evaporated in order to see if there is a sediment; there should be no appreciable amount, and in any case its nature should be noted.

If the water passes these rough tests satisfactorily, it should be submitted to expert investigation by an analytical chemist. The manner of taking the sample is important. It should be of sufficient quantity and accompanied by the fullest particulars. A "Winchester quart" bottle should be obtained, and cleaned and rinsed out as before described. It should be filled to the neck, the stopper being firmly put in and covered by a strip of leather or cloth, which should be tied round and sealed. If a glass stopper is unobtainable, a cork may be used, but it must be a clean, new one. The bottle should be labelled with brief particulars and the date, and at once forwarded to the analyst with the fullest particulars, such as the nature of the source and reason for requiring the analysis. For example, if it is a case of illness, the nature of such illness. In the case of a supply from a well, the approximate depth, position in relation to drains and cesspools, if any, and any other possible source of pollution should be stated. The analysis should be commenced within forty-eight hours if possible. Water supplies require examination from time to time. Occasional pollution may be due to a spell of heavy rainfall, bad condition of filters, or in the case of a house, defective cisterns and fittings.

Not only should the water be submitted to physical inspection and chemical analysis, but, if the report of the chemist is satisfactory, a further sample should be taken, and forwarded, with full particulars, to a bacteriologist. The sample for this purpose is also taken in a special way. A smaller bottle is used, generally of about 8 ounces in capacity. The greatest care is necessary to prevent contamination of the sample, and it is also necessary that it should be kept very cold and examined with the least possible delay. Bacteriologists use special bottle cases for the transmission of samples. The bottle fits into a tin-lined receptacle, surrounded by another casing for holding ice, this in turn being surrounded by a layer of asbestos, and the whole fitting into a wooden box fitted with a lock.

The conclusions of the bacteriologist are mainly based on three considerations, which are (1) the number of micro-organisms present in a sample; (2) the detection of organisms which indicate that the water is subject to sewage pollution; and (3) the location and identification of disease germs.

In addition to the investigations of the chemist and bacteriologist, it is always necessary to make a careful examination of the source of water and its surroundings in order to look out for possible causes of future pollution.

The report of the chemist is sometimes rather too full of technicalities to be readily understood by the surveyor, but there are certain guiding points which may with advantage be referred to. Generally speaking, the organic carbon in a drinking water should not exceed ·2 parts per 100,000; nor should the organic nitrogen exceed ·02 parts per 100,000. A high ratio of the latter to the former indicates the presence of animal organic matter. Some waters contain a fairly large proportion of organic matter of vegetable origin, soft waters of a peaty taste; these are not suitable for regular use, being likely to cause diarrhœa and being liable to become readily infected with disease germs since they contain the food for their development. Among the tests applied by the chemist is one to determine the amount of albuminoid ammonia, i.e. the nitrogen given up as ammonia when the water is treated with an alkaline permanganate solution. It is a test for the nature of the organic matter. The amount of free or saline ammonia is determined by distilling the water. A good drinking water should not contain more than ·008 parts per 100,000 of albuminoid ammonia. Other items in an analytical report are nitrates and nitrites. They, like the free ammonia, are of value only in determining the previous history of the water, since the decomposition of sewage matter produces ammonia nitrates and nitrites. A high figure for free ammonia indicates recent sewage pollution, since, generally speaking, the ammonia is gradually converted into nitrates and nitrites. The free ammonia should not exceed about ·008 parts per 100,000, nor should the nitrates exceed the same amount, generally speaking.

The particulars as to the source of the supply are of the greatest value to the chemist in giving an opinion on the fitness of water for use. Thus, the presence of nitrates in a sample of water collected from a large watershed area of uncultivated land is much more significant of danger than in the case of water from a deep well. A proportion that would be regarded as safe in the latter case would make the sample in the former case open to suspicion.

Another test for organic matter is the amount of oxygen absorbed by the water in contact with permanganate of potash. The figure for this should not exceed, in ordinary cases, ·15 parts per 100,000, though for upland surface water a larger figure is quite permissible. Chlorine is another item; in itself, if of very small amount, it is harmless, but if above a certain figure, it indicates sewage pollution. Any water containing above 1 part per 100,000 is open to suspicion. As chlorine is generally present in the form of common salt, the test for it is of no value in the case of waters from near the sea, or from the neighbourhood of salt deposits. The presence of phosphates in a sample is always an indication of pollution.

The amount of matters in suspension should not exceed 50 parts per 100,000. It should be noted that the foregoing figures are only given as a rough guide, the satisfactory explanation of a higher figure being possible occasionally by the nature of the strata through which the water has passed and other local considerations.

Having dealt with the general features of water, let us next consider the sources from which it is obtained, dealing with this point under two headings, (1) geological, and (2) practical.

Alluvium often rests on an impervious bottom, on which water will collect, and which can be reached by sinking a well. In some parts of the Pleistocene a layer of middle drift is found between two boulder clays, in which case wells sunk through the upper clay will provide a hard water. The Pliocene can be bored in many places for water. In the case of the Oligocene, the sands of the Osborne beds contain hard water, and water is invariably found at the surface of the Barton clay. With the Eocene formation, the Bagshot sands, where they rest on the Bagshot marls, provide a supply for wells. The London clay is impervious, but the Oldhaven, Woolwich, and Reading beds, and the Thanet sands contain much sand and gravel and are full of water in many places.

The Chalk round London forms a fine source of supply, the water being held up by the impervious strata beneath. If the London clay is bored through the water will rise nearly to the surface. The Upper Greensand contains a good deal of water but its area is limited. The Lower Greensand, underlying the Gault, is a good water-bearing stratum. The Hastings Sand furnishes a water of a somewhat chalybeate nature, Tunbridge Wells being situate upon it.

The Upper Oolite is a poor water-bearing stratum, but the Middle Oolite furnishes a good supply, and wells are largely sunk into it; the Lower Oolite also yields a good water in places.

In the case of the Trias, the lower portion of the Keuper series contains porous beds with considerable water, supported on seams of compact marl. Springs occur at the outcrop and plenty of water is obtainable by boring.

The Bunter sandstone is the most important water-bearing stratum in England, except the chalk with greensand. The yield is largely due to the permeability of the strata, and the wells of Manchester and Salford alone yield 6,000,000 gallons per day of clear water, drawn from an area of not more than 7 square miles, largely covered with buildings, streets, and boulder clay. Possibly much of the water percolates from the Rivers Irwell, Irk, and Medlock, which traverse the strata, but if so, the sandstone is a wonderfully effective filter, since the rivers named are little better than sewers. One spring from this source, the Wall Grange spring near Leek in Staffordshire, yields 3,000,000 gallons a day.

The Permian formation also contains much water in its lower beds when they immediately overlie those of the carboniferous series. The Coal Measures contain alternating beds of grits and clay, the former being full of water. The Millstone Grit, where resting on shales, also gives a good supply. The Devonian and Old Red Sandstone rocks frequently furnish springs. The Silurian, Cambrian, and Igneous rocks are only suitable for large collecting areas.

The sources from which water is usually obtained from a practical point of view, are (1) upland surface water, collected from large uncultivated tracts of land; (2) streams and rivers; (3) springs; (4) wells; and (5) rain water collected from roofs and other collecting areas.

The Report of the Rivers Pollution Commissioners classifies the sources in the following ways:—

1. In respect of wholesomeness, palatability, and general fitness for domestic use:—

Wholesome	1. Spring water 2. Deep well water	very palatable.
	3. Upland surface water	moderately palatable
Suspicious	4. Stored rain water	
	5. Surface water from cultivated lands	palatable.
Dangerous	6. River water to which sewage gains access 7. Shallow well water	

2. Classified with regard to softness, they are placed in the following order :—

(1) Rain water; (2) upland surface water; (3) surface water from cultivated lands; (4) polluted river water; (5) spring water; (6) deep well water; and (7) shallow well water.

3. Classifying the geological strata as regards their influence in rendering water sparkling, colourless, palatable, and wholesome, the order of efficiency is given by the report thus :—

(1) Chalk, (2) Oolite, (3) Greensand, (4) Hastings Sand, and (5) New Red Sandstone.

We must now consider the various sources more in detail.

Springs are derived from that portion of the rainfall which has sunk into the soil. They may be divided into two classes, (1) surface springs, and (2) deep-seated springs. The water falling on the surface will percolate downwards until it is stopped by an impervious layer. It will then issue at the lowest point of the porous stratum, usually on the side of a hill or cliff. Fig. 77 shows such a case. It represents a section through a hill with a permeable stratum overlying an impermeable one. The surface water will percolate downwards till its descent is arrested, when it will issue at the point S on

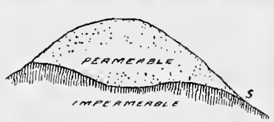


Fig. 77.

the hill-side in the form of a surface spring. Fig. 78 shows another such case. In this a permeable stratum occurs between two which are impermeable, the former coming out to the surface, or outcropping, on either side of the hill.

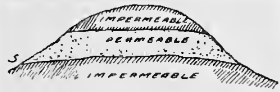


Fig. 78.

Surface water will pass over the upper impermeable layer, and with that collected on the exposed part of the permeable will percolate through the latter, issuing at the lowest point S in the form of a surface spring.

The water from a surface spring is not likely to be nearly as pure as that from a deep-seated spring owing to the water in the latter case having filtered downwards to a greater depth. Fig. 79 gives a section showing one example of a deep-seated spring. Owing to a fault or dislocation of the strata, the water in the permeable stratum is obstructed in its downward flow and

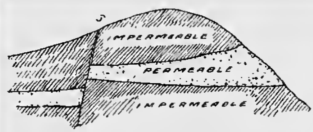


Fig. 79.

finds an outlet upwards through the line of fault, issuing at S. Still another example is shown in Fig. 80, in which the permeable stratum has no natural outlet and so finds one upward through a fissure, or other weak part in the stratum above. Springs give a useful source of water supply for isolated houses in the country or small isolated blocks of cottages.

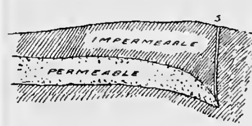


Fig. 80.

The more deeply seated it is, the better, generally speaking, will the water be. Thus, in the cases shown in Figs. 79 and 80 it will be seen that the water is less liable to surface contamination than in those shown in Figs. 77 and 78, owing to its filtering through greater depths. Sometimes the outlet area is rather large, but this can be overcome by forming a channel, or a small gallery, in the hill-side to tap the water before it reaches the surface. Generally speaking, springs do not provide a sufficiently constant source for the supply of towns, but there are a few cases in which towns are supplied in this way, notably Bath, Malvern, and Lancaster, while part of London's supply comes from springs in Hertfordshire, a conduit about 40 miles long having been utilized by the New River Company for the purpose of conveying it.

In supplying houses in the country, a spring may often be obtained at such a height as to supply a storage tank by gravitation. Such tanks are usually made of sufficient size to contain from about three days' to one week's supply. If the spring is large, a ball-valve inlet should be used. The tank should be covered and ventilated, and provided with an overflow. Such tanks can be formed of concrete backed by clay puddle and rendered inside in Portland cement. If the water is not of the best, it may be made to pass through a sand filter before reaching the tank, and in any case if it is not so filtered, pressure filters should be used on the taps supplying drinking water. These filters will be fully described later.

If the level of the available spring does not permit of supplying the storage tank by gravitation, the water must be pumped up to a storage tank situated in the highest part of the house.

Water is obtained from wells in the underground water as in the case of springs, but drawn from a level below that at which it would issue as springs. Wells are classed as shallow and deep respectively, and it is important to note that these terms, as used in this connexion, have no direct reference to depths in feet. Thus, a shallow well may be a greater number of feet in depth than a deep one, the term shallow meaning that the source of supply is the subsoil water, while the supply for deep wells is derived from a water-bearing stratum beneath an impermeable one, and often at a great depth.

The water from shallow wells is always open to suspicion, owing to the liability of pollution from defective drains and cesspools. The underground water is always moving, and by its lateral motion or by its rise and fall in times of heavy rainfall or drought, may place the water in the well in direct communication with sewage-sodden soil. In an attempt to obtain a pure supply from a shallow well, therefore, the well must be as far as possible from any likely sources of contamination, at a higher level than any neighbouring cesspools, be lined (or steined) with brickwork, concrete, stoneware tubes, or iron cylinders, and be covered over. The old-fashioned "draw" or "dipping" well is not permissible under any circumstances, if only owing to the possibility of polluting matters finding their way in at the top.

There are many ways of lining a well with brickwork. The most usual is to form a circular flat ring, or curb, of oak or elm, and having laid this on the ground at the exact site of the well, to build the brickwork on it to a height of about 3 or 4 feet in the form of the cylindrical lining. The ground is then gradually excavated under it so as to allow it to sink down, the brickwork being added at the top as it sinks. The excavation must be very carefully done or the brick lining will get out of true and refuse to sink further. Another method is to line the well for a few feet down from the top and then underpin as the work goes on, supporting the brickwork by timbering and struts. Fig. 81 shows another good method. The sketch represents a section through part of the brick steining at one side of a well. Instead of a wooden curb, one of cast iron

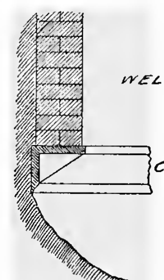


Fig. 81.

is used, as shown at C. Its lower edge is bevelled to help it in cutting its way down as the excavation proceeds. For all such work the bricks used should be radiated, i.e. moulded to the proper radius so that all joints shall be of parallel thickness, and good hard engineering bricks are the best for the purpose. If iron cylinders are used, the joints between them should be carefully pointed with cement. Sometimes they are lined inside with brickwork, but there is no particular advantage in so doing. If the well is of small diameter it is sometimes lined with stoneware tubes, the lower one or two

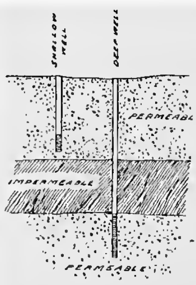


Fig. 82.

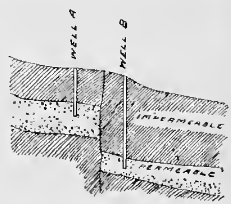


Fig. 83.

being perforated with small holes. Ferro-concrete is also now used for this purpose, a thickness of about 4 inches of good cement concrete being formed, with vertical and horizontal steel rods in the centre of it. The horizontal rods are bent to the form of hoops and are wired to the vertical rods wherever they cross.

Deep wells are not lined throughout in this way; the lining need only be carried down a little way into the impermeable stratum. It is important to note that it does not necessarily follow that, on piercing the impermeable stratum, water will be obtainable. Fig. 82 shows the main point of difference between the shallow and deep well, and so far as one can say from the data furnished by the sketch, water should be obtainable in both wells. The circumstances shown in Fig. 83, however, are quite different. The fault, or dislocation of the strata, ensures water being collected so that well A is ensured a supply, but with the permeable stratum dipping downwards as it does there will be no certainty of a supply to well B, which would probably be a dry or dumb one. Deep wells are often termed Artesian wells, but the term does not correctly apply to all deep wells.

A true Artesian well is one formed in a valley or "basin" under such conditions that the water rises up through it and discharges with some force. Thus, Fig. 84 shows the conditions favouring an Artesian

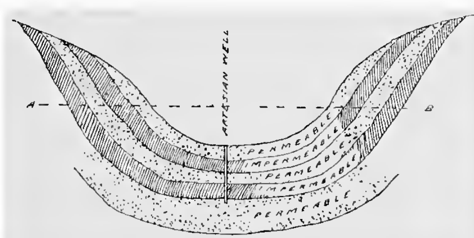


Fig. 84.

well. Assuming the water level, in the lowermost permeable stratum shown, to be at the line AB, water will rise approximately to that level through the well. The name Artesian is derived from the fact that the first such well was sunk in the province of Artois, in France. One of the earliest Artesian wells in London was that sunk in 1844 to supply the fountains in Trafalgar Square. It goes down 393 feet to reach the upper chalk formation.

Deep wells are not, as a rule, dug out for any great depth. They are sunk part way and then completed by a boring of relatively small diameter, sometimes two or three borings being made from the same shaft. The work of well boring involves the use of fairly elaborate tools, a description of which is beyond the province of this book.

For a temporary supply, and for cottages in the country, the "Abyssinian" tube wells are useful. They are made up of strong wrought-iron tubes, driven into the soil, one length being screwed on to another, or, in fairly soft ground, the joint is made by means of collars. The bottom length has a hardened steel spike and is perforated for a length of about 2 feet to let the water in. Fig. 85 shows one method of driving a tube well. The lowermost length is shown in the ground and the next length is connected to it, A being the collar joint. At B two plates are firmly clamped to the upper length by means of bolts. At E is a similar clamp carrying two pulleys. Over these pulleys run ropes, marked D, attached to a heavy weight, or monkey, C. The monkey is pulled up by means of the cords and then allowed to fall, driving the tube in by its impact on the clamp B. An alternative way is to put a protecting cap over the upper end of the tube, with a separate rod above it carrying the monkey. In this case the impact comes on the cap, no clamp being used. This method is said to get over the difficulty of damaging the tube, which sometimes occurs with the clamp method. When the water is reached a pump is screwed on to the uppermost length; for a short time the water is muddy, due to the clearing of the earth out of the perforations and the forming of a cavity around the bottom of the tube, but once this has been done the water runs clear. In any tube well, if the water does not rise within 28 feet of the pump valve, the valve must be taken down the tube to

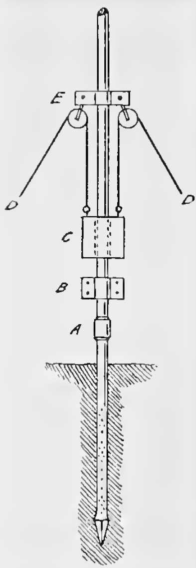


Fig. 85.

within such a distance of the estimated lowest level of the water.

When pumping is carried on from a well, water is drawn in from every direction, so that if another well is sunk within the area from which the first well draws its supply, the yield of the latter will be affected. The area drained by wells is uncertain, but is believed to be a circle the radius of which is approximately the depth of the well.

To increase the yield of a well, adits or tunnels are often driven at the bottom, a series of wells being sometimes connected in this way to concentrate the pumping arrangements in one well.

We come next to the consideration of upland surface water and large inland lakes as a source of supply. The former is the water obtained by storing in reservoirs the water which flows directly off the surface, and which issues in springs, within uncultivated tracts of moorland. As will be seen from the tables already given, such water is wholesome and soft, and many large towns have availed themselves of this source of supply, including Liverpool (from Vyrnwy in Wales), Bradford, Birmingham (from Wales), Leicester, Derby, Nottingham, and Sheffield (from the Derwent Valley). Such waters are, next to rain waters, the most free from dissolved matters, as they have not had time to dissolve solid matters from the soil. Examples of supply from lakes are Glasgow, which obtains its supply from Loch Katrine, about 35 miles away, and Manchester, which is supplied by Lake Thirlmere in Cumberland. The supply from lakes at a high altitude, safeguarded from pollution, is of a high order of purity.

In the case of upland surface supplies, the "gathering ground," watershed, or catchment area is generally at a high altitude. Thus, in the Derwent Valley scheme, before referred to, the watershed forms part of the hilly country known as The Peak district, and for the most part is moorland. It has an area of nearly 32,000 acres, all over 580 feet above sea-level; 26,800 acres are at a height of over 1000 feet and 11,600 acres are above 1500 feet.

The catchment area in such schemes is the area of land draining towards a stream or streams, and is bounded by the watershed line—a line on opposite sides of which the water flows in opposite directions. The quantity of water available from such a source is estimated in either of two ways: (1) by ascertaining the rainfall in the district, and calculating the quantity available after deducting a certain amount, approximately 12 to 15 inches per annum of depth, for loss by absorption and evaporation. The loss due to absorption depends, of course, on the nature of the geological formation; (2) by gauging the flow of the streams flowing from the valley for as long a period as possible, and, if a storage reservoir is to be formed, deducting a small amount for evaporation. The methods of gauging the flow are numerous, including weirs, floats, current meters, Pitot tubes, and other contrivances. From the weir the discharge can be calculated direct, but from the other methods the velocity is obtained, from which the discharge is found by the simple formula:—

$$\text{Quantity} = \text{sectional area} \times \text{velocity, or } Q = AV.$$

The supply in all years is not the same, and also is greater in winter than in summer, therefore large storage reservoirs are constructed to store up part of the winter supply, and the excess rainfall of wet years, in order to provide a supply in time of drought. Such reservoirs take the form of artificial lakes, made by damming the outlet of the valley. The best site for a storage reservoir is a part of the valley where a comparatively short embankment will form a reservoir of large capacity.

Where a reservoir is formed on a stream used by mill owners, a certain part of the supply must be set aside to compensate them. Usually about one-third to one-fourth of the whole available supply is set aside as compensation water, often stored in separate "compensation" reservoirs.

The available capacity or storage room in a reservoir is the volume contained between the highest and lowest working levels, and is less than the total capacity by the volume left for the collection of sediment. No hard and fast rule can be laid down for this, but it occupies in many good examples about one-sixth of the greatest depth of water at the deepest part of the reservoir. The storage reservoir is often adapted for use as a compensation reservoir also. The storage capacity of an impounding or storage reservoir is very considerable. The two reservoirs which have been constructed as a first instalment under the Derwent Valley scheme, have a total capacity of 3940 million gallons.

A large number of towns obtain their water supply from rivers, but many have had to abandon this source owing to increasing pollution by sewage and refuse from manufactories. London is the most notable example of a town taking its main supply from a river. As the dry weather flow of the river may become insufficient, storage reservoirs may be formed to impound the flood waters. This is done in the case of London, two impounding reservoirs having been already provided at Staines, having a total area of 421 acres, with a capacity of 3300 million gallons, while reservoirs have been constructed at Chingford in Essex, with a total area exceeding that of Hyde Park. Provided that improvements can continue to be made in the state of our rivers, there is no doubt that rivers will continue to afford a valuable source of supply for towns. With respect to supplies from rivers it is worth mentioning here the much-debated question of self-purification of rivers. It has been pointed out that water taken some miles below a source of pollution is purer than a sample taken higher up, and the opinion has been expressed that a river flowing with a mean velocity of about 4 miles per hour will purify itself within a distance of about 16 miles from the point of pollution. Some authorities say that when pathogenic or disease-bearing bacteria pass into relatively pure water, they are in an unnatural medium and die off. On the other hand, some conclude that sedimentation is the chief cause of any self-purification. If this be so, there is no guarantee that harmful microbes will not be present and be carried down by the next flood which stirs up the river bed.

River water is usually softer than that derived from wells and springs. It seldom happens that the supply can be delivered by gravitation, but it is cheaper to pump the water than to bring it from a great distance by gravitation.

The last source with which it is necessary to deal is that furnished by the storage of rain water. It is a source which rarely needs to be considered and then only in the case of an isolated country house. Generally, it is only used as a supplementary source, but at times it is the only one. Rain water is very soft, therefore good for cooking and washing, but it is too soft to be very palatable, though somewhat improved by filtration. It is only out in the open country that this source is used, and the question of the rain taking up impurities in its fall does not arise.

The collecting area generally takes the form of the roofs of the buildings and it is important to note that in such case the roof covering should be of slate, it being less absorbent than tiles. If the water is to be used for drinking purposes, there should be no lead gutters or flats owing to the solvent action of the soft water. The gutters and rain-water pipes should be of iron, protected against corrosion preferably by a process such as that introduced by Dr. Angus Smith, and consisting of dipping the articles, when hot, into a hot liquid consisting largely of purified oil of tar.

If the roofs do not furnish a sufficient collecting area, a special collecting area must be formed. It should be carefully fenced in to guard it from pollution, and may be of either of the following forms: (1) a sloping surface of concrete finished with cement or asphalt, falling to a collecting channel communicating with the storage tank; or (2) a similar surface covered with special tiles to form a false floor supporting about a foot of earth covered with grass. The rainfall is partly filtered and purified by the earth and grass, and passes through to the collecting floor below and thence into the channel. Any such surface should be isolated by a channel sunk around it and to a lower level.

Where roofs are used as the collecting surface, a rain-water separator is used. This is a device for diverting the first part of the flow, charged with the washings of the roofs and gutters, to waste; it then automatically directs the after-flow to the storage tank. In estimating the quantity collectible, allowance must be made for the quantity diverted to waste, and for the loss by evaporation from the surface of the water in the underground storage tank. The proportion of rainfall available for actual supply is approximately as follows:—

1. With roofs and similar collecting surfaces, a separator being used, about 65 per cent.

2. Ditto, but without a separator, about 85 per cent.

3. With a grass-collecting surface (part of the rain being retained by the soil), about 60 per cent.

The storage tank should be capable of containing from 90 to 120 days' requirements, according to the annual rainfall of the district. It can be of practically any shape on plan.

From the foregoing a formula can easily be deduced to give the area requisite for the collecting surface, or the quantity obtainable from any given surface.

Suppose we are dealing with case (1) above, in which 65 per cent is obtainable.

Let G = gallons required, or obtainable, per annum.
A = area of collecting surface in square feet.
R = rainfall in inches per annum.

There are approximately 6·25 gallons in a cubic foot.
Quantity in cubic feet = area in square feet × rainfall in feet.

$$\therefore \quad \frac{G}{6{\cdot}25} = A \times \frac{R}{12} \times 65 \text{ per cent,}$$

$$\text{or } G = \frac{A \times R \times 65 \times 6{\cdot}25}{12 \times 100},$$

from which, by simplifying,

$$G = {\cdot}34AR.$$

Transposing,

$$A = \frac{G}{{\cdot}34R}.$$

For case (2) above, on the same reasoning we get:—

$$G = {\cdot}44AR \text{ and } A = \frac{G}{{\cdot}44R};$$

and for case (3):—

$$G = {\cdot}31AR \text{ and } A = \frac{G}{{\cdot}31R}.$$

Example.—A household of seven people, requiring 15 gallons per head per day, is to be supplied only from rain water collected from roofs and similar surfaces, a separator being used. The average rainfall is 28 inches per annum. Determine (1) the area of collecting surface necessary for the supply, and (2) the depth of a circular storage tank having an internal diameter of 16 feet, sufficient to hold 100 days' supply.

$G = 7 \times 15 \times 365 = 38325$ gallons per ann.

$R = 28$ inches.

$$A = \frac{G}{{\cdot}34R} = \frac{38325}{{\cdot}34 \times 28} = 4026 \text{ sq. feet.}$$

100 *days' supply*—

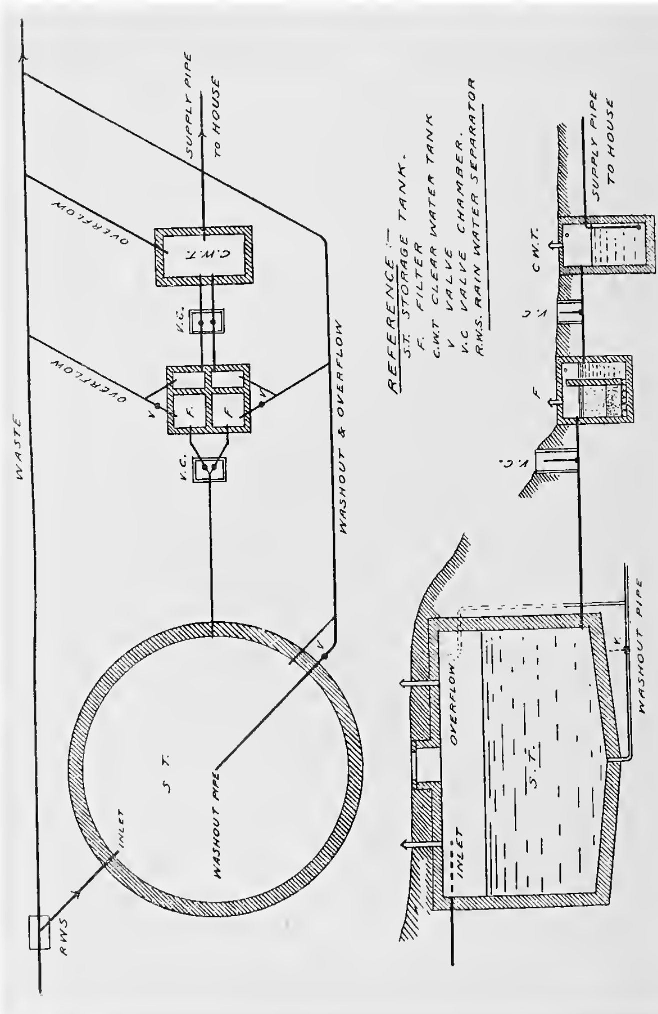
$$\text{Contents of tank in c. ft.} = \frac{7 \times 15 \times 100}{6{\cdot}25} = 1680 \text{ c. ft.}$$

$$\text{Depth of tank} = \frac{\text{cubic contents}}{\text{area}}$$

$$= \frac{1680}{\cdot 7854 D^2} = \frac{1680}{\cdot 7854 \times 16 \times 16}$$
$$= 8 \text{ feet } 4 \text{ inches.}$$

The collecting area must therefore be 4026 square feet, and the tank must have a depth of 8 feet 4 inches below the bottom of the inlet pipe.

The tank could be constructed of brickwork lined with cement, or concrete, or ferro-concrete. It could be roofed over with ferro-concrete in any case, and must have a good-sized manhole cover to provide means of access. It should also have two or three ventilating pipes, carried up a foot or two above the ground and covered with conical shields to keep out impurities. As the water is to be used for drinking purposes, a filter should also be provided. The filters should be constructed of a bed of washed gravel 1 foot thick, underlying a bed of fine sand 1 foot 6 inches thick. Such an arrangement will efficiently filter about 400 to 450 gallons per square yard per day; therefore one about 2 feet square, the smallest size that could be constructed conveniently, would be of ample size. To permit of cleansing, however, the filters should be in duplicate. Adjoining them should be a small filtered-water tank holding about three days' supply. The general arrangement of the parts of such a scheme might be as shown in Figs. 86 and 87. Fig. 86 shows a plan and Fig. 87 a section. It will be seen that the rain-water drains lead to a separator, from which one pipe enters the storage tank, and another goes on to waste. From the storage tank a supply pipe is taken to a pair of filters, either of which can be thrown out of use by a valve, for the purpose of cleansing. Each filter therefore has its own outlet pipe to the clean or filtered-water tank, from which the main supply pipe to the house is taken. Storage tank, filters, and filtered-water tank should all be covered, with manholes for access, and be well ventilated. All three should have overflow pipes, and the storage tank and filters should be provided



Figs. 86 and 87.

with wash-out pipes at the bottom. The overflow pipe and wash-out pipes can be joined together outside the tank. When the valves are in pairs they can be placed in a small valve chamber, but a single valve can be made accessible by placing a vertical pipe over it. The calculated depth of the storage tank should be the difference between the levels of the inlet and outlet, the floor being sloped to the inlet of the wash-out pipe. It will be seen that such a system is most conveniently arranged on a piece of ground with a good fall, but the various parts need not be so close together as is shown, for convenience, in the sketches.

We now come to the methods of purifying water. Water may be purified on a small scale, (1) by allowing any sediment to settle, which may be helped by adding certain substances, such as common alum; (2) by boiling it, to destroy the activity of organic matter, which is an almost absolute safeguard against communication of disease, and incidentally removes much of the hardness; and (3) adding some chemical such as Condy's Fluid, or permanganate of potash, to destroy the organic matter.

Water should be well aerated, a deficiency of oxygen making it more difficult to free it from organic impurities. Aeration also facilitates the precipitation of any iron there may be in solution. Aeration may be obtained by exposing it in an open channel, letting it fall down a series of steps, discharging it as a fountain into an open reservoir, or any similar means.

If the proportion of iron is large, it can be removed by processes involving the use of lime water and compressed air. On the other hand, very turbid water can be clarified and partially purified by treating it with cast-iron borings and shavings in a special apparatus, following with filtration.

Polluted waters are sometimes the only ones available for drinking, and even these can be made fit to use. Thus, Dr. Rideal, the well-known chemical authority, says that the addi-

10

tion of sodium bisulphate in the proportion of 15 grains to a pint, will destroy the typhoid bacillus. Ozone has a powerful effect in the purification of water. The ozone is produced by electrical discharge through absolutely dry air, and its effect is to oxidize or burn up the organic matter and to destroy bacteria. There are many types of apparatus for the purpose, and the system has been largely used on the Continent. As carried out under the Ozonair system the water is first atomized in the presence of a stream of ozone. The spray into which the water is split up then falls on to a receptacle filled with glass spheres, a stream of ozone meanwhile passing up through the spaces between the spheres and again coming into contact with the films of water passing over them. The water issues into a tank at the bottom of the apparatus, in which, for the third time, it is again ozonized by fine jets passing upwards through the water.

The filtration of water can be dealt with under two headings, (1) public, and (2) domestic. The former can also be divided into natural or low pressure filtration, and the latter into mechanical or high pressure.

In England, public supplies are generally passed through sand, or low pressure, filters. Usually the water is passed through one filter only, but sometimes successive filtration is adopted, the water going through one filter and then through another. In the case of the new Derwent Valley works, the water is first passed through a "roughing filter" of about 12 to 16 inches of gravel placed over perforated concrete slabs, in order to reduce the work of the fine or sand filter which completes the purification. Sand filtration, if properly carried out, is very efficient and capable of removing as much as 93 to 99 per cent of the organisms.

The action of such a filter is partly mechanical and partly biological. The former action holds back the suspended matters and forms a film on the upper layer of sand; this film is charged with microbian life, brings about the nitrification of organic matter, and arrests the passage of microbes. The efficiency is due largely to this film on the surface, and until the film is formed bacterial life is not removed. After a time, however, it becomes so dense, that, although the efficiency is increased, the passage of water through it at a reasonable rate, becomes difficult. A thin layer of the sand is therefore scraped off and the process begun again, the water being run to waste for a few days till the film has begun to form again. This necessitates there being at least two filters, but there are generally more.

The bed of sand is usually from 2 to 3 feet thick at first, and thus gradually becomes reduced, but should never be allowed to get less than 1 foot in thickness. It should then be again restored to its original depth by the addition of more sand. The water should not flow down through a filter bed at a greater velocity than about 4 inches per hour, at which rate the filter will deal with 450 gallons per square yard per day. The depth of water over the top of the filter must not be great, or the filtration will be too rapid; about 2 feet is a usual figure. The filters are rectangular basins, usually having concrete walls and floor, backed with clay puddle. On the floor a network of drains is formed to receive the filtered water and conduct it away. They can be of open-jointed pipes, or of special tiles of many shapes, or be formed with bricks. The filtering material is laid over the drains and may consist of say 18 inches of coarse gravel, covered with about 2 feet 6 inches of fine sand, though there is no hard and fast rule as to these depths. They are usually open, but in very cold countries are often covered to reduce the obstruction by frost. The sides may be either vertical or sloping, a less thickness being necessary in the latter case. Fig. 88 shows a section through the inlet end of an ordinary form of sand filter, the inlet taking the shape of a bell-mouthed bend surrounded by a stone slab to prevent the disturbance of the sand around it.

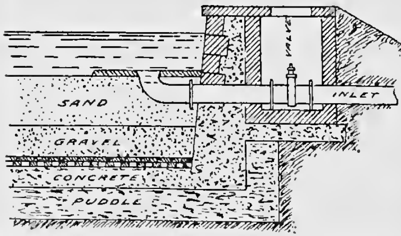


Fig. 88.

Below the gravel a drain grate of bricks is shown, the floor falling to a sunk main drain in the middle. Such a drain might lead to a small chamber at one end, containing means of regulating the depths of water on the filter. A convenient method is to continue the outlet pipe upwards in this chamber and provide it with a telescopic bell-mouth at the top. This can be adjusted by a wheel above it, to any desired height, according to the condition of the film on the surface of the filter, before referred to. Leading up the walls, around the filter, from the drainage grate at the bottom to a height of about a foot above the ground, would be a series of ventilating pipes. The foregoing gives a brief description of the ordinary type of filter, but it will, of course, be understood that there are many modifications, particularly as regards the arrangement of the regulated outlet.

Where the supply is obtained from a river, there may be a bed of sand or gravel alongside, which may be arranged to form a filter, the water passing through it laterally instead of vertically.

Rapid, high pressure, or mechanical filtration has not been largely adopted in this country, but it is largely used abroad. It is generally carried out in a large upright cylinder of iron or steel. There are many forms; in some, the arrangement is as follows: A depth of 2 to 4 feet of coarse sand or crushed quartz is carried on a system of strainers. A chemical coagulant, such as alum, is added to get together the suspended matters, and the water is passed rapidly through the sand, which is agitated by various means. They are either open or closed at the top; in the latter case the water can be admitted under pressure. The filtering material is washed about every twenty-four hours, either by forcing water up through the agitated sand or by compressed air. As much as 20,000 gallons per square yard per day can be passed through such a filter.

One of the best-known types of high pressure filter in use in England is the "Candy" filter. The filtering material is in three layers; the top one is of silica grit, the next, a material termed oxidium, and the bottom one, fine silica sand or grit. The top is closed and the water enters among air under pressure, absorbing it and thus facilitating the oxidation of any organic matter. The filtering medium in this filter is not agitated.

Domestic filters are of two kinds, (1) the low pressure, the most usual form of which is the upright jar with a tap at the bottom, and (2) the high pressure, which is attached to a tap on the pipes supplying the house.

The low pressure portable jar filters are of two types: (1) those containing a quantity or block of filtering material such as animal or vegetable charcoal, manganous carbon, spongy iron, etc.; and (2) those containing hollow, candle-shaped units of baked clay. The former are things to be avoided, as bacterial researches have shown that filters of this type are not really germ proof, while a good candle filter is.

The high pressure candle filter is of various forms, but the principle in all is the same. A metal case contains a hollow candle-shaped filter of fine unglazed earthenware. The water filters through from the outside to the inside of the candle depositing a scum on the outside of it, which is readily removed by taking the candle out of the case and cleaning it. There are several forms of this filter. Fig. 89 shows a section through the Pasteur-Chamberland form. A metal case contains the "candle," and is screwed on to the tap. At the bottom is a glazed nozzle outlet. By unscrewing the collar just above this the candle is at once freed for cleansing purposes. Fig. 90 shows the Berkefeld filter, which is of rather different construction. It has a thicker candle formed of baked fossil earth and filters more rapidly, though its efficiency is less. The water in this case is drawn from the top of the filter through the small pipe shown. The candle is removed by unscrewing the two wing nuts at the top. The small tap at the bottom is for the purpose of scouring out. The Berkefeld filter should be cleansed daily. Another and excellent type of this filter is the Doulton. These filters all pass the water very slowly, and are therefore often provided of larger size, and in cases or batteries containing two or more candles. In the same way, several candles can be put into a filter of the jar form for low pressure filtration, and this is the only type of jar filter that should be used.

Fig. 89.

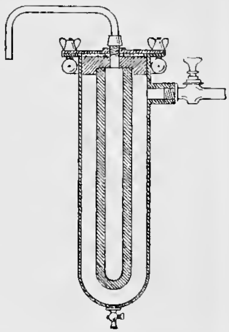
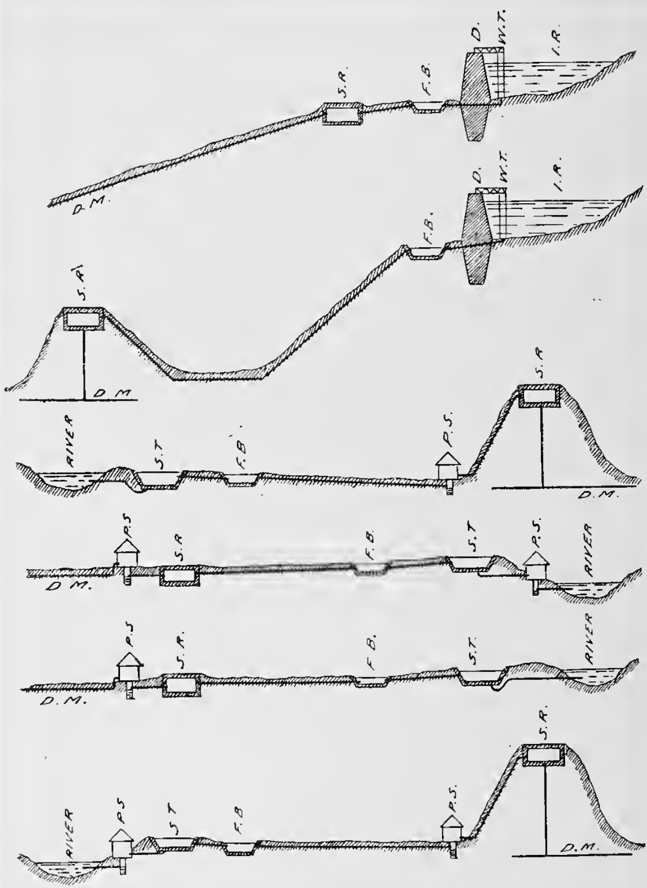


Fig. 90.

It is important to note that there are very many ways in which the water supply works for a town can be arranged, depending on the levels of the land between the source of supply and the point of distribution, and involving either gravitation or pumping systems. A few examples will show some of the many cases that occur in practice, and give an idea of the relative positions of the units forming such a scheme. Thus Figs. 91 and 92 show diagrammatic sections through gravitation schemes, and Figs. 93-96 similar sections through pumping schemes. Thus in Fig. 91 the waters passing through a valley are held up by a dam, D, in an impounding reservoir, I.R., the outlet of which is controlled by a valve at the foot of a water tower, W.T. It passes on to filter beds, F.B., and then into a service reservoir, S.R., from which the distributing mains, D.M., pass to supply the town. A somewhat similar arrangement is shown in Fig. 92, but the levels permit of an elevated position for the service reservoir nearer to the town, which is a better arrangement.

In Fig. 93 the supply is drawn from a river, and passes first into a settling or sedimentation reservoir, then on to filter beds, after which it goes to a pumping station, P.S. From there it is pumped up to an elevated service reservoir, the height of which gives the necessary pressure in the distributing mains; a pressure great enough to ensure the water being thrown over the tops of the houses in case of fire. In Fig. 94 the levels are such that the water has to be pumped up into the settling reservoir, from which it flows by gravitation to the filter beds and on to the service reservoir, the pressure in the distributing mains being provided by a second pumping station. Fig. 95 is a similar case, but the levels permit of the water reaching the settling reservoir by gravitation. Fig. 96 shows a somewhat similar case to Fig. 94, but the filters discharge into a main, leading to pumps which raise the water to an elevated service reservoir, from which the distributing main descends.

We may next briefly consider these various forms of reservoir, their construction and capacity. The reservoirs necessary for the supply of towns with water include: (1) Impounding or storage reservoirs; (2) compensation reservoirs, which are often rendered unnecessary by the special form of the impounding reservoir; (3) settling tanks, or sedimentation or depositing reservoirs; (4) filter beds, which have already been dealt with; and (5) service reservoirs.


D.
W.T.
I.R.
S.R.
F.B.
D.M.
D.
W.T.
I.R.
F.B.
S.R.
D.M.
RIVER
S.T.
F.B.
P.S.
S.R.
D.M.
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RIVER
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S.R.
RIVER
P.S.
S.T.
F.B.
P.S.
D.M.

Figs. 91-96.

Impounding reservoirs are generally partly natural and partly artificial. The site must be such that a dam of comparatively short length will form a reservoir of large capacity. There must be an impervious bed under the whole site at a reasonable depth to ensure water tightness, and any cracks or fissures must be made good with clay puddle or cement concrete. The slope of the bed must be fairly uniform; there should be no parts of shallow depth owing to the encouragement of vegetation. The dam may be entirely of masonry, of concrete, or ferro-concrete, or a mixture of concrete and masonry termed cyclopean rubble, in which the body of the dam is formed of very large rough blocks of stone embedded in concrete, and the whole faced with prepared blocks of stone, or lastly, it may be an earthwork dam faced with granite setts and with a thick wall of clay puddle in the middle. In any case the foundation of the dam must be carried well down into the impervious stratum. Thus, the Howden dam in the Derwent Valley scheme, which is 1080 feet long, has a height of 117 feet, and is carried down below the ground to a depth of 125 feet, the bottom 55 feet taking the form of a watertight curtain wall about 6 feet thick. The thickness of the dam at the ground level is 176 feet and its entire weight is about half a million tons. It was afterwards found that the hill-sides up the reservoir were not absolutely watertight, and "wing" walls were constructed up each side of the valley for a distance of 3000 feet. This is merely mentioned to give an idea of the extensive works which may be needed in connexion with such a scheme. In all such schemes provision must be made for overflow or flood waters, and this is sometimes made by means of an overflow weir or the dam itself, and sometimes by constructing flood channels along the sides of the reservoir. All timber should be removed and all vegetation should be burnt before the reservoir is fit for use, and there should be no houses left on the catchment area above the water level. The capacity of impounding reservoirs is usually determined by Hawksley's formula, which is:—

$$D = \frac{1000}{\sqrt{F}}$$

in which D = number of days' supply to be stored, and
F = $\frac{5}{6}$ average annual rainfall in inches.

Compensation reservoirs may be of the form just described, or entirely artificial, having walls and floor of concrete, backed by clay puddle. Their capacity should be about one-fourth to one-third of that of the storage reservoirs.

Settling reservoirs, also, are usually entirely artificial. The object of them is to provide for the settlement of the suspended matters at the least possible expense. In a perfect system four should be used, one filling, one settling, one discharging on to the filters, and one held in reserve. They are usually cleaned out about twice a year. Humber's rule for the area of settling tanks is:—

$$\text{Area} = \frac{\text{Demand in cubic feet per day}}{\text{Velocity of deposit in feet per day}}.$$

The area is quite independent of the depth, which is usually from 10 to 15 feet, a less depth encouraging the growth of vegetation. Settling tanks are not always worked on the intermittent principle described above, and are sometimes continuous in action, the water always flowing through them at a slow rate. In the latter case they should be long and narrow in order to ensure a regular flow as opposed to a current through the middle.

Service reservoirs are of many forms. They may be open or covered; formed entirely below ground, entirely above, or partly one and partly the other, the upper part being embanked. The daily demand for water varies, and the object of these reservoirs is to keep a reserve near at hand on a compensating basis. A frequent capacity is half a day's supply, but if the water is to be brought from a distance, the capacity is greater, in fact anything from two or three days up to one month's supply to act as a safeguard in case of accidents to the mains conveying the supply through such a distance. They can be of concrete, or ferro-concrete, which is now largely used for them, or even large iron or steel tanks supported on a tower of stone, brick, or iron, in order to get sufficient height to give the required pressure in the mains. They should be placed as near the point of delivery as possible. Probably the largest service reservoirs in the world are those of the Metropolitan Water Board at Honor Oak, having a capacity of about 60 million gallons.

A few notes will not be out of place here in reference to the pressure on the sides and floors of tanks, and in pipes. Pressures are generally given in lbs. per square inch. Water can be taken to weigh, approximately, 62·5 lb. per cubic foot. Pressure exerted on a liquid at rest acts uniformly in all directions and at right angles to the surface exposed to the pressure. The measure of pressure at any point, whether in the case of reservoirs or of pipes, provided the water is at rest, i.e. not flowing through the pipes, is found by multiplying the area of the point, say 1 square inch, or $\frac{1}{144}$ of a square foot, by the depth to which its centre of gravity is immersed, and then multiplying the result by the weight of water per cubic foot.

Example.—Determine the pressure per square inch on (*a*) the floor of a reservoir when the depth of water is 20 feet, and (*b*) the wall of the reservoir at a point 8 feet below the surface of the water.

The fact that the walls may be vertical or sloping makes no difference to the answer.

(*a*) Pressure per sq. in.

$$= \frac{1}{144} \text{ (area of unit in sq. ft.)} \times 20 \text{ (depth in ft.)} \times 62{\cdot}5$$

$$= \frac{1}{144} \times 20 \times 62{\cdot}5 = 8{\cdot}68 \text{ lb. per sq. in.}$$

(*b*) Pressure per sq. in. $= \frac{1}{144} \times 8 \times 62{\cdot}5 = 3{\cdot}47$ lb. per sq. in.

Again, take the case of a pipe main.

Example.—A 24-inch water main communicates directly with a reservoir which discharges into it. The valve at the outlet of the main is shut, and the difference in level between the centre of the valve and the water surface in the reservoir is 190 feet. Find the pressure per square inch on the centre of the valve.

Pressure per sq. in. $= \frac{1}{144} \times 190 \times 62{\cdot}5 = 82{\cdot}46$ lb. per sq. in.

If the valve were *open*, the pressure would not, of course, be the same, but if the pipe will stand the pressure when the valve is shut, it will certainly stand the less pressure when it is open. The case of *pressure* in liquids in motion is beyond the scope of this subject.

Having seen the various ways in which water can be collected and supply works arranged, let us next consider its conveyance from the source to the point of distribution. This may be arranged by means of (1) open channels, (2) covered channels and tunnels, (3) ferro-concrete pipes, and (4) cast-iron, wrought-iron, or steel pipes.

Open channels can only be used where the ground allows of suitable slope. It is obvious that such a channel cannot follow the undulations of the land and go up hill and down dale. It may be formed of concrete lined either with cement, bricks, or masonry, being backed by clay puddle in either case to ensure watertightness. The objections to an open channel are that the water is deteriorated by exposure and wasted by evaporation, gets heated in summer, and in winter expense is incurred in keeping the channel open during frost. The "New River," one of the conduits supplying London, is a well-known example of an open channel.

Covered channels are of somewhat similar construction to those just described, but roofed over, and may be either circular in section, or with vertical sides arched over and with an inverted arch at the bottom. Like the open channel, they must follow the fall of the land, and cannot go up hill and down dale. In some cases, as in the Loch Katrine supply to Glasgow, the covered channel may take the form of a tunnel through rock. Covered channels should be adequately ventilated and have manholes at intervals for convenience of access. Covered channels can be of practically any form in section though usually as above described. They can, and no doubt will in the future be constructed of ferro-concrete, the concrete being reinforced with sheets of "expanded" metal, as has been done in connexion with the supply of Jersey City, U.S.A. The covered channel overcomes the objections given above for open channels, but still has the disadvantage that it cannot follow the undulations of the ground.

Ferro-concrete mains look likely to enter largely into the constructional work of water schemes of the future. They can be taken up hill and down dale, and therefore are in the same category as pipe mains. They require the greatest care in their construction, and upon this the whole of their success or failure depends. One of the best-known types is the "Bonna" pipe, a longitudinal section through one side of such a pipe being shown in Fig. 97. The thickness of the pipe is made up as follows: At about the centre is a thin steel plate with welded longitudinal and transverse joints. Just outside this are a series of longitudinal rods of cruciform section as shown, encased by a spiral

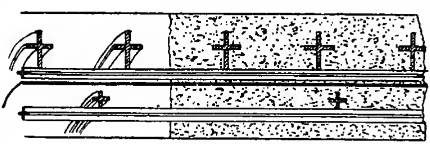

Fig. 97.

formed of larger rods of similar section. Wherever the spiral reinforcement crosses the longitudinal rods they are firmly wired together by steel wire. Inside the steel tube is a similar but lighter reinforcement, also made up of longitudinal and spiral members, but of smaller size and wider apart. The reinforcement of steel is put together first and placed vertically between a removable core and outer moulds of wood. The main body of the pipe, consisting of fine cement concrete, is then filled in, and after it has set the core and moulds are removed. In Fig. 97 part of the concrete is left out to show more clearly the arrangement of the reinforcement. The thickness of the concrete and size of the reinforcing members will, of course, depend on the size of the pipe and the pressure it is intended to withstand, but in determining the sizes only the steel sheeting and the outer members are considered in the calculations. The advantage of using pipes is that the water can be conveyed at varying levels—up hill and down dale—within reasonable limits. Pipes can therefore be laid in a direct line, with a covering of 2 or 3 feet of earth only. With rises and falls there will be accumulations of air at the "summits," and means of escape must be provided; otherwise the pipe will become air-locked and the flow retarded, with a danger of bursting the pipes. There must be no very considerable rises in the pipe line; if an imaginary line be drawn from the level of the water in the reservoir to the point of discharge of the pipe—termed the hydraulic gradient—the pipes should not rise more than 25 feet above this line.

The pipes can be of iron or steel, though in many cases in the Western States of America they are still formed of timber logs with a hole bored through, and stiffened with iron bands round the outside, or built up of timber staves, such pipes being made of as large a diameter as 8 or 9 feet. Wood possesses many features which fit it for the purpose. It is incorrodible, and is a good non-conductor, keeping the water at an even temperature. Iron pipes can be either cast or wrought. The latter and steel pipes are generally built up with riveted joints longitudinally and riveted or bolted flanged joints between the adjacent ends. The cast-iron pipes have almost always socket joints, though it is convenient to use a flanged joint when a valve is to be inserted, as its ready removal is permitted for repairs if needed. The wrought-iron or steel pipes, being stronger, can be of less thickness than pipes of cast iron. All such pipes need to be protected against corrosion by the Angus Smith or other process, since not only does the rusting of the pipe reduce its thickness, but it also makes the inside of the pipe rough and retards the flow, owing to the friction being greater.

Cast-iron pipes are usually jointed with caulked lead, i.e. molten lead poured into the socket and consolidated by means of a caulking tool. In recent years a material called lead wool has been introduced as a substitute for molten lead. It consists of skeins of fine strands of lead, and can be readily used for work under water or other positions in which molten lead would be difficult to use. Fig. 98 shows a section through a caulked-lead joint suitable for a cast-iron aqueduct. It will be seen that the lead is "keyed" in, in order to make the joint more secure. The exact determination of the thickness of the mains is a point of very great importance. Thus, in the Derwent Valley scheme an alteration of the route of an aqueduct twenty miles long took the pipes over higher ground, resulting in less pressure in them and a consequent reduction in thickness, such reduction causing a saving of as much as 6000 tons of cast iron.

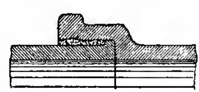

Fig. 98.

We come next to the consideration of this part of our subject from a more local point of view.

CHAPTER VI

THE BUILDING—ITS WATER SUPPLY.

(*CONTINUED*)

THE distributing mains from the service reservoirs are laid along the streets, and should have not less than 2 feet 6 inches to 3 feet of covering over them, according to the nature of the traffic, since they must not only be deep enough to be safe from frost but also far enough below the road surface to be safe from injury from heavy traffic. They are usually of cast iron with caulked-lead joints, though flanged joints are necessary where valves occur, and should be protected against corrosion. The main from the reservoirs should split up into two as soon as possible, in order to diminish, as far as possible, the area affected in case of accidents to mains. Everything should be done to ensure the carrying out of this principle; that is, the limitation of the area affected by accidents to mains. It is done in many ways, but largely by the use of secondary mains, it being possible to throw the supply from one into the other. Dead ends to mains should be avoided owing to the possibility of stagnation; sharp bends and junctions should be avoided also, owing to the loss of pressure they cause.

The pipes should be tested to double the working pressure they will have to sustain. This is done in a hydraulic machine, the pressure being shown by a gauge; a few lengths of pipe can be put together for testing, so as to test the joints as well. The pressure in the mains should always be sufficient to discharge a stream of water well over the highest building in the district, not including, of course, church spires and towers. A good working pressure, and a very usual one, is 80 lb. per square inch, which is equal to a "head" of about 180 feet, or column of water about 180 feet high.

Stop valves or sluices are placed on the mains at distances of 800 to 1000 yards, and also at the commencement of each branch main. They are of various forms, and are made to suit either flanged or socketed pipes. The seatings, or contact parts, of the valve when closed are formed of phosphor bronze in the best quality valve. Fig. 99 shows a vertical section through a valve of this type fixed on a flange-jointed main. The top is square to receive a key, the turning of which raises or lowers the sluice by means of the screw shown.

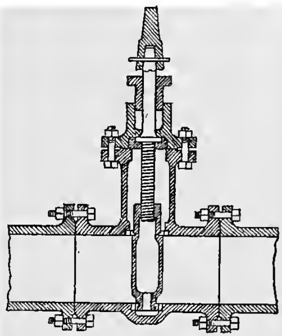

Fig. 99.

Hydrants and fire-plugs should be placed on all mains at intervals of not more than 100 yards. There are two principal types: (1) those with ball valves, and (2) those with sluice valves, as just described. In the former, the pressure of the water holds up a ball of gutta-percha, vulcanite, wood, or metal, against a firm seating, and the ball can be forced down so as to let the water out; this is done by screwing on a stand pipe containing a spindle actuated by a screw. The drawback to this form is that when the mains are empty the ball falls and lets in impurities such as street washings. It is therefore better to use a sluice valve with a branch outlet to which the stand pipe can be screwed.

There are two methods in use as regards the supply of water to the mains. The usual one is that known as the constant system, in which the water is always in the mains, the other system being the intermittent, in which the water is only turned into them for a very limited time during the day. The intermittent system was introduced to overcome the difficulties attendant on a limited supply and with the idea of restricting waste. It is very unsatisfactory and is now but little used. Its disadvantages are:—

1. Large storage tanks are necessary to supply the building during such time as the water is shut off.

2. Drinking water has to be obtained from such cisterns, which are often kept far from clean, being placed in inaccessible, badly lighted places, without covers and without proper ventilation. The water is therefore liable to contamination, and is, further, usually insipid and less palatable after being so stored.

3. The public mains are less liable to contamination through rust, leaky joints, etc., if always full, than if alternately full and empty.

4. The water is not readily available in case of fire. I remember seeing one building burnt out, on the South Coast, a few years ago, through inability to find the "turncock".

5. The system is a hardship on the poor, whose houses are often provided with insufficient storage, leading to the collection of water in all sorts of vessels, suitable and unsuitable, resulting in impurity.

Much water is often collected in this way, and, not being required, is thrown away, and fresh collected when the supply is again turned on, thus causing waste, which the system was intended to obviate.

The necessity of using a cistern is not dispensed with even if the constant service is in use, since a small one is required for the purpose of supplying the sanitary fittings and hot-water service, in case the supply is temporarily cut off for repairs to mains.

When laying on water to a building, it is unnecessary to shut off the water in the public main, there being many appliances in use for making the connexion between the supply pipe to the house and the main under pressure. The principle in all these appliances is similar, and will be understood from the diagrammatic section given in Fig. 100. It shows merely the principal parts of the apparatus, omitting the details. It consists of a watertight box which can be attached to the main by means of a chain or straps, a watertight joint being made with a washer. It has a revolving horizontal cover carrying two "stuffing boxes," SB, equidistant from the centre about which it revolves. Through one of these a combined drill and "tap" (or threader) is put, and through the other a connecting ferrule with a branch.

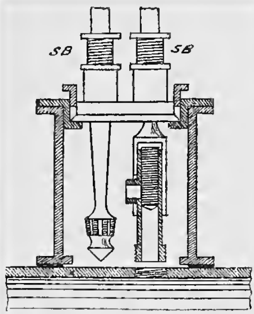

Fig. 100.

The hole is drilled and tapped, and the cover then revolved to bring the ferrule over the hole, into which it is screwed. A screw-plug is fitted to the ferrule, and this is kept screwed down so as to close the branch, as shown, until the house service is laid on.

It can be unscrewed and left in the threaded extension at the top of the ferrule permanently.

The service or supply pipe to the building may be of various materials. For fairly hard water lead is the most suitable, it being strong, pliable, made in long lengths, necessitating few joints, and not likely to injuriously affect the water. Lead pipes thinly coated inside with tin are obtainable, but they are of little value, as the wash of tin is soon worn away by the friction of the flowing water, and the tin is also liable to be destroyed in the making of the joints. Such pipes are intended for soft water, as the tin, unlike lead, is not liable to be dissolved by such water. Lead-cased tin pipes are quite good and very suitable for soft water, though of course more expensive. Iron pipes are often used for hard waters, but they should be protected from corrosion by galvanizing, which consists of coating them with molten zinc, by dipping them in a bath of that metal. Other preservative processes are also used. For soft waters a patented tin-lined iron pipe, known as the Health pipe, has also been much used in recent years.

The sizes of service pipes are largely governed by the water companies' regulations, which usually prescribe the maximum diameters for the various cases, a pipe of ½-inch internal diameter being the usual size for an ordinary dwelling-house. If the supply is intermittent, the diameter must be greater, a ¾-inch pipe being about the equivalent. Lead pipes are made in lengths, or coils, of 60 feet up to a diameter of 1 inch, and from 1¼ inch up to 2 inch diameter in coils of about 40 feet. It used to be a very common practice to denote the thickness of the pipe by describing it as "strong," "middling," or "light," but it is now very general to specify its weight per yard of length. The following table gives suitable weights for service pipes of various diameters:—

Lead Service Pipes off Mains.

Internal diameter in inches .	⅜ in.	½ in.	⅝ in.	¾ in.	1 in.	1¼ in.	1½ in.
Weight in lb. per yard .	5 lb.	6 lb.	7½ lb.	9 lb.	12 lb.	16 lb.	21 lb.

In the case of iron pipes there are three qualities, known as "gas," "water," and "steam" strengths respectively, increasing in weight and thickness in the order given.

The service pipe is laid from the main to the building at a reasonable depth, which should not be less than 2 feet 6 inches to ensure protection from frost and traffic. It is also very desirable to place it in a tarred wooden trough, filling up the latter with pitch, or other bituminous compound.

Just outside the building a stop valve should be placed. It should be protected and made readily accessible by the construction of a small chamber. Fig. 101 shows a section through a suitable form. It consists of a stoneware pipe of special shape, 6 to 9 inches in diameter, supported on two bricks, and carrying a cast-iron hinged cover and frame. The cover can be surrounded, for protection, with a small block of concrete finished in cement, or a small stone slab can be fitted round it.

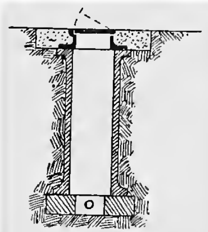

Fig. 101.

There are many forms of stop valve, but the best is that with a "sluice" valve, as this permits of an uninterrupted flow when open. For inside use they usually have a controlling handle or wheel, but for external use they should have a loose key or handle to prevent interference with them. Fig. 102 shows the construction of a stop valve of the sluice or "full-way" type, and Fig. 103 an entirely different form. The mechanism will be apparent from the illustrations, but it should be noted that where likely to be interfered with, instead of the handle or wheel, there would be a square end over which a loose key would fit. Stop valves should be provided both outside and inside the building.

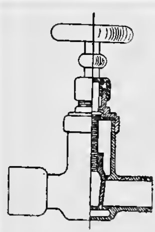

Fig. 102.

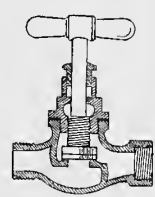

Fig. 103.

On entering the building the pipes should be carried up the faces of internal walls, so far as possible, to protect them from frost. If it is necessary to put them on external walls, or through cold corridors or passages, they should be protected by encasing them in inodorous hair felt, silicate cotton bands, or other similar non-conducting material. Pipes should not be embedded in the plaster of the walls, and if put in a chase or sinking formed especially to receive them, such chase should be of sufficient size to give ready access to the pipes. If wooden casings are used, the fronts should be secured by means of brass screws and cups, so that they are readily removable.

All water pipes should be fixed so that they have a fall towards the lowest point of the system in order that they can be readily emptied for repairs, or as a protection against frost when the house is unoccupied, a draw-off tap being provided near the lowest point for this purpose.

The arrangement of the service pipes depends on whether the constant or the intermittent service is the one in use in the district. Thus, if the constant service is in use, a minimum of cistern accommodation is necessary, sufficient only to supply the boiler of the hot-water service and the sanitary fittings during such time as the water may be temporarily shut off for repairs to the public mains.

In the intermittent service, in which the water is only turned on in the mains for a limited time per day, large storage cisterns are necessary. In many cases two are provided, one to supply the water for drinking and cooking purposes and another to supply the sanitary fittings, but this is unnecessary if the water fittings are of good quality and the closet cisterns are provided with efficient ball valves.

The pipes require to be carefully fixed to guard against damage. Iron pipes can be fixed by means of pipe hooks, an example of which is shown in Fig. 104, the pipe hook being driven into a wooden plug which has previously been driven into a small hole made in the wall. Pipe hooks should not be used for lead pipes as, if carelessly driven in, they are likely to cause damage to the pipes. An alternative is to fix the lead pipes by means of galvanized iron clips, as shown in Fig. 105, screwed into a wooden fillet or "ground," fixed flush with the face of the plastering. Wood plugs could be used but the wood fillet makes a better job. If a secure fixing can be obtained without the use of wooden plugs or fillets, the use of them should be avoided. Plugs often become loose by reason of shrinkage unless they are made of very well-seasoned wood. The clips can also be of brass if preferred. Another method is to attach "tacks" of sheet-lead to the side of the pipe, by means of solder.

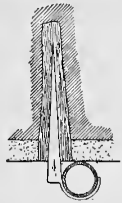

Fig. 104.

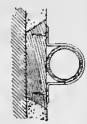

Fig. 105.

Fig. 106 shows a section and Fig. 107 an elevation of such a method of fixing, the tacks being marked T. A wood ground is shown, fixed to plugs driven into the wall, and the tacks, or lugs as they are sometimes called, are screwed to them. The sketches show a double tack, but single tacks are often used for small pipes. Both tacks or clips, whichever may be used, should be about a yard apart.

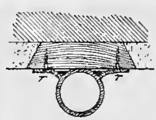

Fig. 106.

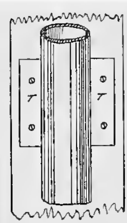

Fig. 107.

In the case of iron pipes, the best method of jointing is to have a screw thread on each end of each pipe and join the two pipes together by means of a loose iron collar having a thread internally; the threaded ends of pipes and inside of collar should be smeared with red lead, and a few strands of spun yarn smeared with the same substance should be wound round the threaded ends when the joint is made. In the case of joints underground, the exposed threads, after the joint is completed, should be painted with red lead for protection from rust.

Lead pipes for water-work should always be jointed by means of the plumber's wiped-solder joint. Fig. 108 shows a part section, and also an elevation of such a joint. The abutting ends are fitted together as shown, and a length of a few inches on each pipe is painted with a mixture of whiting, lampblack, and thin glue, termed "soil"; the ends are then scraped lightly with a tool called a shaving hook. The remaining soil keeps the flux from flowing and gives a clean end to the joint. The solder is then poured on the joint and wiped with a special cloth to the shape shown, a part of the "soil" being left exposed to give a finish to the joint.

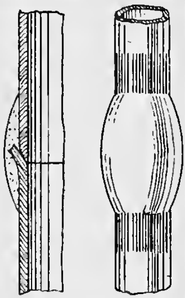

Fig. 108.

A method of jointing lead pipes in an entirely different way is that known as amalgaline jointing. There is no bulbous projection as with the wiped joint, the pipe being, externally, continuous in appearance as shown by the section in Fig. 109. The two adjacent ends are fitted together, as in the sketch, by means of special tools. The abutting surfaces are then cleaned, and a strip of amalgaline wound round the end of the pipe marked A, which may be termed the male end, as opposed to the countersunk or female end of the other pipe. Amalgaline is tinfoil coated with a mixture of stearine and vaseline, and is used in the form of a ribbon ·002 inches in thickness. The abutting ends of the pipe are

Fig. 109.

kept close together while heat is applied by a blow pipe, the ribbon melting and the two pipe ends being fused together. Special fittings are needed for T junctions as shown in Fig. 110, and special sockets are obtainable, if desired, for a joint on a straight length as in Fig. 109. In the latter case, the abutting ends of the pipes would both be shaped as at A in the figure, to fit the opposite ends of the socket. The method is simple, strong, neat in appearance, and economical; the fact of its being simply and quickly made may prevent it becoming a favourite with the plumber.

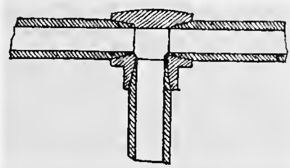

Fig. 110.

Another method of jointing lead pipes in an expeditious manner, such as for temporary work, is by means of special sockets, such as shown in section and part elevation by Fig. 111. The adjacent ends are bossed out as shown, and separated by a ring of triangular section, marked R; two other rings, one plain and one threaded, are placed outside, and the whole tightened up by a nut as shown. This joint was introduced many years ago, and with the connexions of gunmetal is a fine joint, but it has never made much headway owing to the opposition of plumbers to such a labour-saving device.

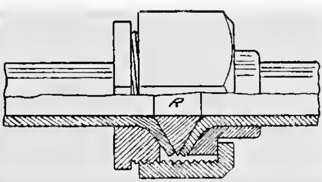

Fig. 111.

The lead-cased tin pipes are best jointed by means of the ordinary wiped-solder joint, with the addition of a short length (about 3 inches) of thin copper or brass tube inside the pipe at the joint, so as to prevent damage to the tin lining in making the joint.

In the case of the tin-lined iron pipe, the ends of the iron pipes are threaded with right and left-hand threads respectively and secured by special collars. The latter are used to ensure no part of the inside of the iron collar being in contact with the water, and are peculiar only in the fact that they have a small vent hole in the middle, through which water will leak and indicate thereby the fact that the collar or coupling is not properly screwed up.

If copper pipes are used, as they sometimes are in good work, the best method of jointing is by means of screw collars as before described, or by means of gunmetal flanges or unions brazed on.

The main pipe entering the building from the outside is termed the rising main. It passes up to the cistern, or cisterns, which may be either open or closed, and of various materials. The usual form is the open cistern, of which the following are the principal varieties:—

The commonest form is that built up of iron sheets, the whole being galvanized after construction. These are relatively light, cheap, and durable, unless the water is very soft, when corrosion soon takes place.

Very large cisterns are often built up of mild steel or wrought-iron plates; also of cast-iron sections. In either case they must be protected against corrosion.

In the case of cisterns built of cast-iron sections, the sections are usually flanged and bolted together, a tight joint being made by planing the abutting flanges and placing a packing of oakum between. The best protection against corrosion is given by what is known as the Angus Smith process. Immediately after casting, the parts are heated to about 600° F. and dipped into a heated solution (about 300° F.) consisting approximately of four parts of coal tar or pitch, three parts of prepared oil, and one part of paranaphthaline. The paranaphthaline gives solidity, the oil fluidity, and the tar adhesiveness.

Another process is "Barffing," which consists of forming a coating of black magnetic oxide over the whole surface. Iron cisterns coated inside with glass enamel can also be obtained.

Wooden cisterns lined with lead, zinc, or copper were once largely used, but they have been almost superseded by those of galvanized iron. They can be readily made of any shape, to suit awkward positions but have practically no other advantages. Lead and zinc are both quite unsuitable for the storage of soft water.

Slate cisterns have no injurious effect on water, but are very heavy. They are constructed of slabs fitted together with grooved joints and strengthened by means of rods or bolts passing from side to side. The joints are made water-tight by a paste made of red and white lead, but care should be taken that the water cannot come in contact with the jointing material. This can be prevented by brushing over the joints with liquid pitch.

Glazed stoneware cisterns are very heavy, but, like slate, do not prejudically affect the water. They are very easily cleaned, owing to the glazed surface, but cannot be obtained of large size.

All cisterns of the foregoing type should be covered with a tightly fitting wooden cover, and should be provided with a lead tray or safe below them to safeguard the building against damage from leakage. The safe is made rather larger than the horizontal section of the cistern, the tray being formed partly by the flooring and partly by a wooden rim fixed to the floor, the floor and rim of the safe being then covered with sheet-lead. Such a safe must have a waste pipe, but that point will be dealt with a little later. All cisterns should be placed in well-lighted, ventilated, and easily accessible positions, so that they may be readily inspected, repaired, or cleansed. They should not be put in a roof unless there is a boarded floor and the underside of the rafters is also boarded to keep out dirt and to ensure that the cistern shall not be easily frozen.

The various inlets and outlets of cisterns next call for notice. The inlet to the ordinary open cistern takes the form of a ball valve, or automatic "tap". There are a great many varieties, a few of which will be described and illustrated. The oldest form was constructed somewhat like an ordinary draw-off tap, closed by a solid plug passing across and through it, and is therefore better termed a ball cock. This plug had a port or hole through it, so that if the plug were revolved till the port coincided with the course of the water, the tap would discharge, and vice versa, if the port were at right angles to the direction of flow the water could not pass through. This plug was actuated by a hollow ball, floating at the end of a lever arm. As the water in the cistern was drawn off, the ball fell and gradually opened the tap to the passage of water, the filling of the cistern again closing the cock by floating the ball upwards. On the outside of the cistern was a hand, moving in line with the lever, so as to indicate to what extent the cock was open, if at all. This type is now practically obsolete, having fallen into disuse partly through the uncertainty of its action and partly through the vibration it caused.

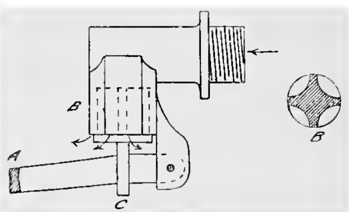

Fig. 112.

Ball valves are made for both high and low pressures. One of the oldest forms is that known as the "Croydon". The low pressure form of this valve is shown in Fig. 112, the lever being broken off at A to permit of the more complicated part of the ball valve being shown to a larger scale. The course of the incoming water is shown by arrowheads. A plug B is connected to the lever at C, and when the cistern is full the plug is held up tightly to prevent the admission of more water. The upper part of the plug B is shown in the elevation by dotted lines and in cross-section by the small sketch at the side. On the ball falling as water is drawn from the cistern, the cross-section of the plug is such that water is allowed to pass in to take its place. This type of ball valve is still in extensive use, but it is only suitable for low pressures, is noisy, and is primitive in principle.

A Croydon high pressure valve is shown in Figs. 113 and 114. In this case the outlet for the water, O, is smaller, a circular plug or piston being held up against it. The plug has a rubber washer, shown in black. From the section it would look as though there was no way out for the water, but this difficulty is overcome by making the section of the casing around the valve in the form shown in Fig. 114. Like the low pressure valve of this type, the high pressure one is noisy, the water entering in two disjointed streams, and unlike other forms of ball valve, no method of silencing can be adopted.

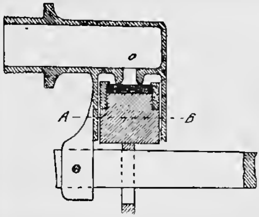

Fig. 113.

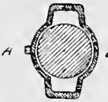

Fig. 114.

Another well-known form is the Portsmouth ball valve.

The high pressure valve of this type is shown in Fig. 115, the plug being horizontal instead of vertical as in the previous example. It will be seen that the falling of the lever, as the copper ball at its end sinks, opens the waterway, O, and the water passes

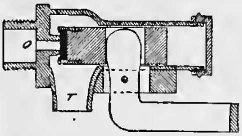

Fig. 115.

vertically downwards through a short tube, T. The screw cap at the end is for the purpose of obtaining access to the plug when necessary to put a new washer.

This form of ball valve, or indeed any with a tube outlet, can be rendered silent in action by attaching a lead or composition pipe to the outlet tube, thus lowering the point of discharge to an inch or so above the bottom of the cistern. It will be seen that such a pipe could not be attached to a Croydon valve.

The best kind of ball valve is that known as the equilibrium variety. The simplest form of such a valve is that shown in

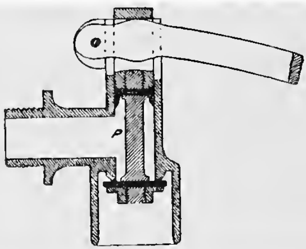

Fig. 116.

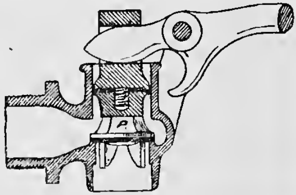

Fig. 117.

Fig. 116. The waterway is closed by a vertical piston, P, which holds up a leather or rubber washer against the outlet. At the upper end of the piston is another washer, in the form of what is known as a "cup" leather, so called from its shape, as shown in black in the section. In the two varieties previously described, the water is always tending to force the valve open, but in this example, the valve is kept in equilibrium by reason of the fact that the water pressure is acting equally on the lower and upper washers. At the same time, the fall of the lever readily opens it, and on rising closes it. Another example of the same type is shown in Fig. 117. It will be seen that the principle is the same though the construction is different. There is not the vibra-

tion and consequent wear on the valve in the equilibrium form that there is in others. This type is suited to both high and low pressures.

Another form of high pressure ball valve is that involving the use of compound levers, arranged so that a very slight upward pressure on the copper ball exerts a considerable thrust on the valve. Fig. 118 shows a well-known variety of this type. It will be seen that a small force acting upwards at the end of the lever, L, would cause a much greater force to be transmitted to the end of the short lever, L.

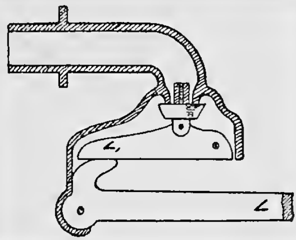

Fig. 118.

Ball valves require occasional adjustment, due to the straining of the lever carrying the ball. This lever is of small section and is usually bent by the plumber in order to put matters right. To guard against the risk of breaking the lever by this practice, an ingenious arrangement, shown in Fig. 119, has been introduced. The lever is in two pieces, A and B, and the necessity of bending the lever is overcome by the provision of a small adjustable screw, S.

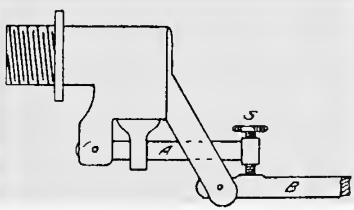

Fig. 119.

Having considered the forms of inlet to cisterns, let us next consider the outlets and the methods of connecting them. The outlets serving fittings should be connected to the side of the cistern, about a couple of inches above the bottom, so as to prevent any sediment that may accumulate from passing to the fittings. An overflow pipe should be provided in all cases, fixed just below the level of the inlet valve and discharging through an external wall in a fairly prominent position so as to act as a warning pipe, since this pipe will only come into use if there is anything wrong with the ball valve. In large cisterns a cleaning-out pipe should be provided, having its mouth flush with the floor of the cistern, controlled by a stop valve, and discharging through an outside wall and over a rain-water head.

The mouth of this pipe can be closed by a plug attached to a chain fastened near the top of the cistern, or a closed vertical pipe can be attached to the plug to enable it to be lifted out. Sometimes the case is dealt with by putting a trumpet-mouthed vertical overflow pipe, the lower end of which fits into the mouth of the cleaning-out pipe and so forms a plug. This is not a good practice, as it does away with the warning effect of the ordinary form of overflow pipe. Cleaning-out pipes and trumpet overflows are not permitted by most water authorities' regulations, but the former are none the less desirable.

The lead safe under the cistern must have a waste pipe which should be carried through an external wall; it serves the purpose of an additional warning pipe since it only discharges when there is something wrong, and should therefore be discharging in a readily noticeable position.

Pipes can be connected to cisterns in various ways. Thus, Fig. 120 shows a part section and part elevation of an ordinary or a single-nutted boiler screw of brass. It is merely a short length of tube with a screw thread at one end, a flange abutting against the outside of the cistern and the nut securing it to the cistern. A lead pipe would be attached to a boiler screw by means of

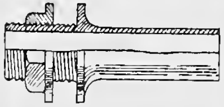

Fig. 120.

a wiped-soldered joint as shown in Fig. 121, which illustrates, also, a double-nutted boiler screw. The difference between this and the ordinary form will be apparent from the sketch.

The connexion of a pipe such as a cleaning-out pipe could be madė by means of a flange washer, nut, and union. Fig. 122 shows such fittings. The flange, F, would be fitted to

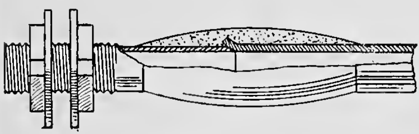

Fig. 121.

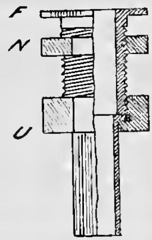

Fig. 122.

the floor of the cistern, the screwed length to which it is attached passing through to the under side, where the nut, N, would secure it. The union, U, would then be coupled up to it, having been previously connected to a lead pipe by means of a wiped joint. A union joint also furnishes a means of connecting a lead pipe to one of iron.

The end of an overflow pipe, waste pipe to a safe, or any similar item, should be finished with a hinged copper flap as shown in section by Fig. 123. The pipe is, of course, laid with a fall, and one frequently sees the end of it cut on the skew so that the flap shall fit closely to it. This is, however, a mistake, as in very cold weather a trickle through

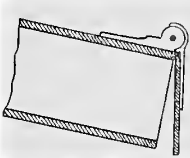

Fig. 123.

the overflow pipe would be sufficient to freeze the flap to the pipe and so close the latter. If constructed as shown, this cannot occur, while the flap, owing to its light weight, readily

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closes should there be a tendency for cold air to rush into the room through the pipe.

It is obvious that the sizes of the cisterns will depend on the probable number of occupants of the building, and the nature of the service. If intermittent the quantity can be readily calculated from knowing the period for which the water is in the mains and the intervals during which it is turned off.

The sizes of the pipes also depend on circumstances. For lavatory basins, closet cisterns, and small sinks a pipe of ½-inch diameter is usual, while for baths, housemaids' sinks, large kitchen sinks, etc., a usual size is ¾-inch diameter. The main service pipe down from the cistern should be not less than 1 inch. It will be obvious, however, that the size of the establishment will always be one factor in determining the size, while, in the case of pipes branching off the rising main, the pressure in the pipes must be considered. The number of fittings supplied by each branch is also a governing factor. Thus, with a moderate pressure a ¾-inch pipe will serve three ½-inch branches, and a 1-inch pipe five branches, and so on in proportion to the cross-sectional areas of the pipes. The pipes should go from point to point by the most direct route possible, be placed on internal walls where possible, be covered where exposed, and be not less than 2 feet away from pipes carrying hot water.

Supplies to taps from which drinking water is obtained should be taken from the rising main, as drinking water should not be taken from a cistern if avoidable. Lavatory basins should be regarded in the same light, as water is often drawn from them for cleaning teeth.

Service pipes from cisterns can be of lighter weight than is needed for service in direct communication with the public mains. The following table is a fair one for this purpose :—

Lead Service Pipes from Cisterns.					
Internal diameter in inches	½ in.	¾ in.	1 in.	1¼ in.	1½ in.
Weight in lb. per yard	4½ lb.	7 lb.	10½ lb.	14 lb.	18 lb.

Stop valves should be provided throughout the system of piping in such positions as are called for in order to furnish every facility for repairs or alterations with as little disturbance of the supply as possible. They should be clearly labelled, such as by means of enamelled iron tablets fixed to the wall above them, stating exactly what they control.

The draw-off taps over the fittings can be of many kinds. They are termed bib-cocks or bib-valves, as opposed to stop-cocks or stop-valves, from which water cannot, of course, be drawn. The simplest form is that known as the plug-cock, constructed similarly to a gas tap, which is, in fact, the only form correctly termed a bib-cock. Fig. 124 shows a sectional elevation of one. The handle forms part of a solid plug passing into and through a socket at right angles to the flowing water, the plug being secured by a washer, W, and nut, N. Through the plug a hole or port, P, is cut, which, when in line with the pipe, allows a through passage of water, while if the port is *across* the pipe no water can get through. This form of tap is simple in construction, but closes very rapidly, with the result that it leads to concussion or water hammer in the pipes, the increase in pressure caused thereby having often been sufficient to burst the pipe.

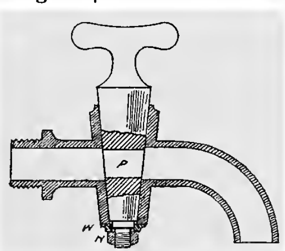


Fig. 124.

Most water authorities' regulations prohibit the use of cocks on pipes which have the full pressure of the mains on them, and insist on the use of valves.

The same construction is adopted for stop-cocks, but the plug principle is not nearly so good as that of the screw-down bib-valve. Fig. 125 shows a section through a fitting of this kind. When the tap is closed the passage of the water is prevented by a small valve, V, which consists of a circular disc with a guiding pin above it and a leather washer, shown in black, below it. This valve is kept down by pressure exerted through the screwing down of the handle, the stem of which has a cavity to receive the guide pin of the valve. The two main parts of the body of the tap are screwed together, with a leather washer between, and if the tap handle gets stiff it is possible that the sudden turning of it might unscrew the upper part of the body of the tap, to prevent which a small screw, S, should be put through the two as shown. In time the leather washer of the valve requires renewing, which necessitates the shutting off of the water at the nearest stop valve and unscrewing the two main parts of the tap. The valve can then be lifted out and attended to. To obviate the shutting off of the water for this purpose an ingenious device has been introduced. The back of the tap is of special construction and it fits into a special connexion. Fig. 126 will explain the detail of this. The screwed back of the tap is not open, as in Fig. 125, but closed, the water entering the tap through two opposite ports, marked P. When the tap is screwed into position as in sketch A, the water can pass through, but if it is necessary to renew

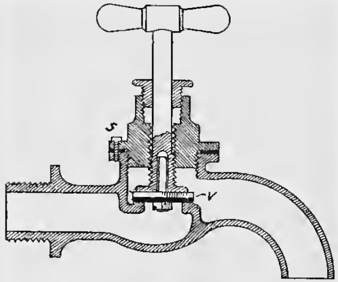


Fig. 125.

the washer and the tap be partly unscrewed, as in sketch B, it cannot, so that the tap may be left as at B while the valve is taken out and attended to, and then screwed in again as at A.

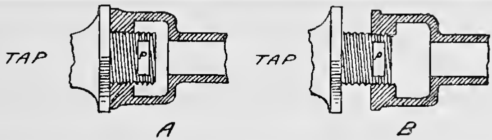


Fig. 126.

The trouble incidental to the frequent renewal of the leather washers of the ordinary form of screw-down bib-valve led to an ingenious form of screw-down tap being introduced by the late Lord Kelvin, the eminent scientist, and which is known by his name. Fig. 127 shows a section through the Kelvin bib-valve. There is no leather washer, the waterway being closed by a metal or vulcanite valve. The spindle controlled by the handle has a domical lower end fitting into a socket of nearly the same shape. Around the spindle is a spring of phosphor bronze, pressing on the outer edge of the valve. When the water is being turned on, the valve rises against this spring, which keeps

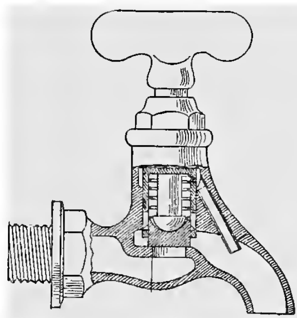


Fig. 127.

the base of the valve parallel with its seat. When being turned off, the spindle rotates the valve on its seating and by this means always keeps the surfaces in contact true. Any water that may rise into the upper part of the tap during opening and closing is carried off by the small tube shown in the sketch.

Another form of tap is the self-closing or spring tap, which is complicated in construction and very liable to get out of order. The only advantage of such a tap is that the water cannot be left running owing to carelessness. They are the most frequent causes of "water hammer" in pipes.

Before leaving the question of domestic cold water supply, reference may be made to closed or pressure cisterns or cylinders. They are very suitable for use in conjunction with the intermittent system. A strong, closed, upright cylinder with a slightly dome-shaped top and bottom is placed high up in the building in an accessible position. It has no ball-valve, but is provided at its base with a service pipe in free communication with the street main. Being a closed vessel, provision must be made for letting out air as the cistern fills and letting it in as it empties. This is done by means of an air valve at the top, the air passing through a strainer or filter of cotton wool before entering the tank. Low down in the service pipe supplying the cistern is a non-return valve preventing the water from running back to the main when the supply to the latter is cut off. The branches to the fittings are taken from the service pipe, the arrangement being such that while the water is on in the mains, the supplies are drawn from the mains, but when the mains are shut off, the supplies are drawn from the cistern. In case of the air-valve getting out of order, an overflow pipe is provided above it. The cistern has also either a separate top bolted on, or a manhole at the side for inspection purposes.

One occasionally finds instances in which there are sharp rapping or knocking sounds in the water supply pipes, to which the name of water hammer is given. It is usually caused by quick closing taps such as plug-cocks, or self-closing or automatic taps. If the taps are near the main, the nuisance is unlikely to occur, but it frequently occurs on long lengths of house services. It is occasionally caused by defective forms of ball-valve. The best remedy is to substitute proper screw-down bib-cocks, or efficient ball-valves, as the case may be, but if some reason prevents the abandonment of the quick closing tap the matter may be remedied by providing an air vessel about 2 feet high and not less than twice the diameter of the pipe to which it is attached. It should be fixed near to the offending tap and either on or at the side of the pipe. The water rises a certain distance in the vessel, the remaining space being occupied by air, which forms an effectual cushion for the shock and prevents the noises occurring.

Water hammer must not be confused with the buzzing sounds that sometimes occur in water pipes. They generally arise from a defective tap. For example, a screw-down bib-cock may have its valve unequally worn, so that it does not rest on its seating evenly. This leads to the pressure on one side being greater than on another, and the valve rotates more or less. The sounds emitted are, however, quite distinct from the sharp rapping noise incidental to water hammer.

It is next necessary to deal with the laying on of hot-water services, and in doing so the principal parts of such a system will first be described separately.

The boiler can either be placed at the back of the kitchen range, or be of the independent type referred to when dealing with warming buildings by means of hot water. The latter form is now often adopted in the case of large houses, but for houses of moderate size the range boiler is usual. The use of an independent boiler does not occasion much greater consumption of fuel, as the range without a boiler needs only about one-half the amount of fuel it would otherwise need. Further, hot-water radiators can be readily connected up to the system.

There are various forms of high pressure range boiler. They can be of wrought-iron or copper, and should always have a manhole for access in order to remove any deposit. In soft-water districts copper is largely used, as otherwise a quantity of rust accumulates in the boiler. Copper boilers are also used in hard-water districts in some cases, often under the misapprehension that less lime deposit, or fur, accumulates in them. This idea is, however, quite erroneous, as the lime is deposited in just the same amount, no matter what the material of the boiler. Copper boilers often have much smaller manholes than those of iron, and this is reasonable in a soft-water district, but where the water is hard, the manhole should be of good size in order to enable the fur or deposit to be chipped off as necessary. The deposit does not adhere so firmly to copper as to iron. Copper boilers have usually a thickness of about $\frac{1}{4}$ inch, but the front plate should be thicker, as it is in contact with the fire.

In the case of iron boilers the usual thickness is $\frac{3}{8}$ inch, and they can be either welded or riveted together. For a close fire range they should always be welded, but for an open fire they can be either welded or riveted.

To keep boilers thoroughly efficient, the deposit should be regularly removed. Where the water is very hard, it might be necessary to do this twice a year, and though inconvenient and expensive, the increase in efficiency of the system would warrant it.

A few forms of range boiler may be briefly described. Fig. 128 shows the simplest form, termed a back boiler; it has no flue, but one is formed by supporting it on fire-bricks as shown. The bricks soon get burned away, and it is much better to use a boiler with a proper flue, such as that shown in Fig. 129, which illustrates a saddle boiler, i.e. one with an arched flue formed in its base. There is little object in the sloping front, in fact it gets less capacity by such formation, and no compensating advantage.

The boiler shown in Fig. 130 is somewhat similar in principle, but has an upright front, and the flue is shaped with flat sides and rounded angles to provide greater heating surface. Boilers can be obtained of L shape on plan, the arched flue going through one arm of the L. This gives greater capacity for certain situations and slightly greater heating efficiency. The best form of boiler is the boot boiler. One form of it is shown in Fig. 131. In this the flue is continued up the back, but in the simplest form of boot boiler it is not so continued, and the boiler is of practically the same efficiency as one of L shape. The best form of boot boiler is one in which the flue is carried up the middle of the back as

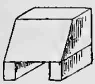


Fig. 128.

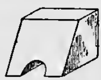


Fig. 129.

Fig. 130.

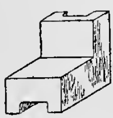


Fig. 131.

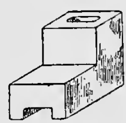


Fig. 132.

shown in Fig. 132. It will be seen that a maximum of heating surface is obtained in this way. The boot boiler in its ordinary form consists practically of two saddle boilers at right angles, and though more expensive than the ordinary saddle boiler, it will supply about double the quantity of hot water in a given time.

In some systems of hot-water supply the storage vessel is placed fairly high up in the building, and in such case it takes the form of a closed rectangular tank. If placed low down, however, the pressure in the vessel is much greater, and it is necessary to use a closed cylinder, since a vessel of that shape is much stronger. In either case the storage vessel is built up of iron plates riveted together, the vessel being afterwards galvanized to protect it from corrosion. The thickness of the plates will depend entirely on the height of the cold-water cistern above the storage vessel. Both cylinders and tanks are made of plates either $\frac{1}{8}$ inch or $\frac{3}{16}$ inch thick, or for smaller sizes or less pressures, a thickness of either 16, 14, or 12 B.W.G. (Birmingham Wire Gauge). Hot-water tanks and cylinders are usually marked as tested to so many lb. per square inch. The pressure the vessel will have to bear can be readily found by allowing 1 lb. per square inch for every 2 feet of height from the hot water to cold-water vessels.

Both cylinders and tanks should have good-sized manholes for access, preferably at the side. The joint between manhole and the vessel can be made in various ways, but it should be remembered that the manhole is intended to be removable without great trouble. One method is to use an india-rubber washer, blackleaded on its lower side to prevent it adhering to the iron; another is to use a cardboard ring, set in a soft putty made of red and white lead and oil; a third is to use such putty with a thin layer of strands of hemp between two thin layers of putty.

Tanks and cylinders should be put in positions which are as little exposed to cold air as possible, but if there is any difficulty about this, they should be protected, to prevent loss of heat, by encasing them with a material such as asbestos cement.

It will be obvious that while the size of the range boiler is limited by the width of the kitchen fire, the sizes of tanks and cylinders will depend on the amount of work they have to do.

The pipes used for conveying hot water should be galvanized wrought-iron welded steam tubing. They should be jointed with red-lead cement and fixed at least 2 feet away from pipes conveying cold water. There should be no right-angled elbows in the course of the pipes, bends being used instead, so as not to impede the circulation of the water. The pipes can be fixed either by means of wall hooks, iron clips, or straps, or by means of special iron clips of such shape that the pipes are kept well away from the face of the wall. If placed in any position in which they are likely to come into contact with cold currents of air, as in a corridor, the pipes should be protected against loss of heat by either a spiral winding of strips of hair felt secured at intervals with wire, or by silicate cotton attached to canvas strips and secured by wire in the same way.

The cold-water supply pipe to the system can be of iron or lead. Any stop-cocks on valves used on the hot-water service should be of the full-way type, to prevent impeding the circulation. Great care is needed in reference to such stop-cocks or valves. They should have loose keys; kept only in the hands of a responsible person, as should a stop-cock be closed and left so, grave danger of explosion may occur.

From the particulars given later as to the arrangement of the pipes, it will be seen that there is a sort of natural safety-valve to a hot-water service in the form of an expansion pipe, and also in the form of a cold-water supply tank. Both of these items may, however, unless the system is most carefully arranged, fail by the action of frost, and it is therefore usual to provide a safety-valve of a more definite type. The reason for this is readily seen. If a hot-water service is sealed, the temperature of the water may rise much above 212° F., the temperature at which water boils under the controlling influence of air, and its consequent expansion may be so great that the boiler or the pipes may be ripped open, the issuing water being converted to steam on meeting the air. If there are any stop-cocks on the service, a safety-valve should always be used, in case the system should be bottled up by the unauthorized closing of one. Another possible cause of explosion in hot-water work is the blocking up of the pipes, or any part of them, by the deposit from hard water, but it is doubtful if this incrustation has ever been allowed to become so pronounced as to cause explosion.

The safety-valve can be placed on a short special pipe communicating directly with the boiler, or one of the ordinary pipes, called a return, just near the boiler; or, best of all, directly on the boiler.

There are several kinds of such valve, such as the spring, lever, deadweight, diaphragm, and fusible plug. In the case of the spring safety-valve, a cylindrical brass case has a valve at the bottom, and a screw cap at the top with a hole through it. Passing downwards through this hole is a vertical spindle with an enlarged conical point resting on the valve. Around the spindle, between the enlargement of the conical point and the underside of the screw cap is a spiral spring, the strength of which can be regulated by screwing in or unscrewing the screw cap. This type of safety-valve is unreliable. As generally constructed, the surfaces in contact between the valve and its seating are too large, and liable to become firmly stuck together.

The lever safety-valve is a regular item in connexion with steam boilers, but it is cumbersome and unsightly in the case of a hot-water service. It consists of a valve held on its seating by a lever having an adjustable weight at its end.

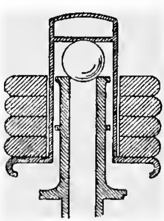


Fig. 133.

The deadweight safety-valve is the best for a hot-water service. It is simple in construction, compact and efficient. In its usual form, the surfaces in contact are very small. It will be seen from Fig. 133 that the pipe is closed by a ball held down by a casing carrying a number of circular weights. From the smallness of the surface in contact with the ball there is no danger of the valve sticking, or even if this did occur, the surfaces are so small that they would break apart under far less pressure than would be necessary to burst the boiler or pipes.

The so-called diaphragm safety-valve is not really a valve at all. Between two short lengths of pipe or tube, a sheet of mica, thin copper, or lead is placed, closing the outlet. The thickness of such sheet or diaphragm is proportioned so that it is the weakest spot in the system, and gives way when there is danger of an explosion. In the case of the fusible plug safety device, which also is not a valve in the true sense of the word, a plug of fusible alloy is placed in a brass case, the plug being of such a nature that it melts at a temperature slightly above boiling-point, and in this way affords relief to the dangerous pressure that would be existing in the system at such a temperature.

All the pipes of a hot-water service should have a fall, in order that the system can be emptied if required, by means of a special draw-off tap provided for the purpose.

The methods of arranging the pipes can be best shown in a diagrammatic way, and in studying the following sketches it must be remembered that pipes shown passing from point to point in a straight line do not necessarily follow that course in actual work, it being necessary to determine the routes of all pipes according to the circumstances of each case, such as the fittings to be served and their relative positions, the impossibility of carrying pipes through certain rooms, and so on. The pipes should, wherever possible, be run so as to necessitate only short branch pipes to the fittings.

There are three principal methods of arranging the parts of a hot-water service, known as the tank, the cylinder, and the combined tank and cylinder systems, there being, of course, variations of each. There are many differences of opinion among hot-water fitters as to the best method of executing certain minor details of the work in any system, but the broad principles of each of the systems referred to are well established.

Fig. 134 shows, diagrammatically, the arrangement of the parts of the tank system as ordinarily carried out. B, the boiler, is fitted with a safety-valve, S.V., and provided with an emptying out pipe, E.O.P., to enable the whole system to be emptied. From the boiler a flow pipe, F, rises to a storage tank, T, near the top of the building, a return pipe, R, completing the circuit of the water between the boiler and tank. The tank is sometimes an open one, but if so, it will be seen that it must be at the same level as the cold-water supply cistern, S.C., or it will overflow. It is difficult to get really hot water from an open tank, and they are therefore but little used. If the tank is closed, provision must be made for the expansion of the water on being heated, and an expansion pipe, E.P., is provided, leading from the top of the tank. It can be taken through the roof, or if a cold supply cistern is near, it can be turned over that as shown. Its end is open, but if the system is well arranged water rarely issues from it. The cold-water supply is laid on by a pipe, C.W.S., and can be connected to the boiler as shown, or to the tank, or to the top of the return pipe. This is largely a matter of economy and individual preference.

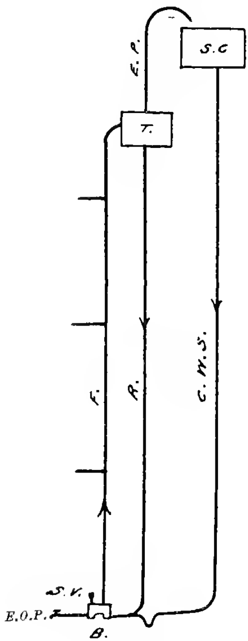


Fig. 134.

The branches to the fittings should be taken from the flow pipe.

The dip shown on the cold-water supply pipe, C.W.S., is to prevent the hot water circulating into such pipe.

Direct connexion of the cold water to the tank, T, sometimes leads to cold water being drawn from such tank.

The phenomena of water circulation have already been dealt with under the heading of hot-water warming, and it is sufficient to add that they can be easily studied by anyone who is sufficiently mechanical to make a small model of glass pipes and flasks, with the aid of rubber corks and tubing, applying the heat from the flame of a candle.

It will be noticed that the flow pipe is taken from the top of the boiler and the return connected to the side low down. If this side connexion is difficult for some reason, the return pipe may be carried down through the top of the boiler, but it must be prolonged downwards to give the right direction to the circulation. Fig. 135 shows a section through a boiler with the pipes so connected. The flow pipe, F, must be finishep quite flush with the underside of the top of the boiler to prevent any accumulation of air, with consequent danger of bursting the boiler. Thus, in Fig. 136 the flow pipe is shown wrongly connected, with a space between the surface of the water and the underside of top of boiler. The rising water would compress the air and the pressure might be sufficient to do serious damage. Similarly the expansion of the water, on heating, would greatly compress the air with the same possible result. Further, there is objection to the noise of the bubbling water when steam forms.

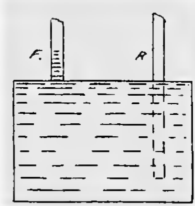


Fig. 135.

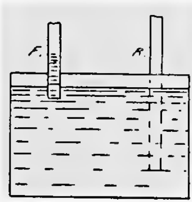


Fig. 136.

An important point to remember is that when a tap is turned on water rushes to it from all directions, and that it is therefore desirable to tap only such pipes, and those only in such places, as will give a hot supply. Thus, in Fig. 134 it will be obvious that hotter water will be obtainable from the flow than from the return pipe. Also that hotter water will be obtainable at the highest of the three branches shown, as it is near the storage tank. The boiler is relatively small compared to the tank, and the water would be forced through it fairly quickly if a tap were opened on the lowest branch shown and left open for a little while. Fig. 137 shows a method not often adopted, on the ground of expense, but one which is based on sound reasoning. No branches are taken from the flow-pipe, but a separate pipe is provided to supply the fittings, drawing water only from the storage tank. The same sketch shows the method of connecting the cold-water supply to the tank instead of the boiler. It will be seen that a dip or trap is formed in the pipe, to prevent back circulation of the hot water. It might, instead, enter at the base of the tank as shown in Fig. 138. The connexions to boilers, tanks, or cylinders should always be made so that there should be no short circuiting. Thus, as an example, in the first sketch of Fig. 138, if the C.W.S. pipe had merely an open end, the cold water would tend to rush up and at once mingle with the hot water issuing from the flow pipe. To obviate this a T-piece is put on

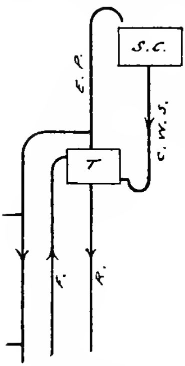


Fig. 137.

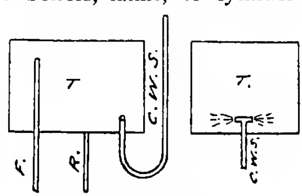


Fig. 138.

the end of the pipe as shown in the second sketch, thus dispersing the water sideways at a low level in the tank.

The emptying-out pipe shown in Fig. 134 is sometimes otherwise placed; it may be replaced by a tap at the bottom of the cylinder, or on the C.W.S. pipe just below cylinder, or on the return pipe. The only drawback to attaching it to the boiler is that if the water is hard there may be sufficient deposit in the boiler to block the mouth of the pipe.

The disadvantages of the Tank system are (1) the water has to travel some distance before reaching the storage tank, so that a good supply is not very quickly obtained; (2) there is a certain amount of heat lost by radiation from the flow and return pipes, and also from the surfaces of the tank, if, as is often the case, it is put in a roof or cold cistern room; on the other hand, the system has the advantages of (1) relative cheapness compared with other systems, and (2) a good supply of hot water to fittings which are high up in the building.

The Cylinder system, in which the cylinder is placed relatively low down in the system, ensures a good supply to the lower fittings, but often a poor one to those high up. Hot water is obtained in less time than with the tank system. There is greater safety where water in the cold supply cistern is liable to run short, it being impossible to empty the cylinder through the draw-off taps as ordinarily arranged since they are all above the cylinder. The flow and return pipes are shorter and there is therefore less loss by radiation on the way to the storage cylinder; further, the cylinder is generally put in a warmer position than a tank, usually in the kitchen.

On the other hand, the system is rather more costly than the tank system, and the cylinder has to stand a higher pressure.

Fig. 139 shows the simplest form of the cylinder system. It is suitable for a house of moderate height provided the fittings are close together, branches being taken from the expansion pipe to them. It will be seen that the hot water will rise in this pipe to approximately the level of the water in the supply cistern.

Fig. 140 shows a more extensive form of the cylinder

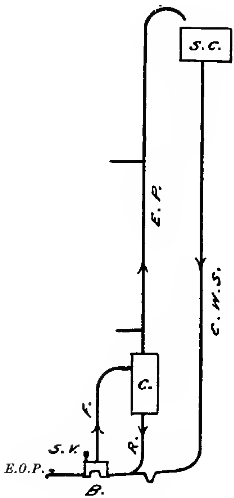


Fig. 139.

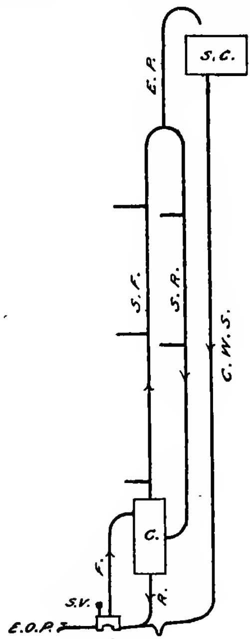


Fig. 140.

system, provided with a secondary flow and return taken round past the various fittings so as to supply them by means of short branches. Branches are taken from both flow and return pipes of the secondary system of circulation, the secondary flow being marked S.F. and secondary return S.R. The letters already used will be adopted in the remaining illustrations to obviate full description in each case. In the remaining examples, also, the safety-valves and cleaning-out pipes are omitted, in order to keep the sketches simple, but they would, of course, be used, as in the cases already dealt with. Fig. 141 shows the method of connecting the C.W.S. pipe to the cylinder instead of the boiler, but here, again, as with the tank, it might enter the bottom of the cylinder.

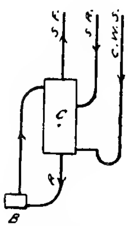


Fig. 141.

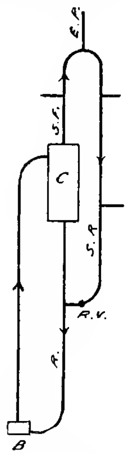


Fig. 142.

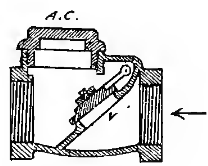


Fig. 143.

To save making two holes through the chimney breast, the flow and return are often brought through the same hole, both entering the side of the cylinder low down, but in such case the flow pipe must be carried up some distance inside the cylinder.

It is sometimes difficult to find a position for the cylinder in the kitchen or near by the boiler; it is then put higher in the building, and branches may be required both above and below it. Fig. 142 shows how this can be arranged, the secondary return being joined into the main return. In such case, to prevent relatively cold water being drawn from main return, a reflux, non-return, or back pressure valve is placed at R.V. The construction of such a valve is shown in Fig. 143. A light valve of copper is hinged so as to readily open, but also readily close against any attempted back flow of water. An access cap is provided at the top to enable inspection and repair of valve as necessary.

The secondary flow and return pipes are sometimes at opposite sides of the building, and it is necessary to run a pipe

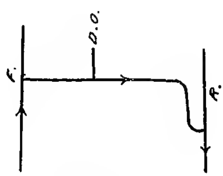


Fig. 144.

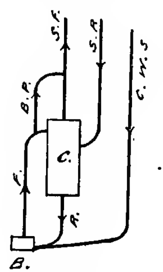


Fig. 145.

from the one to the other as shown in Fig. 144. In such a case, the slight fall generally available for the pipe is insufficient to ensure a good circulation through this extra pipe, and matters are put right by giving the pipe a "drop" as shown, the greater density of the water at the lower part of the drop increasing the velocity of flow through the pipe. D.O. = draw off.

A method adopted sometimes is shown in Fig. 145 consisting of the addition of a bye-pass pipe, B.P., from the main flow to the secondary. The object of this is to give a quicker hot supply than would otherwise be obtainable, by letting a certain amount of water escape going through the cylinder. Such bye-pass must, however, be of considerably smaller section than the other pipes, or the whole of the water will be short circuited and not pass through the cylinder.

Additional power is sometimes given to a hot-water service by using two boilers, say one behind kitchen range and the other in the scullery, or one in the range and the other an independent boiler. The method of arranging the connexions in such case is quite simple, and is shown in Fig. 146. The flow from the second boiler is joined to that of the first, and the return of the second also joins the return of the first. Each boiler would also have its own safety-valve and emptying pipe.

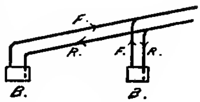


Fig. 146.

The third principal system is the combination of Tank and Cylinder shown in Fig. 147. It is a system possessing the advantages of both the tank and cylinder systems, and also overcoming the disadvantages of both. The general arrangement will be seen from the sketch. The C.W.S. pipe can be connected to the tank, the cylinder, or the boiler, the usual practice being to connect it to the cylinder as shown. This method of arranging the service gives a good supply of hot water to all the fittings, whether high up or low down. It is, of course, better to take branches from the flow pipe only, if this can be conveniently arranged. The combined capacity of the two storage vessels would be made about equal to the capacity of the cylinder which one would use if the cylinder system only were adopted.

An extension of the combined system is shown in Fig. 148, there being two sets of secondary pipes. An ordinary range boiler would be inadequate for so large an installation, so an independent boiler, IB., is shown. The expansion pipes would be at opposite sides of the building, and could either be passed through the roof or turned over a cold-water cistern if one should be near enough.

All the systems just referred to are examples in which the water is heated directly by the boiler. If the water of the district is very hard, there will be a considerable deposit of lime in the pipes and boiler. The deposit does not occur, however, if the water is not raised to boiling-point. A method of indirect heating can therefore be used on the lines shown in Fig. 149. The cylinder is double, i.e. a small one placed

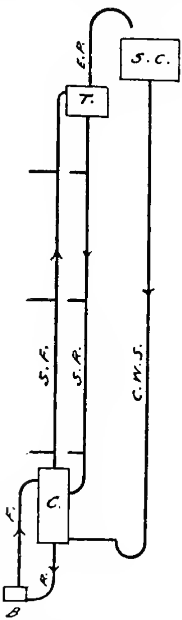


Fig. 147.

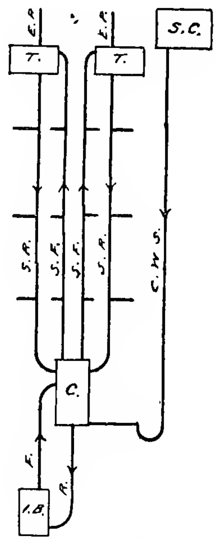


Fig. 148.

within a larger one, the small one being used as a means of heating the water by contact, and the supply to the fittings not passing through the boiler. Thus there are two complete systems in one. The boiler has the usual main flow and return pipes connecting it to the small cylinder, or indirect heater, which has its own expansion pipe. The water supplied to the fittings is passed through the main cylinder and around the heater, but the temperature does not exceed about 180° to 190° F., whereas water does not boil till 212° is reached.

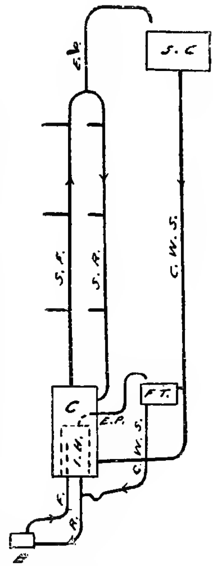


Fig. 149.

Cold water must be laid on to both the boiler and the cylinder, and this is best done by means of a small feed tank, F.T., as the less the height of the feed tank above the heater, the safer is the main body of water from boiling. If there is difficulty in obtaining room for a sufficiently large indirect heater, the difficulty can be overcome by constructing it with cross tubes through which the main body of water can pass, thus increasing the heating area. Instead of the indirect heater in the form of a cylinder, a coil of pipes can be used on the principle of the calorifier.

Extensive hot-water installations can also be worked by means of steam calorifiers, before referred to in connexion with warming, and consisting of steam coils placed in cylinders, the hot-water supply being thus obtained without the use of boilers in the sense in which the word applies to the foregoing notes.

The sizes of the pipes, tanks, etc., must depend on the facts of the particular case, but, generally speaking, main flow and return pipes run from 1 to 2 inches in diameter, secondary $\frac{3}{4}$ to $1\frac{1}{2}$ inches, expansion pipes $\frac{3}{4}$ to $1\frac{1}{2}$ inches, branches to fittings $\frac{1}{2}$ to $\frac{3}{4}$ inch, and the cold-water service $\frac{3}{4}$ to $1\frac{1}{2}$ inches. The cold supply should be of good size in all cases, it being better to have it too large rather than too small.

It would be beyond the scope of this work to deal in a very detailed way with the means of raising water to a height, but a few brief notes may be of interest. The means referred to may be summarized under the following headings: (1) Lift pumps; (2) force pumps; (3) steam pumps; (4) centrifugal pumps; (5) the air lift; and (6) the hydraulic ram.

Fig. 150 gives a diagrammatic section through a lift pump. Passing down into the water of the well is a suction pipe, S.P., having at its foot a strainer or rose, the sum total of the areas of the holes in the strainer being equal to not less than twice the sectional area of the suction pipe. Above the suction pipe is the pump barrel, P.B., opening out of which is either a spout or a pipe termed a delivery pipe, D.P. Working up and down in the barrel is a piston or bucket, B, controlled by a piston rod, P.R., the latter being actuated by either a pump handle or a cranked axle. The bucket has a valve, B.V., and there are also valves at the upper end of the suction pipe, i.e. the suction valve, S.V., and at the lower end of the delivery pipe, i.e. the delivery valve, D.V.

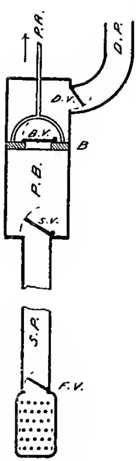


Fig. 150.

A valve is also sometimes used at the foot of the suction pipe, and termed a foot valve, F.V.

The suction pipe cannot be of unlimited length, since the water rises in it by atmospheric pressure on the surface of the water in the well. Theoretically, the atmospheric pressure will support a column of water 34 feet in height, but practically the height is taken as about 25 feet, to allow for friction in the pipes, and other items. This means that when the rose or strainer is immersed below the lowest working level of the water in the well, there should not be a greater distance than 25 feet between the top of the bucket and such lowest working level.

Briefly, the action of such a pump is as follows: As the bucket is raised, there is a tendency to cause a partial vacuum in the part of the pump barrel below it. The water consequently forces open the suction valve and rises into the space below the piston. As the bucket descends, the pressure closes the suction valve and opens the bucket valve, allowing the water to pass to the upper side of the bucket. On the bucket again rising it lifts this water, which forces open the delivery valve and passes up the delivery pipe, the delivery valve closing again on the descent of the bucket. If the delivery pipe is replaced by a spout, there is, of course, no valve such as that marked D.V.

If the well is very deep, the pump barrels have to be placed in it, and piston rods extended to the top. The pump barrels are supported on girders, with a small platform to facilitate access, and the piston rods are kept in a true line by means of guides in the form of anti-friction wheels.

Two pump barrels may be placed side by side, served by a common suction pipe, and serving a common delivery pipe, the bucket of the one going down as that of the other goes up.

A Force pump, or as it is sometimes termed, a Lift and Force pump, is shown diagrammatically in Fig. 151. In this case the piston has no valve in it, and the entrance to the delivery pipe is at the bottom of the barrel. The reason for this will be obvious, as no water can pass to the upper side of the piston. The arrowhead shows the piston to be descending, in which case the pressure will close the suction valve, open the delivery valve, and force water up the delivery pipe. On the piston rising, the

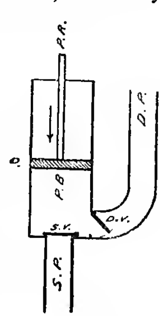


Fig. 151.

weight of water in delivery pipe will close the delivery valve. The suction valve will open and admit more water, and the piston descending again the whole process will be repeated.

Another kind of force pump is that shown at the left-hand side of Fig. 152. In this form the piston takes the shape of a solid plunger, P, of almost the same sectional area as the barrel. It will be seen that its action is similar to that shown in Fig. 151, the plunger displacing a certain quantity of water each time it descends, and forcing it into the delivery main.

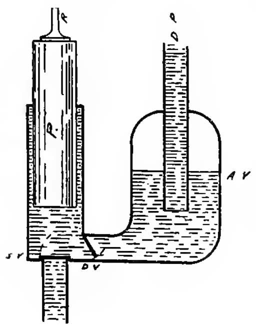


Fig. 152.

A careful study of the foregoing brief notes will show that the discharge of a pump would, unless means were taken to prevent it, be occurring in intermittent jerks, instead of a continuous supply. This is obviated in various ways. At the right-hand side of Fig. 152 is an air vessel, in the top of which air is imprisoned. The air acts as a cushion, being compressed as the water rises in the vessel when the delivery valve is open, and expanding again when the delivery valve is closed. This expansion of the air forces a certain quantity of water up the delivery pipe when the plunger is not doing so and so makes the supply continuous.

Air vessels require to be carefully proportioned, and means should be adopted for making good the loss of air from the vessel, which occurs by the water absorbing some of it and carrying it up the delivery pipe. This adjustment is made either by a valve of special form, and termed a snifting valve, or by means of two small taps, one at the top to let the air in, and the other at the bottom to let some of the water out.

Another method of obtaining a continuous supply is to use a double-acting pump. Thus, Fig. 153 shows a diagrammatic section of a double-acting force pump, the action of which is as follows: As the piston descends, the lower suction valve closes and the lower delivery valve opens, water being forced up the delivery pipe. While this is occurring, water is entering the pump barrel above the piston, through the upper suction valve, the upper delivery valve being closed. As the piston rises the upper delivery valve opens, and the upper suction valve closes, water entering the barrel below the piston, to be displaced on the next descent of the piston.

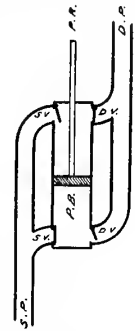


Fig. 153.

A variation of the foregoing pumps is that known as the Bucket and Plunger pump, a combination of the suction and force pumps. The piston fills the sectional area of the barrel, and has valves in it, but the piston-rod is enlarged to half the sectional area of the barrel, to act as a plunger on the up stroke.

Steam pumps are of many patterns, but the principle involved is that of driving the water out of the pump barrel or chamber by the admission of steam, a good example being the Pulsometer pump.

Centrifugal, or rotary, pumps are entirely different in principle, the principle adopted being practically that of a reversed turbine. Instead of a wheel being driven by water power, a power-driven wheel actuates the water and forces it out of a chamber into the delivery pipe. In the centre of a casing formed like a volute shaped pipe is a thin wheel having a series of curved blades on each side. The water enters the casing on each side of the wheel and the revolving of the latter throws it into the delivery pipe. Such a pump is not well suited for high lifts.

The principle of the air lift for raising water is that of reducing the weight of a column of water by means of compressed air. A pipe is passed down the well to a depth greater below the water than the height the water is to be raised. Compressed air is admitted to the bottom of this pipe, but does not *mix* with the water in the ordinary sense of the word mix. The effect is to form thin layers of air and water in the pipe, with a resulting decrease in density, the water in the well or borehole acting downwards to force this lighter compound up through the tube. It will be seen that air-compressing plant is needed for this method of raising water, the method being therefore only applicable to work on a large scale, and then only in cases in which there is a considerable depth of water in the well.

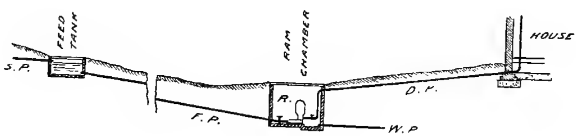


Fig. 154.

Hydraulic rams are often used in connexion with the supply of water to large country houses. The principle underlying their construction is that of using the momentum of a body of water falling through an inclined pipe to raise a smaller quantity of water through a height. There are both "single-acting" and "double-acting" hydraulic rams. The former type is that in which the water lifted comes from the same source as the water utilized for driving the ram, while in the latter the water lifted is pure, and that used for driving the ram is impure, or at any rate, of doubtful quality.

The sketch, Fig. 154, shows an outline section of the arrangement of a water supply system in which a single-acting ram is used. A feed tank of watertight construction, and furnished with a strainer and grit chamber, is fed by a supply pipe, S.P., from, say, a stream. From the feed tank a feed pipe, F.P., or, as it is often termed, a drive pipe, passes to the ram, which will be dealt with more in detail later. The ram passes a small proportion of the water into the delivery pipe, D.P., but the bulk of it into the waste pipe, W.P., the latter quantity being used to work the ram.

Fig. 155 shows a section through a ram. There are many makes of these, varying much in detail, but all alike in principle. The water enters from the feed pipe at F.P., the feed pipe being a comparatively large one. D.V. is a dash valve, whose weight is very little greater than the water pressure due to the head of water behind it; hence, when the water is at rest in the pipes, the valve falls and water flows out through the valve to waste. As the velocity increases, the impact of the water on the valve closes it, and the momentum then opens the valve, V, admitting water to the air vessel. There the air is compressed, and its reaction in expanding forces the water up the delivery pipe. The pressure in the feed pipe is by this step reduced and both valves fall. Water again escapes at the dash valve and the whole cycle of events occurs again, and continues so long as the supply is maintained. The length of the feed pipe should not be less than the height it is desired to raise water above the ram.

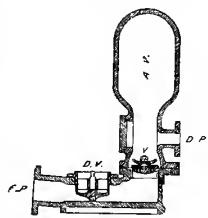


Fig. 155.

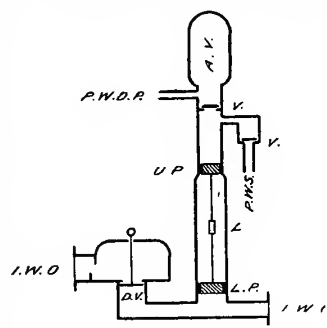


Fig. 156.

A diagrammatic section of a ram on the double-acting principle is shown in Fig. 156. It is really a combination of a ram and a pump. The pure water enters the pure wàter supply pipe, P.W.S., and passes through a valve into the space above the upper piston, U.P. The impure water enters the lower part of the apparatus, through the pipe marked I.W.I. and passes on to the dash valve, D.V., working this part on just the same principle as with the single-acting ram, except that when the dash valve closes, the impure water does not rise higher into the apparatus but merely exerts its force on the under side of the lower piston, forcing it up and so displacing the pure water into the pure water delivery pipe. The upper and lower pistons are connected by means of a rigid rod, through which a weighted level passes at L, to facilitate the downward movement after the pure water has been displaced. In this case, also the cycle of events continues so long as the supplies are kept up.

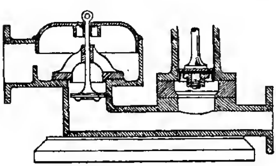


Fig. 157.

The pistons must of course be tightly fitting to prevent the passage of impure water. Fig. 157 gives an enlarged and more detailed section of the lower part of the apparatus, showing by a thick line the cup leather put to the pistons to ensure this result.

CHAPTER VII

THE BUILDING—ITS SANITARY FITTINGS AND WASTE PIPES.

IN dealing with the waste matters from buildings, there are two principal systems, known respectively as the "Conservancy" or "Dry" system, and the "Water Carriage". The former involves the use of earth-closets and privies, and the latter, water-closets, drains, sewers, cesspools, etc.

In sparsely populated country districts the use of earth-closets and privies is permissible where no convenient position can be found for a cesspool, and where there is no regular public supply of water, but they should not be permitted in populous districts as their use is against the best interests of health. All waste matters should be removed from the vicinity of the building as speedily as possible.

The conservancy system has always been somewhat popular in the large towns of the North of England and the Midlands, where sanitary progress has been far less rapid than in the South, but even in the northern towns privies and earth-closets are now slowly but surely being superseded by water-closets. A plentiful supply of water is essential to the success of any system involving water-closets and drainage, and where this cannot be obtained a good form of earth-closet is the best. In some of the northern towns a plentiful supply is not readily obtainable, and recourse is had to a form of closet known as a slopwater closet, in which the closet is flushed (more or less) by means of the waste water from sinks, rain-water pipes, etc.

The earliest form of closet, or privy, consisted merely of a seat placed over a shallow pit termed a midden. The midden was sometimes lined with brick, slate, or stone slabs, but was more often unlined, and was furnished with no means of deodorizing the waste matters. More modern forms have either a fixed or movable receptacle, the latter system forming what is termed a pail-closet.

Special pails are provided by the local authority, and periodically removed in special vans, being replaced by clean ones. The pails are emptied and disinfected before being used again. The receptacle under the seat, whether furnished with a pail or not, should be of watertight construction, and the seat and riser should be readily removable.

In some places the privy is combined with an ashpit, the two being constructed back to back and communicating below the seat. A special shoot conducts the ashes so that they fall on to the foul matter and act as a deodorant.

The usual official requirements as to privies are the following :—

1. Not less than 40 feet from any well, spring, etc., used as a source of drinking or domestic water.

2. Ready means of access for cleansing.

3. Apartment to be properly ventilated.

4. Floor to be not less than 6 inches above ground, of non-absorbent material, and falling ½ inch to 1 foot towards door.

5. Space beneath seat to be lined with non-absorbent material, and the floor of it to be not less than 3 inches above ground.

6. If a movable receptacle is provided, its capacity is not to exceed 2 cubic feet, or if a fixed receptacle, 8 cubic feet.

7. The space below seat must have no communication with any drain and not be exposed to rainfall.

8. The privy is not to be less than 6 feet from the main building; and lastly, it is usual to require some provision for

the application of dry earth or ashes from time to time in the case of a privy having a fixed receptacle.

A much better apparatus is the earth-closet, which, like the privy, can have either a fixed or movable receptacle. In either case provision is made for the systematic application of dry earth to deodorize the discharges, which is best done automatically. There are many kinds of earth-closet, the best being those in which the earth is applied merely by the weight of the user on the seat actuating a series of levers. The earth should be of a loamy, vegetable nature, sand or gravel being of little value as a deodorant. The application of suitable earth turns the excremental matter into a sort of vegetable mould.

The usual official requirements for earth-closets are the following:—

1. One wall at least to be an external wall of the building.

2. To have a window not less than 2 square feet in area, made to open, and also an air brick, air shaft, or other additional means of ventilation.

3. To have a receptacle for dry earth, with means of applying same as required, the means being preferably automatic.

4. Floor not to be less than 3 inches above ground.

5. Space below seat to be lined with non-absorbent materials.

6. Ready means of access for cleansing.

7. If movable receptacle its capacity must not exceed 2 cubic feet, and if fixed receptacle 40 cubic feet; and

8. Space below seat must have no connexion with any drain and not be exposed to rainfall.

The fittings used in conjunction with the water carriage system include water-closets, flushing cisterns, lavatory basins, baths, sinks, and urinals.

Great progress was made in the design and arrangement of sanitary fittings about twenty years ago, but there have been no sensational advances in recent years. To be quite efficient, all sanitary fittings should be of simple construction, as self-cleansing as possible, made of non-absorbent and incorrodible materials, and readily connected to waste pipes. All parts should be made readily accessible, and the fittings should not be enclosed in wooden or other casings. Such enclosures are very apt to become receptacles for dust and dirt.

As already stated, slopwater closets are often used where an ample supply of clean water is not available. These closets are of several types. Fig. 158 shows one type, in which S = seat, F = floor of closet, G.L. = outside ground level, and F.D. = flushing drain, fed by the waste from sink and rain-water pipes. Below the seat are oval pipes leading down to a trap. The flushing drain seldom has more than a mere dribble passing

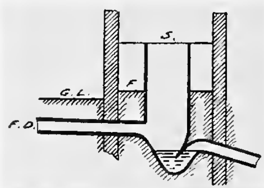


Fig. 158.

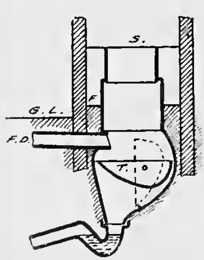


Fig. 159.

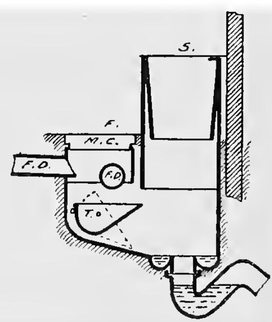


Fig. 160.

through it, and the flushing effect on the trap is naturally very slight. Fig. 159 shows a different type, in which a tipper, T, is hung on pivots below the opening in the seat. This receives the discharges and is also fed by the flushing drain, and when full, overbalances and discharges its contents into the mouth of the trap below. It is so balanced that, after doing so, it regains its original position. A third type is shown in Fig. 160 in which the tipper is placed at one side, the foul matters falling either into the trap or into a small annular channel around it, filled with water as shown. A movable cover is provided over the tipper, M.C., for convenience of access. It will be seen from this sketch that more than one drain can be led to the tipper if desired. It is doubtful if the type shown in Fig. 160 is quite as efficient as that shown in Fig. 159, as the space around the mouth of the trap is apt to get very foul. Still another type is shown in Fig. 161 in which there is a proper closet pan with a water seal, flushed at the top by means of a tipper above ground, fed by a sink waste pipe and a rain-water pipe. There is no flushing rim around the top of the pan, but the water is introduced in such a way as to give a piral flush to the pan. If the tipper happens to discharge when the pan is in use, the user is apt to get splashed, but notwithstanding this, Fig. 161 shows the least objectionable of the four types illustrated. In each case the sketches are diagrammatic, the joints being omitted to simplify the illustration.

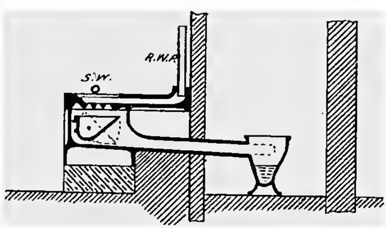


Fig. 161.

We may next consider water-closets of the usual type. The position and treatment of closets and other sanitary fittings in the design of a building is a matter of far greater importance than is generally recognized. All fittings should be placed against external walls, to ensure short lengths of waste pipe. All fittings of similar nature should be arranged over one another on the various floors, to simplify the scheme of drainage. In old houses one often finds a water-closet in the middle of the building, with no natural lighting and no ventilation worthy of the name. While one does not find such a condition of things in a modern house, one often finds that water-closets are placed in any odd part of the plan without regard to the scheme of underground drainage, so that closets on one floor do not come over those on another. Under these circumstances the cost of the drainage is increased and its efficiency often lessened.

There are certain conditions that should be fulfilled in order to obtain a really sanitary closet. They include the following: (1) at least one wall of the apartment should be an external wall of the building; (2) there should be a good window for light and ventilation, or if possible, two windows to permit of a current of air through the apartment, and in any case the window or windows so placed as to give plenty of light around the apparatus; (3) a non-absorbent floor and walls, or if this is impossible owing to cost, a tile dado around the sides and back of the apparatus; in a public water-closet it is better that the walls should be of white glazed bricks or tiles, and the floor of tiles or mosaic work, but in a private house this would generally be objected to on the ground of appearance; (4) a pedestal apparatus; (5) a trap forming part of the apparatus, or if a separate trap, close to the apparatus and above the floor; (6) the pan and trap to be of incorrodible material, the former white glazed earthenware, and the latter either the same or of drawn lead, or of iron, glass enamelled inside; (7) the whole of the apparatus to be simple in design, with no movable working parts to get out of order, and to be easily accessible; (8) a siphonic water waste-preventing cistern over the back of the pan, it being placed there to obviate the loss of flushing power caused by bends; and (9) the full force of the flush should be directed on the contents of the trap and not wasted by being diverted to accessory parts. If such accessory parts be thought desirable, as in the case of some of the "siphonic" closets, a larger cistern should be used. The flush, in its passage to the trap, should thoroughly cleanse the pan.

There should be no hidden, inaccessible parts to a sanitary fitting, no matter what the purpose of the fitting may be. Numerous examples of such objectionable items might be given, some practically obsolete, others doomed to become so. Such are the "pan" closet, the "D" trap, the "tip up" lavatory basin, basins and baths with overflow pipes entered only through a few small holes pierced in the material of the fitting, and so on.

In dealing with closet apparatus, it will be well to divide them into two sections, one, those which are objectionable, and the other, those which are allowable or desirable.

One of the oldest forms of pan is that known as the Long Hopper. It is in the form of an inverted cone, and usually has no flushing rim, but merely a spreader for the water, in the form of an oyster shell. It is a bad form, owing to there being no water in the pan for discharges to fall into, and also owing to the fact that the outlet is in such a position that the discharges are apt to foul the back of the pan. This type of pan is now rarely met with and should be condemned where found. Somewhat similar is the pan known as the Short Hopper shown in Fig. 163. The sides are sometimes concave as shown, and some-

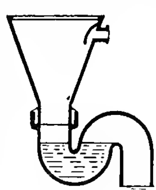


Fig. 162.

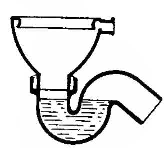


Fig. 163.

times straight. In some forms a flushing rim is provided as shown in the sketch; in others, merely a spreader. The disadvantages of this type are the same as for that just given.

Another insanitary apparatus is the Pan or Container closet shown in Fig. 164. It consists of a conical basin of glazed earthenware, fixed over a large cast-iron container, C, the outlet of the basin, being closed by a hinged copper pan, P, holding water and held up by leverage. The solids fall into the pan, P, and, on pulling up a handle in the seat, the pan falls to the position shown by dotted lines, throwing the contents into the container, the bottom of which, around the outlet, becomes very foul. The water is usually admitted to the basin behind a spreader, S. The sketch shows the outlet of the container joined to a D trap, D.T., by the dip pipe, D.P., there being a lead safe or tray, L.S., on the floor, the waste pipe, W.P., of which communicates with the trap. The sketch shows the apparatus as usually installed, and the whole arrangement is hopelessly insanitary. Such a closet should be condemned wherever found, but it is rapidly becoming obsolete.

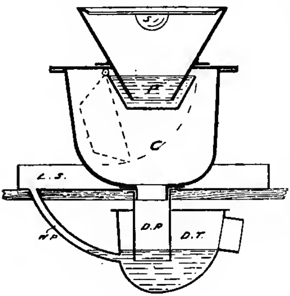


Fig. 164.

The next sketch, Fig. 165, shows a section through a Wash-out closet, another insanitary type. The pan is so constructed that there is a shallow basin of water directly below the seat, the water being of insufficient depth to cover deposits, resulting in smell. If the water be made deeper, the force of the flush from the cistern is insufficient to wash out

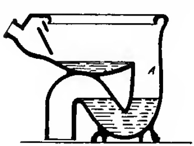


Fig. 165.

the solids and change the contents of the basin. Further, the washing out of the basin throws solid matters against the side at A, leaving them to decompose until possibly washed out by the next flush, while the water merely falls into the trap without force. This type of closet pan should be condemned wherever found.

Fig. 166 shows a type of pan which has been much discredited, and known as the valve closet. It is rather complicated, and in the old forms had many objectionable features. In the most modern forms, however, it can be classed as a sanitary fitting. The chief advantages claimed for it are (1) that it is almost noiseless in action, (2) the discharges fall into a fairly deep body of water, and (3) if the house is unoccupied for a long time there is great protection given by the depth of water against evaporation. For example, the water above the valve must first be evaporated, then there is some protection left by the valve fitting up tightly against the outlet, and further there is the trap with its water seal below the point A.

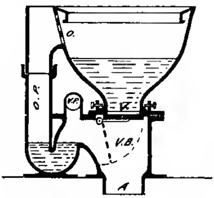


Fig. 166.

In London the valve closet is doomed by the regulations of the Metropolitan Water Board, which provide that all valve closets shall be flushed by water waste-preventing cisterns, which will negative the noiseless action.

The valve, V, is held up by leverage, and opens downwards on pulling up the handle in the seat. It allows the contents to pass through the valve box, V.B., into the trap below. It is possible that the valve may by accident become set fast, and an overflow pipe has therefore to be provided. The overflow openings are shown at O, and it will be seen that they communicate with the overflow pipe, O.P., which is open at the top for convenience of access. The overflow pipe is isolated from the valve box by a trap, and the valve box is provided with a ventilating pipe, V.P., carried to the outside of the building. The pan is of glazed earthenware, and the valve box and overflow pipe should be of cast iron, glass enamelled inside. Valve closets are usually cased in with a wooden seat and riser right across the apartment, but they can be obtained in "pedestal" form, and there is then little to find fault with from a sanitary point of view. It should be noted this remark applies only to a modern form of valve closet, with accessible overflow, and glass enamelled valve box and overflow pipe, the whole enclosed in a glazed earthenware pedestal.

One of the best forms of closet at the present time is that known as the Wash-down, one type of which is shown in Fig. 167. It will be seen that it is based on the hopper type, but that the outlet of the pan is sealed by water, having a reasonable surface area. The back is made nearly vertical, and in some varieties of this type, quite vertical, to guard against fouling. There is a good seal to the trap, and a proper flushing rim is provided around the top of the pan. In some types the trap is separate, and in such case the joint between it and the pan should be below water level, so as to readily indicate any defect in the joint. A wash-down closet should have a good seal, not less than 2 to 2½ inches, as it is rather liable to become unsealed if a bucket of slops be thrown into the pan.

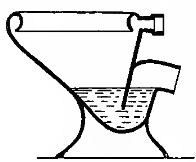


Fig. 167.

Fig. 168 shows a second variety of this type of closet, a "wash-down" with large water area. With this type fouling of the pan is practically impossible. The larger area of water is obtained partly by making the front more concave, and partly by increasing the depth of the seal. In Fig. 169 a third variety of wash-down apparatus is illustrated, differing from the two previous examples in the addition of an after-flush chamber, A.F.C., between the top of the trap and the under side of the flushing arm of the pan. When the pan is flushed,

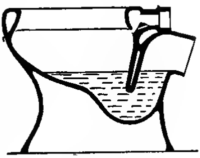


Fig. 168.

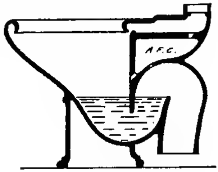


Fig. 169.

water enters this chamber and fills it, while the bulk of the water from the cistern passes on to flush the pan. The outlet of the after-flush chamber is small, and the water comes from it more slowly, in consequence, to ensure there being sufficient water left in the trap at the end of the flush.

We come next to closets of what are known as the Siphonic type, of which there are two principal varieties, (1) those with two traps, and (2) those with one only. The best-known example of the former is that shown in Fig. 170 and known as the Century closet. It will be seen that there are two traps, one formed in the pan itself and the other separate and at a lower level. The water is laid on to two points, (1) the flushing rim, and (2) the top of the space between

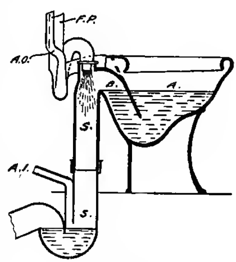


Fig. 170.

the traps, the flushing pipe being marked F.P. Above the lower trap is an air inlet pipe; when the water begins to rush down the space S.S. it closes the mouth of the air inlet pipe, A.I., and causes a partial vacuum around the outlet of the pan. The water stands at the same level at both A and B at the commencement, because both surfaces of water are subject to the same influence, that of atmospheric pressure only, but on water rushing down S.S. the atmospheric pressure on B is reduced and an overbalancing occurs, the atmospheric pressure on A forcing the contents of the pan out, followed by the bulk of the water descending from the flushing cistern. There is a trap at the foot of the flushing pipe, provided with a ventilating pipe, A.O.

It will be seen that when the water at the end of the flush falls below the end of the pipe A.I., air rushes in and stops the siphonage. It will be seen that this type of closet is rather complicated in construction, though having nothing mechanical in its nature, and therefore requires skilful fixing, but it is thoroughly efficient and fulfils all the requirements of a high-class sanitary fitting.

A good example of the siphonic closet with a single trap is shown in Fig. 171. It will be seen that it has an exceptionally deep seal and large water area. The siphonic action is set up by rapidly raising the water level in the basin, and so overbalancing the other column of water, which fills the arm A, B, full bore. This arm has an enlargement of its section just below B, to which the ventilating pipe is fixed, obviating a check to the siphonic action at B, owing to the sudden compression of the air in that arm of the siphon. It will be seen that the soil pipe is still trapped if the basin is removed.

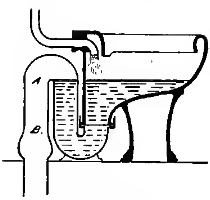


Fig. 171.

Before leaving the description of the various types of water-closet, reference must be made to trough closets and latrines, such as are used in factories and some types of school. The oldest form is merely a semicircular trough, covered by a continuous seat with a series of holes in it, trapped at one end, and flushed out at intervals by means of an automatic flushing tank. Such a fitting is very liable to fouling, difficult to keep clean, and is quite lacking in privacy. Another type is in the form of an oval pipe running from end to end, with short oval branches passing up under the holes in the seat. This is better but still not good.

Even in the roughest of communities all closets should be separate to ensure reasonable privacy. Fig. 172 shows, diagrammatically, an excellent arrangement for such cases, in the form of a siphonic latrine. There are separate pans divided by divisions or partitions, D, and communicating with a longitudinal pipe, the end of which is raised to provide a body of water in each pan. A siphon, S, is produced at the end of the

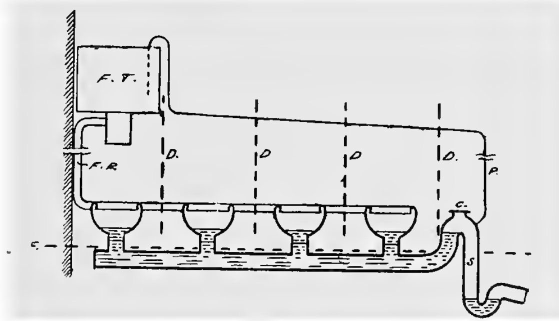


Fig. 172.

range of pans, with an access cover, C, at the top of the bend. Each pan has a flushing rim, and the flushing pipe has a branch to each. An automatic flushing tank, F.T., provides the flush at frequent intervals, and, after flushing, the siphonage is checked by a small pipe, P, which lets air into the siphon as soon as the water level in the flushing tank drops below the end of the pipe, shown by dotted lines inside the tank. The flushing tank would, of course, be higher than shown in the sketch, which is broken to save space.

We may next consider the means of flushing closets. The usual method is by means of a cistern, at a height of a few feet above the apparatus, with a capacity of two gallons. In some places a larger volume is permitted by the water authorities, but in very few. For a siphonic closet a three-gallon flush should be used wherever possible.

The old type of cistern was operated by means of valves, the pulling of the handle raising the valve and letting the water out. To empty the cistern, it was necessary to hold the handle till the water had all gone. Some types had one valve, others two, but cisterns of this kind have now been superseded by others of siphonic action, of the "pull and let go" type, termed siphonic water-waste preventers. There are very many forms of such cistern, but a few examples will indicate the principles underlying the construction of practically all of them. They differ only in the method of setting up the siphonic action. In the following sketches, which are diagrammatic, the ball valves and overflow pipes are omitted for the sake of clearness. The example shown in Fig. 173, though siphonic in action, has a valve. On pulling the handle the valve, V, is raised and allows water to rush through the branch, B. The effect of this is to lessen the pressure of the atmosphere on the small surface of water, A, with the result that the water rises over the bend and sets the siphon in action, the water continuing to flow until it falls below the level of the open end of the pipe.

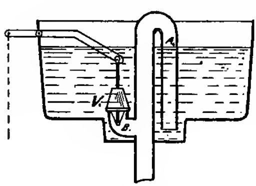


Fig. 173.

In Fig. 174 the pulling of the handle lifts a body of water into the bend and so starts the siphon. The end of the pipe in the cistern terminates in a cylinder, C, closed at the top and open at the bottom so that water can rise into it when the cistern fills. Through this cylinder passes a vertical spindle which lifts a circular disc, D.D., on the handle being pulled. It is by this disc that the water is lifted, the disc fitting quite loosely in the cylinder. Another variety of this type is shown in Fig. 175, in which the cylinder or dome is

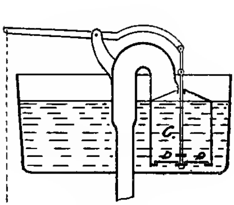


Fig. 174.

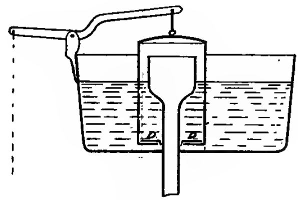


Fig. 175.

movable. It is raised by pulling the handle, and lifts a body of water on a loose disc, D.D., as before, into the mouth of the vertical pipe. This removes the atmospheric pressure in the dome and starts the siphonage. Another way in which the same principle is applied is shown in Fig. 176. In this case the pulling of the handle pushes a loosely fitting piston, P, along the open end of the pipe and forces a body of water over the bend. The examples in Figs. 174 and 175 show that siphonage can be started by lifting a body of water vertically, that in Fig. 176 by a horizontal force, and that in the next figures, Figs. 177 and 178, by a vertical downward force. Fig. 178 is an outline plan of the cistern. Around the dome, which in this case is fixed, is an iron disc or washer, I.W., which on being forced down forces the water up under the dome and into the mouth of the flushing pipe. There are three levers all joined together in one casting, and pivoted on the line P.P. At the end of lever, L, is the handle, and at the ends of the levers, L_1 and L_2, are vertical rods, R.R., connected to the iron

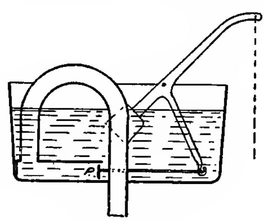
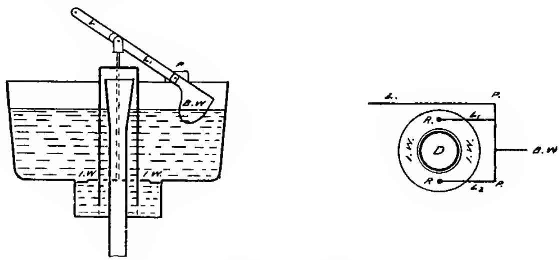


Fig. 176.

washer. As the handle is pulled down, the rods go down too, forcing down the washer ; the equilibrium of the apparatus is restored by a balance weight, B.W.



Figs. 177 and 178.

The cistern shown in Fig. 179 depends on a different principle. The raising of the dome produces a partial vacuum in the space S, causing the water to follow the dome and fill the pipe, the water in the pipe at S overbalancing the small body of water on the other side of the trap and forcing it over the bend, B, thus starting siphonage. A more direct application of this principle is shown in the stoneware cistern illustrated by Fig. 180. The raising of the dome, by a rapid pull of the handle, causes the water to follow the dome and fall into the mouth of the pipe. The handle is forked so as to grip the two opposite sides of the dome, the short connecting piece, shown in dotted lines, ensuring the vertical rise of the latter.

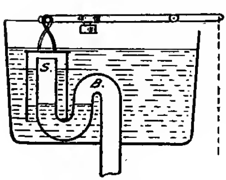


Fig. 179.

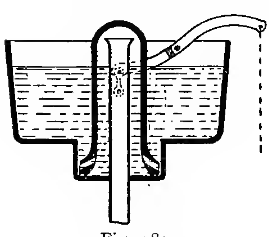


Fig. 180.

As a last example, involving still another principle, Fig. 181 shows a cistern operated pneumatically instead of by a handle. A loosely hinged valve, V, enables the water to rise into the open end of the flush pipe, F.P., and into the chamber, C. The small pipe A.P. is an air pipe passing down to a point about 2 feet above the seat, where it terminates in a small circular leather bellows actuated by a push button like that of an electric bell. On pushing the button, sufficient force of air is exerted at A to drive the water out of the chamber, and over the bend of the flushing pipe.

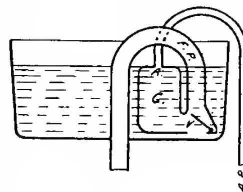


Fig. 181.

A two gallon water-waste preventer should discharge in about five or six seconds, and refill in from a half to three-quarters of a minute.

The method of flushing a valve closet is necessarily different from that applicable to closets with a free outlet. Fig. 182 shows the arrangement in outline. The outside line shows an iron frame. It carries a handle, H, to which a lever, L, is connected, the lever controlling the water inlet to the pan. On pulling up the handle the water is turned on, and as the lever, L, falls, by reason of the weight, W, it is gradually shut off. It would be instantly shut off but for the bellows regulator, B.R. This consists of a cylinder containing a small leather bellows connected to a spindle, S, the bellows having a valve at the bottom. The spindle passes through the bellows and collapses it as the handle is raised, and the descent of the spindle can be retarded to any extent by means of a small tap fixed near the top of the cylinder.

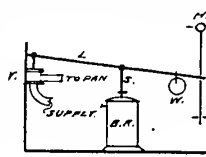


Fig. 182.

Other forms of regulator are used, but that described is the most usual. Some forms of inlet valve do not require regulators, but they are usually complicated in construction and liable to get out of order. Fig. 183 shows the construction of the usual form of water inlet for a valve closet. It will be seen that it is opened by the raising of the lever and closed as the lever goes down again. If a valve closet is to be flushed by means of a water-waste preventing cistern, the pull of the cistern can be coupled up to the gearing of the valve apparatus.

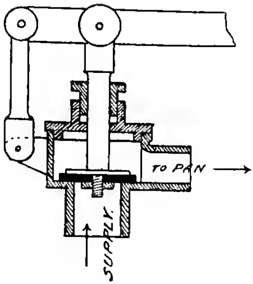


Fig. 183.

The most important point in the design of lavatory basins is that the overflow shall be readily accessible for cleaning. Fig. 184 shows a common form of overflow which is quite inaccessible, while Fig. 185 shows one which is nearly as bad. In the latter, the waste and overflow are combined, in a small chamber behind the basin, in the form of a vertical hollow tube, the lower end of which acts as a plug. On pulling up the knob at the top, the water can escape, and in case the basin is filled too full, the water flows over the open top of the tube and away through the outlet. This form of overflow and plug can be readily made accessible by putting it in a recess at the back of the basin instead of in an enclosed chamber. It is true that, as shown in Fig. 185, the top plate can be unscrewed,

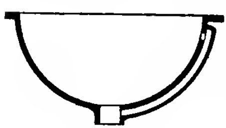


Fig. 184.

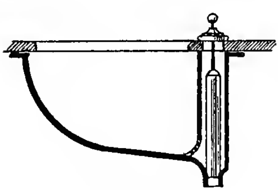


Fig. 185.

and the tube lifted out for cleaning, but this seldom gets done, it being a case of "out of sight, out of mind". If in an open recess, the tube can hang on a hook and be readily lifted off for cleaning.

A good form of overflow is that known as a weir, two varieties of which are shown in section in Fig. 186. In both these cases the overflow bends round to join the outlet of the basin. A much better form is shown in Fig. 187, the overflow being larger, and leading straight down to the mouth of the trap below the fitting. It need hardly be said that the overflow is not the full width of the basin, but merely consists of a recessed chamber. The entrance to the overflow is often guarded by a brass or nickel-plated grating, hinged to the basin.

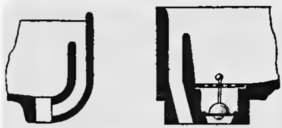


Fig. 186.

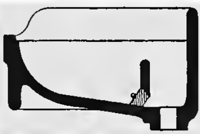


Fig. 187.

An excellent form of waste and overflow is shown in Fig. 188. Both overflow and outlet are guarded by nickel-plated gratings. Behind the outlet opening is a plug, capable of being moved backwards and forwards by a lever handle at the top of the spindle, S. When the waste outlet is opened by a turn of the handle, the plug, through the agency of a crank at C, passes back into a recess, R, leaving both outlet and overflow fully open. It will be seen, too, that the overflow passes vertically down to the trap and is quite accessible.

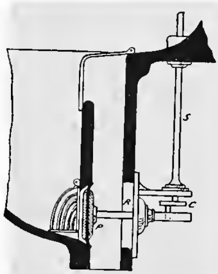


Fig. 188.

Quite a different kind of waste and overflow is shown in Fig. 189 of the type known as a gate waste. Across a recess in the back of the basin is a plate of metal or vulcanite, sliding in grooves, and shown by a thick line in the sketch. An overflow opening is cut in it as at O, and the lifting of the plate allows the water to run away. On removing the plate the whole of the overflow passage is accessible. In the particular example shown, the trap is partly formed in the basin itself to obviate the existence of even the short length of pipe that would otherwise occur above the trap and be liable to become fouled.

The arrangement of the "Tip Up" type of lavatory basin is shown by a line diagram in Fig. 190. The chamber below the basin, and the under side of the latter, are apt to become

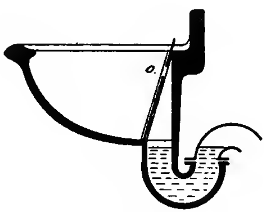


Fig. 189.

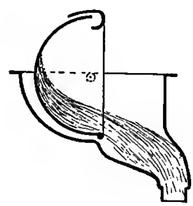


Fig. 190.

coated with dirty soap suds, and, while this can be readily removed by lifting the basin out, a fitting which requires no such attention is obviously preferable.

Lavatory basins should be fixed on brackets or cantilevers, so that the space below them is uninterrupted and accessible, and the wall behind them should be faced with non-absorbent material, such as tiling.

The general principles of the design of baths are similar to those for lavatory basins. There should be a good-sized waste outlet and an accessible overflow. While lavatory basins are now almost invariably of white glazed earthenware, there is a larger selection of materials in the case of baths. They can be of tinned copper, cast-iron either paint-enamelled, stove-enamelled, or porcelain-enamelled, of white glazed fireclay or earthenware, or of marble.

The copper bath takes very little heat out of the water, but requires to be carried on cradling in order to be strong enough to stand the weight of the water and of the individual. Further, it is often found that the floor of the bath gets uneven and prevents the entire emptying of the water. Such a bath must also be enclosed. Cast-iron baths are largely used in small houses on the score of economy, being finished with paint enamel. Such baths are very difficult to keep clean, and the extra cost of porcelain enamel, i.e. enamel which has been vitrified, is amply justified, the inside of the bath being then non-absorbent and highly glazed. Porcelain or fireclay baths are the best of all. It was at one time thought that they robbed the water of much of its heat, but experience has proved this not to be the case to any extent. Marble baths look well, but are very costly to construct, and it is certainly difficult to get a really hot bath in one.

A common form of overflow to a bath is one guarded by a readily removable circular grating, but this is not so good as a type which is immediately accessible. The form of waste and overflow shown in Fig. 188 is also applied to baths. Fig. 191 shows the application of the tube waste and overflow combined, the tube being attached to a hook. Such tubes can be of metal or vulcanite and should stand in a recess at the end of the bath, as in the case of lavatory basins. A form of waste outlet sometimes adopted is that shown in Fig. 192, which shows, diagrammatically, a valve outlet, V, controlled by a weighted lever, W.L. A chain or rod connects the lever with the top of the bath casing where this method is adopted. In some places the water companies will not allow a bath overflow to be joined up to the waste pipe, but requires it to be treated as a warning pipe. Fig. 193 shows the arrangement of the pipes in such case, assuming a valve outlet to be used. The sketch is perhaps self-explanatory, but it will be seen that the overflow pipe is discharged

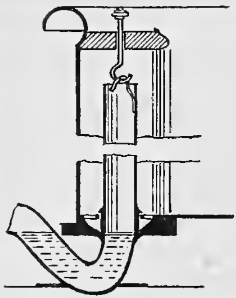


Fig. 191.

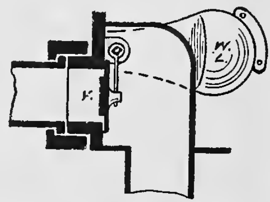


Fig. 192.

over the mouth of the waste pipe of the lead safe under the bath. The valve leads into a trap, T, which is provided with a ventilating pipe, V.P.

There are several varieties of sink, including the scullery sink, butler's pantry sink, slop sink, and housemaid's sink.

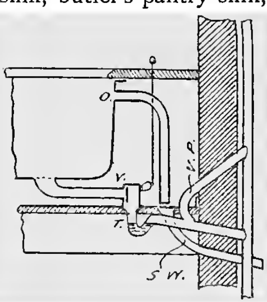


Fig. 193.

Scullery sinks are best made of glazed fireclay, other materials being unsuitable. They are of two kinds, shallow and deep. The shallow sink has usually a grating outlet and really serves only the purpose of a safe. Having an open grating as outlet it requires no overflow. Scullery sinks are often used as washing-up sinks, and in such case require plug outlets, and consequently overflows, which, as in the case of other fittings, should be accessible. If intended as washing-up sinks, they should be about 10 inches deep. Some are fitted with a removable hardwood draining-board. Some also are made in two compartments, one for washing and the other for rinsing, in which case the overflow is usually put in the partition between the two sinks. A desirable feature in such a sink is a high back or skirting, of the same material as the sink and usually made in one piece with it.

Lead, iron, copper, or wood are unsuitable for the greasy work of a scullery sink, and are open to other objections.

In large houses separate sinks are often provided for the dressing and cleaning of vegetables. They can be very similar to the double sink just described but usually have standing (or tube) wastes and overflows, with a removable perforated copper shield round to prevent the passage of grit, potato peelings, etc., into the waste pipe. Vegetable sinks are also often built up of slate, or made of porcelain-enamelled cast iron.

Butler's pantry sinks should not be of glazed fireclay owing to the more delicate nature of the articles washed in them—china, glass, etc. They can be either of hardwood, such as teak, or of wood lined with copper, tinned copper, or white metal. In the former case they should be made up of boards grooved and tongued together, and jointed with red and white lead putty, the whole being bolted together with galvanized iron bolts. All the internal angles should be rounded to facilitate cleansing, and if such sinks are well looked after they are about the best for the purpose.

If the sink is metal lined, the outer sink of wood should have its internal angles rounded or splayed. Copper is serviceable as a lining but is difficult to keep clean in appearance. Tinned copper or white metal are much better, but lead is unsuitable, owing to its surface becoming very uneven on exposure to hot and cold water in turn.

Small drip sinks are often provided under draw-off taps on landings and in housemaids' closets. They are really more in the nature of lead safes than sinks, and are formed usually on the floor by laying down a wood border of half-round section, and lining the whole with sheet-lead. A grating outlet should be provided. Drip sinks are also obtainable in glazed fireclay.

In a relatively small house slop-sinks are rarely found, a pedestal closet with a dished slab top, or slop top, admirably serving the purpose. In very large houses, however, they should be put. They are made of porcelain-enamelled cast iron or of glazed earthenware, in shape somewhat like a W.C. pan, with a flushing rim, and a water waste-preventing cistern over. One sometimes finds them with a hinged grating over, and hot and cold-water taps to facilitate the washing of bedroom utensils. This arrangement is not good, owing to the possibility of the cold-water tap being used for filling water bottles.

Not only is it objectionable to fill bottles from a tap over a foul fitting, but the taps are apt to be used to hang cloths on that have been used for washing bedroom utensils. A much better way is to arrange a housemaid's sink and a slop-sink side by side, the taps over the former and the flushing cistern over the latter. The outlet of the housemaid's sink is in the form of a grating and its waste pipe discharges into the side of the slop-sink.

In a dwelling-house one does not often find a separate urinal. A pedestal closet with a lift-up seat fulfils the purpose adequately. A few words on the design of urinals will not, however, be out of place when dealing with sanitary fittings. At one time the idea was to get as little fouling surface as possible, using the old-fashioned upright or lip basins, with waste pipes leading from them. Though such a basin may be perfectly flushed, the surrounding wall and floor is liable to fouling and is unflushed. It is better, therefore, to give a much larger fouling surface, recognize that practically every part of the urinal is liable to be fouled, and provide for the adequate flushing of such larger surface. The whole of the work around a urinal should be of non-absorbent materials, such as tiled wall and floor, glazed fireclay urinal stalls, etc. About the best type of urinal is that made up of stalls which are semi-circular on plan, have upright backs, and shaped bases discharging into a glazed channel in front, covered by a readily removable brass or galvanized grating. An automatic flushing cistern should be used, its capacity being dependent on the number of stalls, a usual allowance being one gallon per stall. The water reaches the stalls through perforated, or sparge, pipes around their tops.

The outlets of all ordinary sanitary fittings should be "trapped". There are a large number of kinds of trap, good, bad, and indifferent, and it will be well to first deal with the essentials of a satisfactory trap. The object of a trap is to prevent the pollution of air. Thus, in the case of a lavatory basin, there would be a length of waste pipe which would get more or less coated with dirty soapy water, the pipe therefore becoming a foul pipe. The air in the room being warmer than that outside the house, the colder air would pass through the pipe to the room, and be contaminated. This can be prevented by the use of a trap, which should be put as near to the fitting as possible. In the case of a W.C. the necessity for the trap is of course far greater, since the W.C. is either directly connected to the drain or is connected to a soil pipe by a short branch, the former being directly connected to the drain, and not disconnected as in the case of a lavatory, bath, or sink.

A satisfactory type of trap is one that is self-cleansing, simple in form, devoid of angles, corners, or cavities, holds only a small quantity of water with a good depth of seal, made of incorrodible materials, and easily connected to fittings and to pipes.

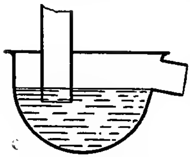


Fig. 194.

It will be well to deal firstly with varieties of traps which are open to objection. Fig. 194 shows a section through a D trap. It will be seen that it fulfils hardly any of the conditions just laid down for a satisfactory trap. It is not self-cleansing, is rectangular both in plan and in cross-section, and holds too much water with but a poor seal. It is a type wholly to be condemned and is fast becoming obsolete. Fig. 195 shows one form of "lip" trap. It is not self-cleansing, and like the D trap holds too much water. Other forms of lip trap are shown in Figs. 196 and 197. Their construction

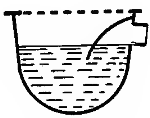


Fig. 195.

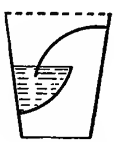


Fig. 196.

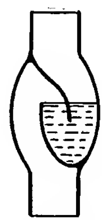


Fig. 197.

will be evident from the sketches. They all possess the same outstanding defects, i.e. lack of self-cleansing power, inaccessibility, with angles and cavities. A trap of another form,

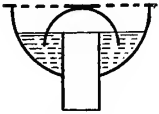


Fig. 198.

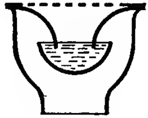


Fig. 199.

yet very similar in principle, is that known as the "bell" trap. It is illustrated by Fig. 198, and was at one time largely used for sinks. The dotted line shows the grating outlet of the sink, to which is attached a bell or dome, the latter dipping into a channel of water, circular on plan. It was very liable to get choked, when it was at once unsealed by lifting up the grating with the help of a fork. To overcome this objection, the "inverted bell" trap was introduced. From Fig. 199 it will be seen that in form it is open to as much condemnation as the ordinary bell trap, though it could not be so readily unsealed. The inverted bell was of course kept in position by light metal stays, connecting it to the casing of the trap.

A trap of entirely different form is the bottle trap shown in Fig. 200. It usually had a good seal, but is open to serious objections as it is in no way self-cleansing or accessible. Mechanical traps were at one time very popular, but they are unnecessarily complicated, and possess no advantages.

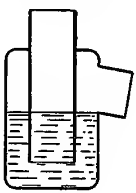


Fig. 200.

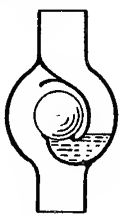


Fig. 201.

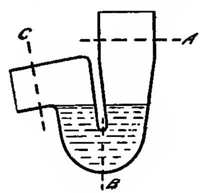


Fig. 202.

An example of such a trap, known as a ball trap, is shown in Fig. 201. The ball can be of vulcanite or rubber, and is intended to supplement the small water seal shown. All the traps already described must be regarded as bad forms. The simplest form of trap is merely a bent pipe. It obviates angles, cavities, or any inaccessible parts, and gives a self-cleansing type. Fig. 202 shows a section of an "Anti D" trap which fulfils practically all the essentials of a satisfactory trap. The trumpet-shaped inlet is not bound to be present in a trap of this type, but it is certainly a desirable feature. A cross-section at A is circular, at B oval, and at C a square with the corners rounded. The object of the last-mentioned feature is the prevention of siphonage of the water seal, and while this is effected, it is in almost all cases wise to use other means also of guarding against siphonage. This peculiar section of the outlet makes the "Anti D" trap a little more difficult to connect to pipes than if it were cylindrical.

One of the best types of trap is the P or $\frac{1}{2}$-S trap shown in Fig. 203. It is of circular section throughout, simple, and self-cleansing, with a good seal while holding a comparatively small body of water. In the smaller sizes, 2-inch diameter and less, it is provided with a screw-cleaning eye at the lowest point, as shown in Fig. 204, which is a section of an S trap. A form which is midway between the S and the $\frac{1}{2}$-S, shown in Fig. 205, is known as a $\frac{3}{4}$-S trap. With the smaller sizes of all these traps a screw-cleaning eye is provided. The question as to which of these traps is used for any particular case is largely dependent on the available room. One other form, also quite a sanitary trap, is that known as a "running" trap (Fig. 206).

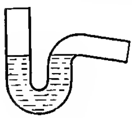


Fig. 203.

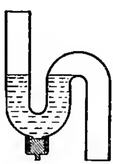


Fig. 204.

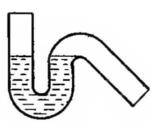


Fig. 205.

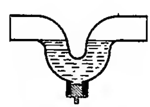


Fig. 206.

The best material for traps is drawn lead. It is easily connected to fittings and pipes, and is incorrodible. If iron is used, the trap should be glass-enamelled inside.

The joints around the various fittings next call for attention. In the case of a W.C. there is the joint between the flushing pipe and the apparatus, and that between the pan and trap. The flushing pipe is joined to the cistern by means of a union, and to the pan in a variety of ways. Various forms of india-rubber cone are used, the pipe fitting into the flushing arm and a joint made with putty of red and white lead, and the cone being then placed around it and secured with copper wire. Some joints are made with rubber rings compressed by screw collars, so as to tightly pack the space between the lead and earthenware. Another method is to use special collars of lead, hinged together in two pieces, and secured by a small bolt. The collar connects the pipe to the flushing arm and is packed inside with red and white lead.

The joint between the pan and trap depends on the material of the latter. If the trap is of iron, a cement joint is all that is needed. If of lead, many means are adopted. One often sees the lead dressed out to form a socket, which fits over the outlet of the pan, the space between being filled with red and white lead putty. If the trap is formed in the pan itself, the joint is, of course, between the outlet of the trap and the pipe. With an iron pipe a cement joint is all that is needed. With lead, the best plan is to use a brass socket, as shown in Fig. 207, connected to the lead pipe with a wiped joint and to the pan with a cement joint.

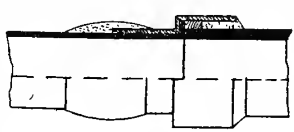


Fig. 207.

Another good joint between the pan and lead is that given, half in section and half in elevation, by Fig. 208. It is made up as follows: Between the lead and earthenware is a flat rubber ring, and outside the lead a flat brass ring. Screw clamps, as shown, are used to bind the whole together. Another way of getting over the difficulty of ensuring a water-tight joint is found in what is known as the Metallo-Keramic

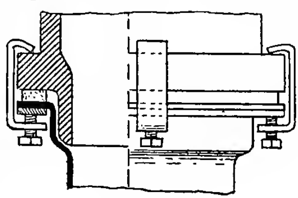


Fig. 208.

joint. The outgo of the pan is coated, before firing it in the kiln, with a composition containing platinum. This gives a thin film to which a lead pipe can be soldered. A socketed short length of lead pipe is jointed to the earthenware with an ordinary soldered joint, the joint being subjected to a severe test. The lead is incapable of separation from the earthenware without fracture of the latter. Other somewhat similar joints are made.

The joint between the lavatory basins, baths, and sinks and their respective traps are made by means of unions and wiped joints, both before described.

In almost all cases a trap below a fitting is liable to lose its seal. It may do so in either of three ways: (1) by evaporation, (2) by siphonage, and (3) by momentum. To guard against evaporation, a good seal should be provided. To guard against the second and third cases, the trap should be ventilated.

The reasons for this will be seen from Fig. 209. For example, if the fitting charged the trap full bore when emptying, the volume of water acting on C would overbalance the atmospheric resistance at D, and the water would either all pass through CDE, emptying the trap, or it would tend to cause a partial vacuum at D. It is, however, well known that nature does not allow a vacuum, therefore the trap would be emptied. This may be obviated by putting a ventilating pipe, V.P., near the outgo of the trap, in order to supply air and preserve the seal.

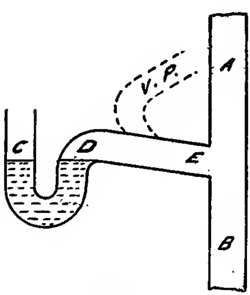


Fig. 209.

Again, if there were two or three fittings, one over the other, discharging into the same waste pipe, the lower traps would be liable to siphonage from another cause. A discharge down the pipe AB tends to momentarily compress the air in front of it, and, referring again to Fig. 209, the effect of this would be to cause a slight excess of pressure at D, momentarily overcoming the normal atmospheric pressure at C, and raising the level of the water at that point. Almost immediately after, however, the discharge has passed the end E of the pipe DE, tending to momentarily lessen the pressure on the surface of the water at D, allowing the atmospheric pressure on C to recover itself, and to raise the water level at D and lessen it at C. This is called siphonage by momentum, and if the discharge is fairly vigorous and fills the pipe, the contents of the trap are almost certain to be forced out. This increasing and decreasing of the pressure on the surfaces of the water forming the seal is very similar to the bouncing of an elastic material.

The ventilating pipe near the outgo of the trap provides an escape for the increased pressure in the first instance, and supplies the air to meet the diminished pressure in the second case. A ventilating pipe to a trap is also known as an anti-siphonage pipe.

The form of the connexion of the vent pipe should be particularly noted from Fig. 209. It will be seen that the pipe is joined by a bend, pointing in the direction of the flow through the trap, which is the only satisfactory method, as it obviates the fouling of the entrance to the pipe. If it is connected vertically, or in any other way than that shown, the entrance is very liable to become stopped up. Though not generally provided for in the provinces, the by-laws of the London County Council prohibit any other method in the Metropolis than that shown in the figure.

Should a fitting be quite separate from any others, its trap may be ventilated, except in the case of a closet or housemaid's sink, by carrying the vent pipe through the nearest external wall, enlarging its outer end, and fitting it with a circular grating flush with the wall.

Each trap should be separately ventilated, but where the fittings are arranged in tiers, or in ranges, the anti-siphonage pipes of the traps may be branched into a main anti-siphonage pipe. This method is shown diagrammatically in Fig. 210, which shows a method of dealing with the wastes of a range of three lavatory basins. Each basin is shown separately trapped, and discharging into a main waste pipe, W.P., and each trap is ventilated into a main anti-siphonage pipe, A-S.P. At the end of the waste pipe a screw-cleaning eye would be provided, S.C.E., and a similar cleaning eye would be put at the bottom of each trap. Sometimes ranges of lavatory basins

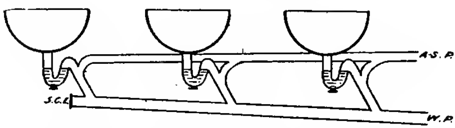


Fig. 210.

are dealt with differently, the separate waste pipes not being trapped but discharging over and into an open channel trapped at the end, the lower ends of the waste pipes being furnished with a bend pointing along the channel. This method is permissible, but it is doubtful if it is as good as that shown in Fig. 210.

Fig. 211 shows the arrangement of a tier of closets showing each trap ventilated into a main anti-siphonage pipe which is finally turned into the soil pipe above the highest fitting. An alternative is to carry the main anti-siphonage pipe well above the roof instead of connecting it to the soil pipe. In the sketch, the anti-siphonage and soil pipes are shown one behind the other for the sake of clearness, but actually the two pipes would be parallel on the outside face of the wall. Anti-siphonage pipes can be of either lead or iron.

For ordinary closet work branch vent pipes of 2 inches in diameter are sufficient, discharging into a main pipe a size larger. For lavatories, baths, and sinks the branch pipe can be a size smaller than the diameter of the trap, the main pipe being of the same diameter as the trap. For the range of basins in Fig. 210 fair sizes would be as follows: Traps and branch wastes $1\frac{1}{2}$ inch, waste pipe 2 inches, branch vent pipes $1\frac{1}{4}$ inch, and anti-siphonage pipe $1\frac{1}{2}$ inch. If the main vent pipe is very long, its diameter should be slightly increased.

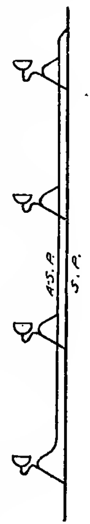


Fig. 211.

The trap of a single closet on a ground floor, with none above it, is not usually ventilated, but it becomes necessary if another is at any time allowed to discharge into the same soil pipe at a higher level.

A scullery sink on a ground floor need not have its trap ventilated, for the reason that a flat-bottomed vessel does not charge its trap full bore all the time it is emptying, and also, that in the case of such a fitting on a ground floor, the waste pipe would be of short length, and disconnected, so that the air in it could never exert any appreciable excess over the normal pressure of the atmosphere.

Passing from the inside of the building to the outside, for all main waste and soil pipes should be outside the building, we may next consider the kinds of waste pipe, the materials used for them, their joints, fixing, and the method of dealing with their top and bottom ends.

They comprise rain-water pipes, carrying the rain water from the roofs, soil pipes, taking the wastes from closets and housemaids' sinks, and pipes taking the wastes from baths, lavatories, and sinks. Lead and iron are about the only two materials used in each case. Lead has the advantage that it is incorrodible, but it is rarely used for rain-water pipes. It is, however, largely used for other waste pipes, being obtainable in longer lengths than iron, thus necessitating fewer joints; it will give slightly, without damage, in the case of settlement of the building, whereas iron pipes might crack; further, the joints can be more perfectly made than with iron. If iron is used, it should be protected against corrosion, either by galvanizing or by the Angus Smith process, both of which have been previously described.

In the case of rain-water pipes, if iron is used, they should be jointed with red lead putty, but they are often found, unfortunately, without any jointing material, the adjacent ends merely fitting one within the other.

In the case of soil pipes, if of lead they should be jointed with wiped soldered joints as already described; the joint requires to be thoroughly sound. Sometimes a fancy joint known as the astragal joint is found, but it is not strong enough for soil pipe work. It is illustrated, partly in section and partly in elevation, in Fig. 212, and its construction will be evident. Occasionally, in old work, one comes across the joint shown in Fig. 213, and known as the blown, or copper-bit joint, but it is entirely unsuitable for soil pipe work. If the soil pipe is of iron, it should have caulked lead joints. Such a joint is shown in Fig. 214. A few strands of tarred hemp are first rammed into the socket, and the remaining space is then filled up with molten lead, which is afterwards hammered in, or caulked. Lead wool may be used in lieu of molten lead.

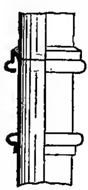


Fig. 212.

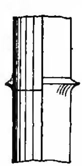


Fig. 213.

The diameters of soil pipes are usually fixed by local by-laws or Building Acts. The Model By-Laws of the Local Government Board prescribe a minimum diameter of 4 inches, and the by-laws of the London County Council a minimum of 3½ inches. It is a great mistake to use a soil pipe of such a diameter that it does not get properly flushed throughout each time a water waste-preventer is discharged. Provided it is large enough for the work it has to do, the smaller it is the better, as it will be kept in a cleanly state. Three and a half inches is a sufficient diameter for any ordinary case, taking say a tier of three closets, but beyond that the size should be slightly increased, say 4 inches for a building of six floors, and 4½ inches for higher buildings. There is little doubt that a smaller diameter could be used for the lower buildings if the use of soft paper in closets was universal, but unfortunately this is by no means the case, especially in tenement dwellings, office buildings, and factories, in which case newspapers, brown paper, etc., are often used.

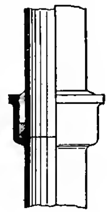


Fig. 214.

If the soil pipe is of lead, it should be of what is known as drawn-lead; that is to say, seamless. Before the introduction of drawn-lead soil pipes, the pipes were made up of sheet-lead with soldered seams, and such pipes are often found in old buildings. They are very apt to be found defective and are often found inside the building, which is not allowable from a sanitary point of view. The lead of soil pipes should weigh not less than 8 lb. per square foot of surface.

Iron soil pipes should be of heavy section, or they will not stand the caulking of the joints. If 3½ inches in diameter they should weigh about 48 lb. per 6 feet length, and if 4 inches, about 54 lb.

The waste pipes from baths, lavatories, and sinks can also be of either lead or iron, the relative advantages and disadvantages of the two materials being as before stated. There is a point to be contended with in the case of these pipes that does not occur in the other cases, due to the fact that water of varying temperatures, from hot to cold, passes through them. If of iron, they are often jointed with caulked lead, but lead is an unsuitable material as its coefficient of expansion is different to that of iron, the result being that the fluctuations of temperature cause the weakening of the joint. Portland cement is often used, and it is not open to the foregoing objections. Rust cement is also a good material, made up of cast-iron borings and sal ammoniac, the resulting cement having about the same coefficient of expansion as the iron pipe. If the cement is required to be quick setting, sulphur may be substituted for the sal ammoniac.

Expansion joints are also often used, involving non-rigid conditions. Rubber rings may be used in the sockets, but they are objectionable on the ground that they perish. A better plan is to use a tightly packed band of greased hemp. Such a joint is shown in Fig. 215. It is difficult to form a satisfactory expansion joint with lead, but a form commonly found is made by enlarging the end of one pipe to form a socket, the end of the adjoining pipe being also enlarged, but merely at its extreme end. The two pipes are put together with a tightly fitting india-rubber ring between them, a collar being soldered round the upper pipe, with sufficient projection to prevent the rain getting into the joint. Wiped soldered joints are often used on main waste pipes. From the fact that the expansion and contraction is less appreciable, and can be better provided for in iron, it is better to make main waste pipes of that material provided they are properly protected against corrosion.

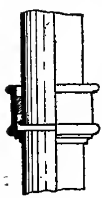


Fig. 215.

If the main pipe, either waste or soil, is of iron, and the branch pipe of lead, the joint is best made by means of a brass thimble or ferrule.

In all main wastes or soil pipe systems on an extensive system, proper access caps or doors should be provided at principal bends and junctions, for the purpose of inspection and cleansing if necessary.

In the case of lead waste pipes, and also overflow pipes, the weights of the pipes should be what are known as "middling," as opposed to the "strong" pipes used for water services. The following table is a guide to this:—

Internal Diameter of Pipe.	Approximate Weight per Yard of Length.
$\frac{3}{4}$ inch.	5 lb.
1 ,,	7 ,,
$1\frac{1}{4}$,,	9 ,,
$1\frac{1}{2}$,,	10 ,,
2 inches.	12 ,,

Iron rain-water pipes are fixed, usually, by means of lugs or ears, cast on the pipe at the side of the socket. In very large pipes, or ornamental ones, they may be fixed by means of iron straps gripping the pipe just below the socket. Lead pipes may be fixed by means of tacks as already described, soldered to the pipe, or by means of cast straps. In the case of soil pipes, if of iron, straps are used, the heavier sections of pipe not being provided with lugs or ears; if of lead, the usual method is by means of soldered tacks of sheet-lead, three being used to every 10 feet length. Sometimes a soil pipe is fixed in a chase or groove formed in the wall, and in such case a common form of joint is as shown in Fig. 216, and known as a flange joint. It will be seen that such a method not only provides a means of jointing, but, at the same time, of fixing, a washer of sheet-lead being placed around the joint where the pipe passes through a hole in a wooden block, and the joint completed by means of solder.

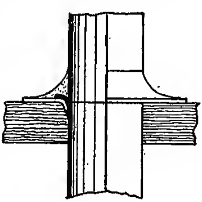


Fig. 216.

For bath, lavatory, and sink wastes, the pipes are fixed by lugs, straps, or tacks, according to the material and the size of pipe. Wherever iron pipes are to be painted, it is a good plan to fix them away from the wall so that they are accessible all round. This is easily accomplished by special iron collars made in two pieces, the back one having an arm to build into the wall. Another great advantage of this method is that in case of leakage the liability of dampness on the wall is reduced to a minimum.

We may next consider the methods of dealing with the upper and lower ends of these pipes.

In the case of rain-water pipes the pipe is either connected to a gutter, or terminates in what is known as a hopper head.

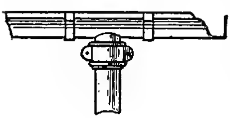


Fig. 217.

Fig. 217 shows a nozzle outlet of an eaves gutter, the nozzle fitting into and being jointed to an ordinary rain-water pipe. In the case of a parapet or similar gutter, a short pipe or tube is led through the wall to discharge over a more or less ornamental rain-water head, or hopper head, which has an outlet jointed to the socket of the rain-water pipe. Such heads can be of either iron or lead, of varying shapes or plan, such as rectangular, half octagonal, semi-circular, etc. Fig. 218 shows one in the form of half an octagon.

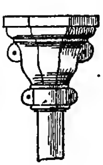


Fig. 218.

The upper end of a soil pipe should be carried up well above the roof, and clear of any windows or skylights. It should have its end in as exposed a position as possible, and not be placed in an angle beside a chimney or any similar position, the object being to enable the wind to blow across the top of it and induce an up draught. Again, if just against a chimney-pot there would be a possibility of a down draught conveying smell into the room served by the chimney. There should be no bends in this upper end of the pipe if avoidable, so as not to check the up draught, and the top of the pipe should be provided with a wire-ball grating to prevent obstruction by birds' nests.

The upper end of a main waste pipe serving baths, lavatories, or sinks, should be similarly treated, but, being of smaller diameter, a wire-ball grating is unnecessary, and the usual plan is to fix two wires at right angles across the top by means of solder.

The method of dealing with the foot of a rain-water pipe will depend on the nature of the drainage system, the procedure differing according to whether or not there are separate drains for the rain water. If the pipe discharges into a drain used exclusively for rain water, two methods are available. One is to directly connect the rain-water pipe to the drain by means of a tapered bend, using a cement joint. One often finds, say, a 3-inch pipe jointed to a 4-inch stoneware bend, which gives a very poor job owing to the difficulty of making a satisfactory joint, but if a bend tapering from 3 to 4 inches diameter is used, a good job can be made. The other method is to use a rain-water "shoe" of iron or stoneware. A section of such a shoe is given in Fig. 219. The rain-water pipe is connected at P, but if it is required to connect a second pipe it can be readily done at the side, as shown by the dotted line.

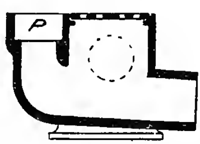


Fig. 219.

The grating allows for the ventilation of the drain and also gives access to any accumulation of rust. Another method of dealing with the rust difficulty is to use a proper "rust pocket". Fig. 220 shows a section, and Fig. 221 a plan of such an item. It will be seen that a fairly deep receptacle or pocket is provided directly under the pipe, and made accessible for the removal of the rust, which often falls in flakes, by means of a cover at C, fixed at ground level. Rust pockets should also be put at the foot of any iron pipes, other than soil pipes, used in connexion with the ventilation of any drain.

If there is only one set of drains, taking both foul wastes and rain water, it becomes necessary to disconnect the rain-

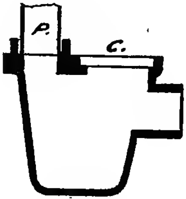


Fig. 220.

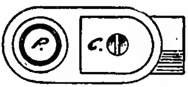


Fig. 221.

water pipes from the drains; if not disconnected, they will act as drain ventilators, and their upper ends are not in suitable positions for this purpose, even if the pipe be perfectly jointed. The usual method is to terminate the lower end of the rain-water pipe with a shoe, or spout, discharging over a gulley.

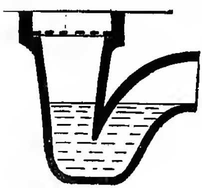


Fig. 222.

A common form of gulley is shown in Fig. 222. It will be seen that it is nothing more than a trap with its inlet at ground level. A well-designed gulley should fulfil the following conditions: (1) It should be of self-cleansing form; (2) it should have a seal of not less than $2\frac{1}{2}$ inches; (3) it should have a flat base to ensure its stability and permit of its being firmly set; (4) it should be set perfectly level and be securely jointed to the drain; (5) the grating should have good openings to deliver the water rapidly into the gulley and yet be small enough to keep out leaves, etc.; and (6) the grating, if of iron, should be protected against corrosion, and should permit of ready removal for cleansing the gulley, while having, normally, a watertight joint.

If to be used in a path, or in the middle of a yard, the upper surface of the grating must be flush with the top of the gulley, but if under a rain-water pipe it is an advantage to have a deep top to the gulley, to obviate splashing, the grating being 2 or 3 inches below the top, as shown in Fig. 220.

Another method of dealing with the foot of a rain-water pipe is to discharge the rain water *into* a gulley, below the grating and above the water level, the rain-water pipe fitting into a socket as shown at P in Fig. 223, which shows what is known as Hellyer rain-water interceptor. It is merely a gulley with a back inlet as well as the usual grating at the top. Additional inlets can be provided at the sides if desired.

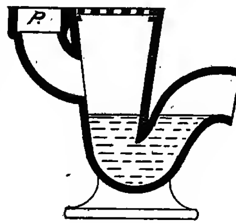


Fig. 223.

Figs. 224 and 225 show, respectively, a section and plan of something a little more elaborate for the same purpose. One or more pipes can be connected to the gulley, below the grating G, but above the water level as in the last case, but in

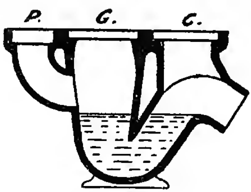


Fig. 224.

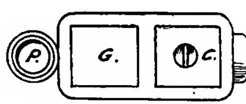


Fig. 225.

this example a means of access to the drain is provided in the form of a tightly fitting cover C, at the outlet of the gulley. This cover should, of course, have a secure, airtight joint. Another form of access gulley is shown in Fig. 226, there being no access cover at ground level as in the previous case, as ecurely jointed stopper being provided at ,S instead.

Waste pipes from baths or similar fittings are often taken through the wall and discharged there, over a rain-water hopper head such as that shown in Fig. 218. This practice is open to objection, as the dirty soapy water splashes round the mouth of the hopper head and remains there decomposing. This is apt to lead to a sickly smell, which frequently finds its way into the house. In some places this method is prohibited, and in any case it is very undesirable.

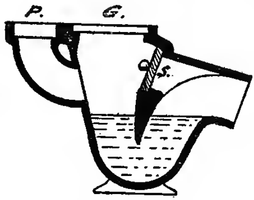


Fig. 226.

The waste pipes from such fittings should be carried down to ground level, and also above the roof; in no case should they be directly connected to a drain, being always disconnected by means of a gulley, which gives a first line of defence to the house against the drain air, the second line being the trap under the fitting. Such a waste pipe should not discharge over a gulley, like a rain-water pipe, as the soapy water will splash over the gulley top and collect there.

The model by-laws provide that waste pipes from baths, lavatories, and sinks shall discharge in the open air, over a channel leading to a trapped gulley grating at least 18 inches away. Fig. 227 shows such a channel, made of glazed stoneware. The dotted lines indicate gratings, the lower one being over the inlet to the gulley, and the upper one being intended to prevent the obstruction of the channel by dead leaves, etc. Channels for this purpose should be of careful design, free from angles and corners.

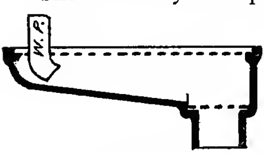


Fig. 227.

Another method is to discharge the waste into a gulley below the grating and above water level, as shown for rain-water in Figs. 223 to 226, while a third method is to use a grease trap. Grease traps are things to be avoided wherever possible and are not necessary for a private house. For hotels, clubs, or any places where exceptionally large quantities of greasy water are discharged, grease traps are practically a necessity, as the grease, in cooling, would tend to form a coating on the inside of the drain and so gradually reduce its diameter. There are two types, (1) those in which the grease is removed by hand, and (2) those in which it is broken up by a powerful flush of water and washed through the drain in its solid state. They will be dealt with under the heading of drainage as they are only desirable in special cases.

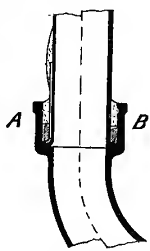


Fig. 228.

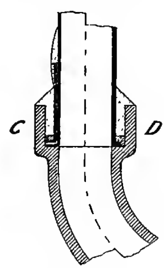


Fig. 229.

Soil pipes should be directly connected to the drain without the intervention of any trap other than those at the outlets of the closets. The method of making the connexion depends upon the materials of which the soil pipe and drain are composed. Thus, if the drain be of cast iron and the soil pipe lead, the foot of the latter would be strengthened by means of a brass or gunmetal ferrule or thimble and a caulked lead joint made to the junction of the two, as shown at A in Fig. 228. If both soil pipe and drain be of iron, the ordinary caulked lead joint would be used, as shown at B in the same figure. If, however, the drain be of stoneware, with a lead soil pipe, the joint would be made with the help of a ferrule, using Portland cement mortar instead of caulked lead. The pouring of molten lead into the socket would split it to pieces, and even if lead wool be used, the caulking would split the socket. The joint for this case is shown at C in Fig. 229. If the soil pipe be of iron and the drain of stoneware, a cement joint is all that is necessary, as at D.

Having brought the waste matters down to ground level, we will next deal with the underground drainage.

CHAPTER VIII

THE BUILDING—ITS DRAINAGE.

LITTLE seems known of the drainage of the past. The Romans used sewers, and presumably, therefore, drains, but there seems no record of the use of drains in England until the time of Inigo Jones, in the seventeenth century.

It has been already pointed out that the keynote of all sanitary work is simplicity and accessibility, and this applies thoroughly to the question of drainage. The foul matters should be removed from the vicinity of the building in as speedy a manner as possible, and there is no reason why this should not be done in every case, no matter how complicated the plan of the building, provided that the positions of the sanitary fittings be carefully arranged.

It will be well, at the outset, to lay down a series of general principles which should govern the design of any drainage scheme:—

1. The relative levels of the building and the sewer, or other point of outlet, should be accurately determined.

2. The pipes should be of non-absorbent materials and laid with watertight joints.

3. The diameters of the drains should be proportionate to the work they are called upon to do.

4. The drains should be laid in straight lines between points of access, all changes of direction or gradient being open to inspection.

5. Branch drains should be as short as possible.

6. The drains should not pass near trees owing to the liability of damage by the roots.

7. There should be no right-angled junctions, all connexions being made so that the incoming drain points in the direction of the flow of the sewage.

8. The drains should be laid to gradients which will ensure their being self-cleansing, or if this is impossible, owing to the nature of the levels, automatic means of flushing should be provided.

9. All inlets to foul drains should be trapped, except in the case of soil pipes, at the feet of which no traps should be used.

10. No drains should pass under buildings if it is possible to arrange them otherwise.

11. All entrances to drains should be outside the building.

12. There should be ample means of access for inspection.

13. The drainage should be disconnected from the sewer by means of a proper intercepting trap.

14. The system of drainage should be properly ventilated.

15. It is desirable to provide a separate system of drains to take the rain water in most cases.

The foregoing points may now be dealt with in more detail. Pipes for underground drains may be of glazed stoneware, of glazed fireclay, or of cast-iron protected against corrosion. The circumstances under which either should be used require careful consideration. The pipes of stoneware or clay are not so strong as those of iron, and are not so fitted to withstand the vibration of heavy traffic such as is so general in our large towns. Further, they are only from two to three feet long (according to diameter) as opposed to nine feet, the length up to which iron pipes are readily obtainable. This means that the iron drain has about one-quarter the number of joints that a corresponding drain of stoneware would have in any ordinary case, apart from which the caulked lead joint of the iron drain is stronger than any joint in general use for stoneware.

It will be seen, therefore, that for drains under buildings or near buildings, and in densely populated districts iron drains should be used. The only reason that they are not in such general use is that they are more expensive, the increase in cost being from 20 to 25 per cent.

It is important to note, however, that there are some purposes, even in the face of the foregoing remarks, for which iron drains, as at present obtainable, are entirely unsuitable. The pipes are protected against corrosion by three principal processes: (1) by the Angus Smith process; (2) by the Barff or Bower-Barff process; and (3) by giving them a glass-enamel lining, all of which have been previously described. Neither of these protective coatings are of much value in connexion with sewage containing strong acid solutions, such as one might get from certain trade processes. Thus, experiments have shown the following results from the use of weak solutions of sulphuric acid.

A pipe treated by the Angus Smith process was tested with a ·5 per cent solution of acid for a period of twenty-four hours, at the end of which the coating was peeling off, leaving the pipe without protection. The same percentage solution destroyed the protective coating of a Barffed pipe in the same period. The glass-enamelled surface of another pipe was completely destroyed by a 1 per cent solution in the same time, whereas a salt-glazed fireclay pipe withstood, without injury, a 5 per cent solution for the twenty-four hours.

These results show that while suitable for domestic work, the nature of the sewage to be carried must receive careful consideration in draining a factory building.

A stoneware pipe is of very different quality to one of fireclay. The former come chiefly from Dorsetshire and Devonshire, and the latter principally from the Midlands.

Their manufacture will be found described in a later chapter, but the points of difference may be here explained. A good stoneware pipe is non-absorbent, even when unglazed, whereas a fireclay pipe is otherwise. If a pipe of each kind be broken, the fractured surface can be readily inspected. That of the stoneware pipe will be of a porcelainous nature and will not absorb moisture if wetted with the tongue, whereas that of the fireclay pipe is rough and will readily absorb moisture. At the same time, it need hardly be pointed out that there are grades of quality in both cases, and that there is little to choose between a good fireclay pipe and an inferior quality of stoneware.

The caulked lead joint, which is used for iron drains, has been already described.

Stoneware or fireclay pipes are jointed in a variety of ways. The joint in general use is known as the ordinary cement joint, but there are other forms which consist partly of cement and partly of rings of bituminous composition. The latter may be divided into those having a single seal and double seal respectively and are used chiefly for sewerage rather than drainage work. As they are also obtainable for the latter purpose they may be here described. There are a great number of varieties of each type, but illustrations are given only of those possessing distinctive features.

The evils of leaky drains are too well known to need reference. In all ordinary cases it is a case of using the most economical and efficient joint, and the ordinary cement joint will no doubt continue to hold first place in public favour so long as stoneware pipes are used. Fig. 230 shows the joint in section. The best method of making the joint is to first of all caulk the joint with a few strands of tarred gaskin, or hemp, well rammed into the socket to prevent the cement finding its way to the inside of the pipe. This should be done by means of a proper caulking tool. The joint is completed by filling

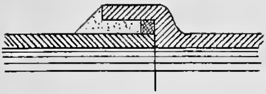


Fig. 230.

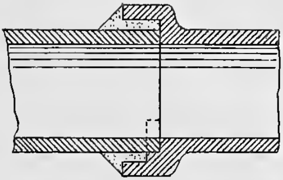


Fig. 231.

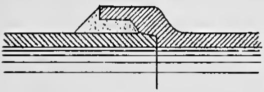


Fig. 232.

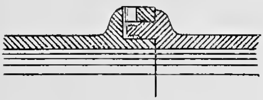


Fig. 233.

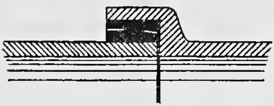


Fig. 234.

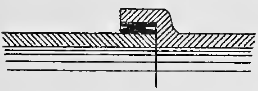


Fig. 235.

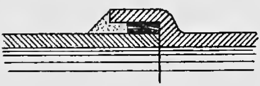


Fig. 236.

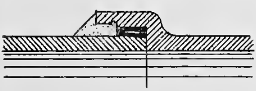


Fig. 237.

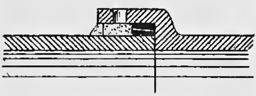


Fig. 238.

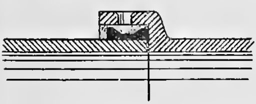


Fig. 239.

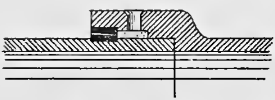


Fig. 240.

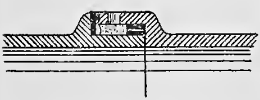


Fig. 241.

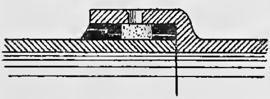


Fig. 242.

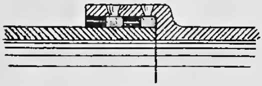


Fig. 243.

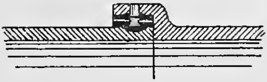


Fig. 244.

up the socket with cement mortar, composed of, say, one part of Portland cement to two of sand, extending the mortar beyond the socket to form a triangular fillet neatly bevelled off at an angle of 45 degrees. The term cement mortar is very vague, and it is most important to point out that the Portland cement should be of first-rate quality supplied by a firm of repute, and that it should be in fit condition for use. If too fresh, or insufficiently aerated, the mortar will expand, with the risk of cracking the socket, and if over-aerated, will shrink and lead to a leaky joint. The sand also should be good, sharp pit sand and quite clean, i.e. free from particles of ordinary earth. River sand with its rounded grains, and sea sand with its excess of salt, are both unsuitable. The mortar should be of the right consistency, as, if containing too much water, it will tend to fall to the lower side, or invert, of the pipe, and leave the upper part imperfectly filled.

Many surveyors prefer a joint with more elasticity than a cement joint possesses, and in such case use instead a bituminous mixture composed of asphalt, pitch, and sand or chalk, boiled together in a cauldron alongside the trench, and filled into the socket in a molten state by the aid of special moulds, or a rough mould made of clay placed around the joint temporarily.

To prevent the possibility of the spigot dropping in the socket owing to improper caulking with gaskin, or to the absence of such caulking, various modifications have been made to the form of socket. Thus Fig. 231 shows Doulton's Invert Shoulder joint, Fig. 232 what is known as the Free-flow pipe, and Fig. 233 the Archer joint. In the last named the cement is poured in in a liquid state, through a hole at the top of the socket, there being another hole for the escape of the air. The best proportion is three parts of cement to two of water by volume.

We come next to joints formed by the contact of rings of bituminous composition, moulded on the spigot and socket. Fig. 234 shows a section of the Stanford joint. The form of the rings should be noticed and compared with that of the rings in Fig. 235, which represents Doulton's Self-adjusting joint, which is designed somewhat on the ball-and-socket principle. The ring in the socket is of parallel thickness and that on the spigot is segmental.

In Fig. 236 is shown the section of a Double-seal joint made up of composition rings backed by cement mortar. Fig. 237 shows another form of Double-seal joint, differing in that it has a fairly large groove in the socket, to afford a key for the mortar. The Hassall Single-lined joint is shown in Fig. 238, a small fillet of clay being put round the mouth of the socket, and liquid cement poured in to fill up the space. Another form of compound joint is the Parker, given in Fig. 239; it will be seen that the shape of the ring is such as to give a good key. The sections of these joints are largely self-explanatory. Fig. 240 is the True Invert, having the rings at the mouth of the socket, and the base of the socket exactly fitting the spigot. Fig. 241 is the Sykes joint in which a collar is formed on the spigot, there being a composition ring on it, against which the end of the socket abuts. Fig. 242 is the Hassall Double-lined, having two pairs of composition rings with a band of cement between; Fig. 243, the Solus, having two pairs of rings and two bands of cement; and Fig. 244 the Secure joint, having one pair of rings, but so formed as to produce a band of cement of dovetailed section.

One of the best joints introduced in recent years is the "Grouted Composite" joint, shown in Fig. 245. It is a very secure joint and can be rapidly laid. A band of canvas goes nearly all round the joint, being secured by wire to the socket and spigot. There is a small space between the ends of the canvas, through which the cement grout is poured. The inner rings are of the form already described as the Doulton Self-adjusting joint, and the substantial backing of cement makes a very strong joint. The canvas probably perishes before long, but that does not matter, as it has done its work. The pipes can be more rapidly laid than most of the more complicated joints.

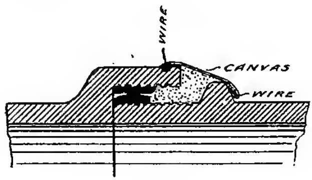


Fig. 245.

Fig. 246.

A joint of an entirely different nature is shown in Fig. 246, and known as the Rubite. The pipes have no sockets but have annular grooves near to the ends, the joints being formed of a band of bituminous material termed rubite, poured into moulds temporarily placed round the joint, a little soft clay being smeared on the abutting ends in order to prevent the composition reaching the inside of the pipes and causing an obstruction. The joint has considerable elasticity and is therefore well able to resist the tendency to damage by reason of settlements. The joint requires making with the greatest care and should be placed in the hands of the patentees subject to a guarantee of efficiency.

The following table gives the details of sizes of ordinary stoneware pipes of good make:—

Internal Diameter in Inches.	Thickness in Inches.	Depth of Socket in Inches.	Total Length of Pipe in Feet.
4 in.	$\frac{1}{2}$ in.	$1\frac{1}{2}$ in.	2 ft. $1\frac{1}{2}$ in.
6 ,,	$\frac{5}{8}$,,	$1\frac{3}{4}$,,	2 ,, $1\frac{3}{4}$,,
9 ,,	$\frac{3}{4}$,,	2 ,,	2 ,, 2 ,,
12 ,,	1 ,,	2 ,,	2 ft. 2 in. and 2 ft. 8 in.

Little need be said in reference to the diameters of drains. For a small house both branch and main drains should be made of 4-inch pipes. For a large house, the main drain should be 6 inches and the branches 4 inches in diameter. In the case of a very extensive drainage scheme a larger main drain might be found necessary, but it should always be remembered that the smaller the diameter of a drain, provided that it is large enough to carry off the requisite quantity of sewage, the more self-cleansing will it be.

The necessity for laying drains in straight lines from point to point, both in plan and in section, has long been recognized owing to the fact that in such case there is a minimum of retardation to the flow of sewage, and that satisfactory means of inspection can thereby be obtained. It will be more convenient to deal with the construction and arrangement of the means of inspection, i.e. inspection bends and junctions, and inspection chambers or manholes, later on, as it can be better dealt with in conjunction with the question of disconnexion from the sewer.

The reason that the branch drains should be as short as possible is that there are not such good facilities, as a rule, for their inspection as there are for the inspection of main drains. As has been shown, gulleys are obtainable with access stoppers so that a cleaning rod could be passed through to the manhole, or vice versa, but these gulleys are not so largely used as they should be. When they are used, it is most important that they should not be tampered with by incompetent persons, owing to the risk of the stopper being insecurely replaced and thus leaving a ventilating opening to the drain at ground level and adjacent to the building—in fact, of negativing the entire value of the gulley.

Further, short branch drains, up to about 20 feet in length, do not require ventilating, while longer ones do.

Considerable damage is often found to drains owing to the roots of trees exerting sufficient force, in expanding, to crack the pipes, particularly if of fireclay. Not only is the pipe cracked, it is often burst in and a stoppage caused by the earth and the roots penetrating. There need be no trouble under this heading if trees are avoided when determining the plan of the drainage system.

If a main pipe, with liquid flowing through it, has a branch pipe connected to it at right angles, two things occur: (1) the velocity of flow in the main pipe is slightly checked, and (2) the liquid flowing from the branch pipe runs straight *across* the main pipe and rebounds, instead of its force being spent in aiding the flow along the main pipe. Both these points are overcome by making the connexion by a bend pointing in the direction of flow in the main pipe.

We may next consider the question of gradient. To be self-cleansing, house drains should have such inclination as will produce a minimum velocity of 3 feet per second. If this cannot be obtained, automatic means of flushing should be provided. The depth of the sewer, into which the house drain is to be branched, is the controlling factor in determining the inclination, and, in the erection of new property, the level of the lowest point from which water or sewage has to be conveyed should be so adjusted to the level of the sewer as to allow of an inclination that will produce a self-cleansing velocity in the drain throughout its whole length. On the other hand, it should be pointed out that too steep a gradient is almost as bad as one which is too flat, owing to the wear and tear on the pipes and to the agitation of the sewage, as it passes along, liberating foul odours.

There is a very simple rule, known as Maguire's, for obtaining the most suitable gradient for drains of different diameters. It is that the gradient shall equal 1 in (diameter in inches × 10). Thus, a 4-inch drain should have a fall of 1 in 40, 6-inch 1 in 60, and 9-inch 1 in 90, or thereabouts.

It is necessary, however, to deal with proper methods of determining the gradient necessary for any particular set of conditions, the velocity produced by any particular gradient, and the amount discharged by drains of various sizes laid at varying gradients.

There are many formulæ, and it is unnecessary to go into more than one or two, and it is not considered necessary herein to adduce a proof of their accuracy, which can, however be readily shown.

One of the best-known formulæ is that known as Chezy's, expressed as follows:—

$$V = C\sqrt{RS}$$

in which V = velocity of flow in feet per second.

C = a variable coefficient.

R = hydraulic mean depth

$= \left(\dfrac{\text{sectional area of flow}}{\text{wetted perimeter}}\right)$ in feet.

S = fall over length

= the sine of the slope.

Various authorities have given different values for C, among the principal being Beardmore's 94·2, Eytelwein's 93·4; and Downing's 100. The coefficient has not, however, a fixed value, as it must depend on the size of the pipe, or stream, and on the degree of roughness of its sides or bed.

It has been shown that the true value of C in Chezy's formula is $\sqrt{\dfrac{2g}{f}}$, in which

g = the gravitation unit = 32·2, and

f = the coefficient of friction.

For a good clean stoneware pipe drain, of from 4 to 9 inches diameter, the value of f may be taken as ·0065, which gives, from the formula just shown, the value of C as 99·53. For all practical purposes, therefore, Downing's coefficient of 100 may be used.

A formula largely used at one time, and known as Eytelwein's, is:—

$$V = 55\sqrt{\text{H.M.D.} \times 2F}$$

in which V = velocity of flow in feet per minute.

H.M.D = hydraulic mean depth.

F = fall in feet per mile.

This formula agrees with that of Chezy if the value of C in the latter be taken as 93·4.

No matter which formula be used, the discharge is found by the simple formula:—

$$Q = AV,$$

in which Q = quantity discharged in cubic feet per second.

A = sectional area of flow in square feet, and

V = velocity of flow in feet per second.

Drains are not always full, and if spoken of as flowing one-quarter full, it is commonly understood to mean "full to the extent of one-quarter of its depth or diameter," and *not* "full to the extent of one-quarter of its sectional area".

If flowing full or half-full the H.M.D. $= \left(\frac{\text{diam.}}{4}\right)$ feet,

a statement which can be readily proved, thus:—

$$\textit{If full, } \text{H.M.D.} = \frac{\text{sectional area}}{\text{wetted perimeter}}$$

$$= \frac{\text{area of circle}}{\text{circumference}}$$

$$= \frac{3{\cdot}1416 \times \text{radius}^2}{2 \times 3{\cdot}1416 \times \text{radius}}$$

$$= \frac{\text{radius}}{2} \text{ or } \frac{\text{diameter}}{4}$$

$$\textit{If half-full},\ \text{H.M.D.} = \frac{\frac{1}{2}\ \text{area of circle}}{\frac{1}{2}\ \text{circumference}},$$

which it will be seen must give the same result as the above, owing to the $\frac{1}{2}$ cancelling out at top and bottom.

If the drain is flowing with a depth equal to any other proportion of its diameter, the H.M.D. must be taken from a table, or fully worked out as follows:—

Example.

Find the H.M.D. for a 9-inch drain flowing one-third full.

Let Fig. 247 illustrate the case in section.

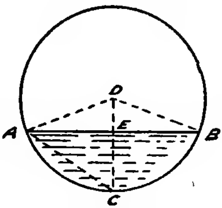


Fig. 247.

The depth EC will be 3 inches.

First find the wetted perimeter, i.e. the arc ACB.

The rule for this is:—

$$\text{Length of arc} = \frac{8 \text{ times the chord of } \frac{1}{2} \text{ arc} - \text{chord of whole arc}}{3}$$

Find the chord of half the arc, i.e. AC.

$AB = 2AE$, and $AE = \sqrt{AD^2 - DE^2}$ (Euclid, I. 47.)

$DC = 4{\cdot}5$ in. $\therefore AE = \sqrt{4{\cdot}5^2 - 1{\cdot}5^2}$

$= 4{\cdot}24$

$\therefore AB = 2 \times 4{\cdot}24 = 8{\cdot}48.$

Similarly $AC = \sqrt{AE^2 + EC^2}$

$= \sqrt{4{\cdot}24^2 + 3^2}$

$\therefore AC = 5{\cdot}2.$

Then, as already stated,

$$\text{Arc ACB} = \frac{8AC - AB}{3}$$

$$= \frac{41{\cdot}6 - 8{\cdot}48}{3}$$

$= 11{\cdot}04$ inches = wetted perimeter.

Next find the sectional area of flow.

This equals the area of ACBD less the area of ADB

$$= \left(\frac{ACB \times DC}{2}\right) - \left(\frac{AB \times DE}{2}\right)$$

$$= \left(\frac{11{\cdot}04 \times 4{\cdot}5}{2}\right) - \left(\frac{8{\cdot}48 \times 1{\cdot}5}{2}\right)$$

$$= 24{\cdot}84 - 6{\cdot}36$$

$$= 18{\cdot}48 \text{ sq. inches.}$$

Lastly,

$$\text{H.M.D.} = \frac{\text{sectional area}}{\text{wetted perimeter}}$$

$$= \frac{18{\cdot}48}{11{\cdot}04} = 1{\cdot}67 \text{ in. or } {\cdot}14 \text{ ft.} \quad \text{Answer.}$$

The following table gives the values of both the H.M.D. and the sectional area of flow, the latter being required when finding the discharge. The letter D throughout the table stands for diameter of drain, or sewer, in feet. As we shall, later, have to deal with sewerage, the figures for sewers of egg-shaped section have been here included.

Sectional Form of Drain or Sewer.	Pipes Flowing							
	$\frac{1}{3}$ Full.		$\frac{1}{2}$ Full.		$\frac{2}{3}$ Full.		Full.	
	H.M.D.	Sec. Area.	H.M.D	Sec. Area.	H.M.D.	Sec. Area.	H.M.D.	Sec. Area.
Circular .	·186 D	·229 D^2	·25 D	·393 D^2	·291 D	·556 D^2	·25 D	·785 D^2
Egg-shaped	·206 D	·285 D^2	·268 D	·509 D^2	·316 D	·756 D^2	·29 D	1·149 D^2

An example will show the use of the formula and the foregoing table:—

Example.

Determine the gradient at which a 6-inch drain must be laid, in order that the velocity of flow through it shall be 4 feet per second when only one-third full. Also find the quantity, in cubic feet per minute, that it will discharge when flowing two-thirds full.

$V = c\sqrt{rs}.$

$c = 100.$

$s = \dfrac{\text{fall}}{\text{length}} = \dfrac{1}{x} = \text{gradient}.$

$r = \text{H.M.D.} = \cdot 5 \times \cdot 186 = \cdot 093.$

$v = 4.$

Transposing the formula we get:—

$$V = 100\sqrt{rs}.$$

$$\frac{V}{100} = \sqrt{rs}.$$

$$\left(\frac{V}{100}\right)^2 = rs.$$

$$\frac{\left(\frac{V}{100}\right)^2}{r} = s = \frac{1}{x}.$$

$$\frac{\left(\frac{4}{100}\right)^2}{\cdot 093} = \frac{1}{x}.$$

$$\therefore \cdot 0172 = \frac{1}{x}.$$

$$\text{and } x = \frac{1}{\cdot 0172}$$

$$= 58 \cdot 12.$$

$\therefore$ Gradient = 1 in 58·12. *Ans.*

$$Q = Av$$

$$= \cdot 556D^2 \times (4 \times 60)$$

$$= \cdot 556 \times \cdot 5 \times \cdot 5 \times 240.$$

Discharge = 33·36 cu. ft. per minute. *Ans.*

Where the available fall is insufficient to give a self-cleansing velocity, various means are available for automatic flushing. Fig. 248 shows a section through a siphonic flushing gulley suitable for a branch drain. It is made of glazed stoneware and is designed to hold up the collected waste water from sinks, lavatories, or rain-water pipes, releasing it with considerable flushing force when sufficient water has accumulated to start the siphonic action.

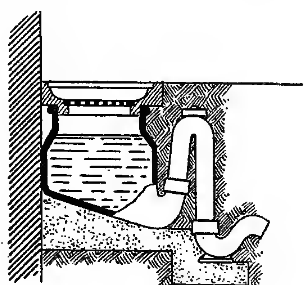


Fig. 248.

Fig. 249 shows a tipper arranged for the same purpose at the head of a drain, the mouth of the drain being enlarged to utilize the flushing power to the best advantage. This is done by the use of tapering pipes. Thus, that next to the tipper is tapered from 12 to 9 inches, the next one from 9 to 6 inches, and the third from 6 to 4 inches. The tipper is provided in a cemented brick chamber with a concrete floor finished with a cement surface, and is fed by waste pipes from baths, lavatories, etc. It has a capacity of about 20 to 25 gallons.

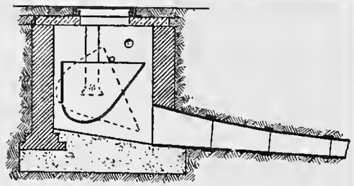


Fig. 249.

The best method of flushing a main drain is by means of an automatic tank. There are various patterns of these, but Fig. 250 shows a section of one of the best known, the Field flushing tank. For small sizes it can be made of iron, and for large, of a combination of brickwork and iron. It is usually placed adjacent to a manhole at the head of a main drain, and can be supplied with water from a water main, or rain-water can be utilized. Such tanks do not work satisfactorily with dirty water, such as sink wastes.

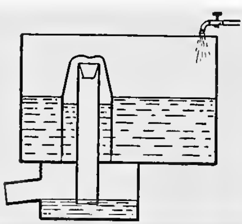


Fig. 250.

The construction and working of the tank is as follows. There are two compartments to it, an upper main tank, and a smaller one, termed a trapping box, below. The lower one contains a small quantity of water for the purpose of trapping, or sealing, the lower end of a pipe which passes up through the water in the tank above. This pipe is covered by a "dome" which reaches nearly to the floor of the main tank, being supported on feet. As the water rises in the tank, it will be seen that it can also rise under the dome, and will at first rise an almost equal amount both inside and outside. Between the surface of the water which is rising under the dome, and the surface of the water at the foot of the pipe, air is being gradually compressed, and when the water under the dome reaches the mouth of the pipe it falls over through this highly compressed air, displacing, by agitation, the resistance offered by the seal at the foot of the flushing pipe. This sets up the siphonic action, and the whole contents of the main tank are then driven out by atmospheric pressure. It should be noted that the mouth of the pipe has a funnel-shaped inlet. Were it not for this, the water would form a sort of lining to the pipe, running away to the trapping box without causing the breaking of the seal at the foot. At the end of the flush the trapping box retains sufficient water to restore the seal.

The capacity of the flushing tank depends on the diameter of the drain and the length, and the following table gives an idea of the necessary provision.

Flushing Tanks.

Diameter of Drain.	Length.	Capacity in Gallons.	Diameter of Flush Pipe.
4 in.	50 ft.	30	3 in.
4 "	100 "	60	3 "
6 "	50 "	60	4 "
6 "	100 "	100	4 "
9 "	100 "	200	6 "
9 "	150 "	300	6 "

In amplifying the general principles underlying the design of a system of drainage, we come next to item No. 9, in reference to the trapping of inlets to drains. Generally speaking, the inlets are trapped by the use of a gulley, various types of which have been described in the preceding chapter. Sometimes grease traps are used, but these are only necessary in the case of large institutions and hotels, from which much greasy water is discharged, and in the case of country houses having bacterial installations for the disposal of the sewage. The grease has to be intercepted in the latter case as it is prejudicial to the bacterial treatment.

One form of grease trap is shown in Fig. 251. It will be seen that it has a solid cover, and an inspection stopper on the outlet. The dotted line shows the base of a perforated iron tray capable of being lifted out by means of a handle at either side, one handle being shown in the sketch. The accumulation of grease can be lifted out by this means, and it is important to note that such fittings should receive regular attention. Some such grease trap as that shown would be used where the grease must be intercepted from the drains.

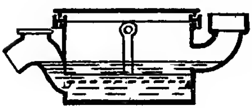


Fig. 251.

Another form of grease trap is that which is illustrated in Fig. 252. It is arranged to take two or three waste pipes, and has a flushing rim connected to an automatic flushing tank, which can be above ground and inside the building. It is in three pieces, the centre one being capable of being turned in any direction. The force of the flush breaks up the accumulation of grease and washes it through the drain.

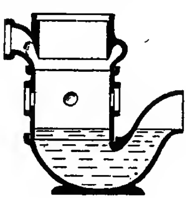


Fig. 252.

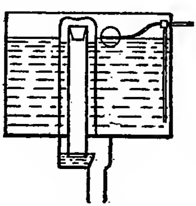


Fig. 253.

A suitable type of automatic flushing tank for this purpose is shown in Fig. 253, fed by an ordinary ball valve. The principle of it is very similar to that of the Field tank already described.

The only inlets to foul drains which are not trapped are those at the feet of the soil pipes. These are directly connected to the drain to assist in its ventilation.

Wherever it is possible to avoid it, drains should not be laid under buildings. A leaky drain is obviously a more serious thing under a building than a defective drain under a garden, apart from the expense and inconvenience in taking up floors, etc., for repairs. Further, if a drain passes under a wall, it is possible that, in settling, such wall will crush the pipes or cause other defects. This may be guarded against by forming a proper arched opening in the wall, just over the pipe, with a clear space between the two. If the drain must pass under the building, iron pipes, glass-enamelled or treated with the Angus Smith process, should be used, jointed with caulked lead. If the extra cost will not permit of this, glazed stoneware pipes should be used, completely encased in not less than 6 inches of concrete. In the case of a factory producing sewage of a strongly acid nature, iron pipes should not be used in any case.

All entrances to the drains should be outside the building if possible. One often finds gulleys in the floors of old basement houses. A room may have been a washhouse and subsequently converted to other purposes, with the result that the gulley has ceased to receive any water as originally intended. In such case it will, in time, lose its seal by evaporation, and ventilate the drain into the house. On ceasing to be used, a gulley, and the drain attached to it, should be removed, or if this is difficult for any reason, the gulley should be filled up with fine concrete, and cemented over. In the case of some houses, entrances to the drain have to occur inside the building, such, for example, as in the case of a house built over the entire site. In such examples there should be means of inspection at the foot of every waste pipe, provided with hermetically sealed covers.

In every system of drainage there should be ample means of inspection in the form of inspection bends or junctions, or proper inspection chambers or manholes. At the manhole at the lowermost end of the drain, just inside the boundary of the premises, a disconnecting or intercepting trap should be put to disconnect the drain from the sewer. In some places the use of the intercepting trap is optional, and there is much to be said for and against its use, but that point will be fully referred to later.

If the drain is not more than 2½ feet below the surface, means of inspection may be provided, in the case of a single bend or junction, in the form of an inspection bend or inspection junction. Fig. 254 shows a plan of the latter, in which two drains meet at a right angle. Junctions for drains meeting at other angles are of course obtainable. It will be seen that the point of junction is open, a socket pointing upwards from it, and capable of receiving the spigot of either a 15 or an 18-inch pipe, which is built in and carried up to ground level. It is there finished with a stone slab or small block of concrete around it, and provided with an air-tight cover. This is a cheap substitute for a manhole, but its use should be limited to a single junction and then only if the branch drain carries rain water.

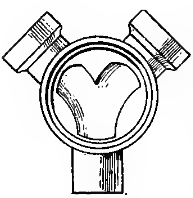
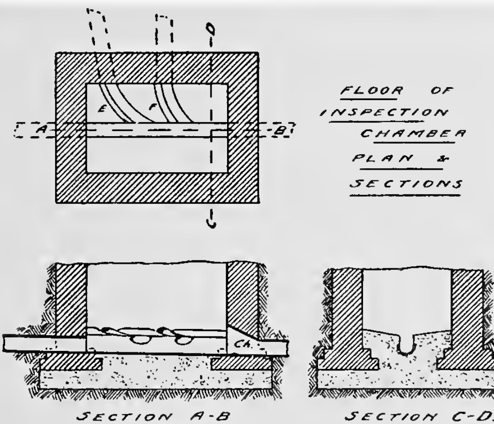


Fig. 254.

In any other case, or if the depth of the drain is greater than 2½ feet, a proper manhole should be used. The size will of course depend on the depth and the number of junctions. If only about 3 feet deep it will be easy to reach to the bottom of it, but if of greater depth it must be made large enough for a man to get inside. The size may therefore range from about 2 feet by 1½ feet, up to 4½ by 2½ feet.

The manhole is usually formed with open channels in the floor of it, but it is far better to put closed channels, confining any foul air to the pipes instead of making the manhole a receptacle for its collection. As ordinarily constructed, however, a manhole can be formed with brick or concrete walls, finished with cement rendering, or lined with salt-glazed



Figs. 255-257.

bricks, which is much better for testing purposes as the walls can then be made practically non-absorbent. The floor should be of concrete, and if open channels are used they should be of white glazed fireclay. Figs. 255-257 show a plan, and longitudinal and cross-sections, of such a manhole floor. The plan shows two branch drains connected by means of white glazed channel bends. To prevent the sewage flowing over the sides of the bends at E and F, what are known as three-quarter section bends are used. There are many patented varieties of bend, but that shown in Fig. 258 is about as good as any. The cross-section C-D shows the sides of the main channel benched up with concrete so as to give a greater depth to it than would be furnished by the semicircular section of the straight channel. The longitudinal section A-B shows the bends discharging about 2 or 3 inches above the bottom of the main channel, which is the most convenient way to arrange them. A chute or enlarged entrance (Ch.) is provided at the outlet end, to facilitate the passing of drain rods through the drain for cleansing purposes.

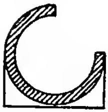


Fig. 258.

The top of the manhole should be corbelled over to reduce its size, and finished with an airtight cover of galvanized iron. The cover should be of good thickness, in order to stand any reasonable traffic over it. There are many forms of joint for these covers. Some are merely kept down by their own weight, some are capable of being locked by a turn buckle, and others can be screwed down. The best method is to use a double cover such as that shown in Fig. 259. The lower cover fits into a deep groove and is of a domical shape. The moisture in the air of the drain condenses when it comes in contact with the cold iron cover, and the water trickles down its under side to the channel or groove and forms a sound water seal. Over this cover is another, fitting into a groove filled with grease, sand, or plastic cement. Fig. 260 shows a good type of joint for a single cover, the grooves being filled with a jointing material as just described. Some types of cover are bedded on a rubber ring, but rubber soon perishes and is

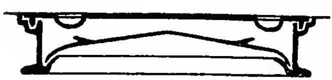


Fig. 259.

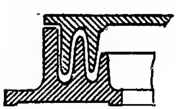


Fig. 260.

an unsuitable material. Fig. 261 shows the arrangement of a cover secured by gunmetal screws, and Fig. 262 the form of frame that is sometimes used when the cover has to be let into a stone slab.

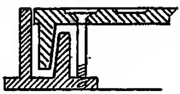


Fig. 261.

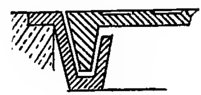
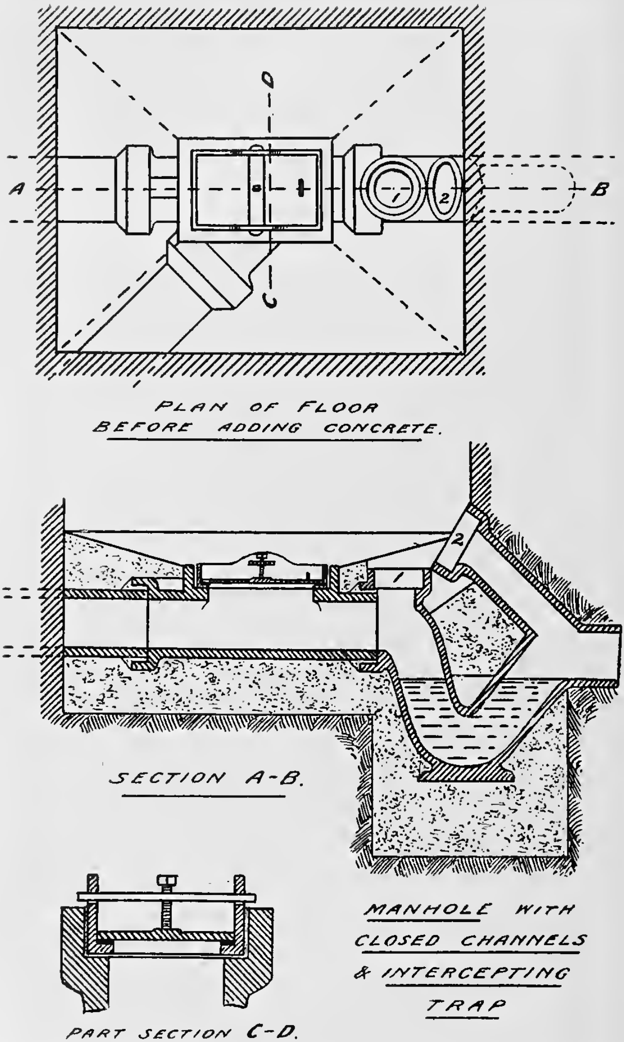


Fig. 262.

A manhole with closed channels can be formed even if the drains are of stoneware. Figs. 263-265 show a plan and sections of such an example, together with the method of arranging the disconnexion from the sewer. The plan shows the closed pipes with an access cover at the point of junction. The concrete would be filled in over them, and would slope down from all four sides to the rectangular cover in the centre as shown in the section. The part section C-D, Fig. 265, shows more clearly how the channel is closed. An iron frame, protected against corrosion, is set in cement, in a socket formed in the stoneware. Inside this is a flat iron plate bedded on a prepared felt washer, and kept tight by a bolt passed through a cross bar which passes through openings at its two ends. Similar stoppers, but of course circular, could be used for the two openings marked 1 and 2 on the intercepting trap, or No. 1 opening could be utilized for a fresh air inlet pipe.

The intercepting trap shown is of special form owing to the special nature of the manhole floor, but its general arrangement is similar to that of all intercepting traps.

For many years past it has been a recognized thing for local authorities to insist on the provision of an intercepting trap for the purpose of disconnecting the drain from the sewer. The Model By-laws of the Local Government Board require the interception to be used though there is no provision for the use of any particular or standardized form. Anything in the way of a bent pipe with a cleaning arm would apparently satisfy the by-law. Consequently some very inferior types


A
B
C
D
1
2
PLAN OF FLOOR
BEFORE ADDING CONCRETE.
SECTION A-B.
PART SECTION C-D.
MANHOLE WITH
CLOSED CHANNELS
& INTERCEPTING
TRAP

Figs. 263-265.

have been allowed to be used, with the result that in some places blockages of the trap have been of very frequent occurrence. This was particularly so at Willesden, and the Council applied to the Local Government Board to sanction a by-law dispensing with the trap. The outcome was that the Board appointed a Departmental Committee to inquire and report with regard to the use of intercepting traps on house drains.

The Committee issued its report in 1912, after taking the evidence of fifty-two witnesses and making many experiments. The report was looked forward to as dealing with a controversial matter of great importance, but on publication did not give very great satisfaction, largely on account of the composition of the list of witnesses examined, which contained the name of no single surveyor in private practice, only two names of sanitary inspectors, and four of architects. Twenty-two were doctors or chemists, sixteen were municipal engineers, six civil engineers, and two private individuals.

It has been a recognized fact at all times that any trap in a pipe must necessarily offer an impediment to the flow of liquid, and that if the intercepting trap could be safely dispensed with, the foul matters could more rapidly be removed from the vicinity of the building. But the free communication between the air of the sewers and the air of the drains was also generally regarded as undesirable in view of the general opinion that the public sewers are, on the whole, of much less satisfactory construction than the house drains. The trap could only be safely omitted if one could rely on the perfect construction, maintenance, and supervision of all house drains, and the impossibility of gulleys and closet traps becoming unsealed either by siphonage or evaporation.

Such blockages as occur in interceptors are chiefly due to preventable causes, such as imperfect design of the trap, imperfect fixing of the stopper of the cleaning arm, imperfect setting of the trap, and the presence in the drain of things which have no business there, such as scrubbing-brushes, tin cans, etc.

A section of the municipal engineers has for years agitated for the abolition of the interceptor, in order to solve the vexed problem of sewer ventilation, since without the trap the soil pipes of all the houses would act as sewer vent shafts. It was generally regarded that the air of a sewer was apt to be more foul than that of a drain, though it is also easy to see that the air of some drains might be more foul than that of some sewers, and vice versa. It was also well known that many sewer men had met their deaths by suffocation, and that there was no record of such a case in connexion with ordinary house drainage.

The report of the Departmental Committee was therefore awaited with considerable interest, and its conclusions may be briefly set forth :—

The disadvantages of the trap are substantial, but may to some extent be obviated.

The liability of the trap to become blocked appears to be insuperable, but the evil effect may be minimized by the use of closed channels in manholes so as to disclose the fact of blockage very soon, and prevent nuisance arising.

The trap does serve as an effectual barrier to the entry of sewer air into the house drain, and it is not liable to be forced and rendered useless by pressure of air from the sewer.

In the absence of an interceptor the traps or even an unventilated house drain are not liable to be forced by pressure from the sewer.

The water seal of an efficient trap which has been forced by air pressure is not destroyed.

The entry of sewer air into the dwelling may be practically excluded if the house drain is constructed of iron pipes.

The most frequent characteristic of sewer air is the presence of smell, and it is harmless apart from smell.

Sewage microbes are rarely present in sewer air, but may be present in drain air in large numbers, due to splashing, which rarely occurs in sewers.

The bacterial danger of sewer air is incomparably less than the bacterial danger of drain air, and the entry of sewer air into a house is of correspondingly smaller importance than the entry of drain air.

Human beings deliberately exposed to the effects of sewer air do not appear to be affected in health.

The experience of districts without intercepting traps does not show that their absence has been harmful.

The necessity of the intercepting trap has not therefore been established.

In ordinary cases the smell of sewer air is less perceptible when the intercepting trap is omitted, owing to opportunity being afforded for sewer air to escape, entirely, at a height above ground.

There are exceptional cases where the interceptor may be required, in order to prevent perceptible smell from the escape of sewer air from the tops of ventilating shafts of house drains.

Sewage may be so offensive that the escape of sewer air, even at a height, is a perceptible nuisance.

The importance of the effect which the presence of the interceptor has on the ventilation of sewers, has probably been exaggerated.

The fresh-air inlet customarily used in connexion with an intercepting chamber is unnecessary, and a dangerous encumbrance. (This recommendation is particularly unsound. If the channels of the manholes are closed, and the fresh-air inlet dispensed with, the rush of water from any fitting will be liable to unseal the traps of gulleys or fittings. If, however, the pipe at the inlet end is carried up, it forms a sort of safety-valve for the escape of air when water is rushing through the pipe.)

The foregoing is a very brief, but careful, abstract of the report of the Committee as submitted to the Local Government Board, and the future action of the Board in regard to drainage by-laws is awaited with natural interest. The complete upsetting of the views generally held, before this inquiry, as to the relative natures of sewer and drain air is of very great import, though it has been pointed out that bacteriology is a comparatively new science and that the evidence taken and accepted by the Committee must not be taken as absolutely conclusive. The fact of sewer air smelling in some circumstances is important, as it has been pointed out that the phenomenon of smell is due to the diffusion, in the air, of infinitely small particles of the substance smelt.

The use of the interceptor will probably be made optional in the future, and it seems only reasonable that an owner should be allowed to use the trap if he holds the view that it is desirable.

If the effect of the report is that iron drainage under and around domestic buildings, and closed channels in all manholes, become compulsory, the Committee will have amply justified its creation. The question of the fresh-air inlet will be referred to under drain ventilation, as will some of the findings of the Committee.

On reference to Fig. 264, it will be seen that the intercepting trap should have a good seal, be set perfectly level, and that there should be a drop, or cascade, at its entrance. A cleaning arm should be provided for access to the length of drain leading from the trap to the sewer. Fig. 266 shows another type in frequent use, there being a cascade at C and a small weir at W. The cleaning arm is marked C.A. and should have a very secure stopper at S. Much of the trouble

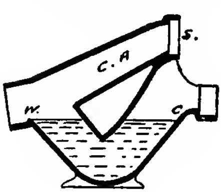


Fig. 266.

in intercepting traps has been due to the defective fixing of the stopper. They have often been jointed by means of the Stanford and similar joints, but this has proved unsatisfactory where a blockage has occurred, as the stopper could not readily be removed to allow the accumulated sewage to run away so that the trap could become accessible for cleansing. Often the stopper has been loosely fixed and fallen into the mouth of the trap, thus causing the blockage. In such case the blockage was not readily detected, owing to the sewage escaping through the cleaning arm to the sewer. A sheet of glass has often been used as a stopper, firmly cemented in the socket. In case of blockage, this could be readily broken to allow the sewage to escape, but the arrangement is rather primitive. The best thing to do is to provide a mechanical stopper such as that shown in Fig. 267. This consists of an iron frame securely set in cement in the socket of the cleaning arm, and receiving a circular iron plate. The plate is kept tight by a cross bar of wedge-shaped section as shown. Attached to the bar, and also to the plate, is a chain hung on to a hook near the top of the manhole. On a blockage occurring a pull of the chain releases the stopper. Another mechanical stopper is shown in Fig. 268. In this example the bar is fixed to the plate and fits in a socket at each side, formed by a projection on the frame as shown by the small sketch at the side of the figure. On pulling the chain the bar is released, and the plate comes away with it.

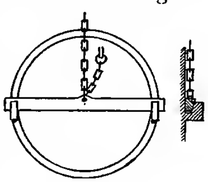


Fig. 267.

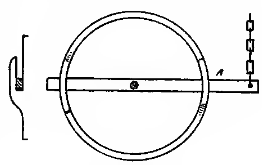


Fig. 268.

A good form of intercepting trap should have a seal of not less than 2½ inches, and hold only a relatively small quantity of water. Of course this depends on the maker, but average figures are: a 4-inch trap holds from $3\frac{1}{2}$ to $5\frac{1}{2}$ pints, and a 6-inch from 6 to 9 pints. The trap should have a drop down to the water at its entrance, of about 2 inches in the case of a 4-inch, and 4 to 6 inches in the case of a 6-inch trap, to give

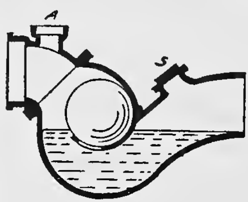


Fig. 269.

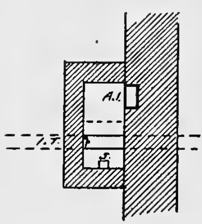


Fig. 270.

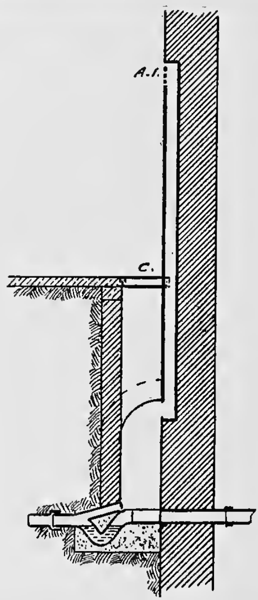


Fig. 271.

a cascade action, and so submerge light floating matters and force them down the drain. It should not, however, have a vertical wall opposite the inlet, as that tends to check the velocity of the water, which beats against it and falls down into the trap, robbed of any scouring power it previously had due to its velocity.

Fig. 269 shows a special type of interceptor, designed for use in positions in which the branch leading to the sewer is subject to tidal action. It has a light ball which is held up against the inlet on the tide forcing the sewage back up

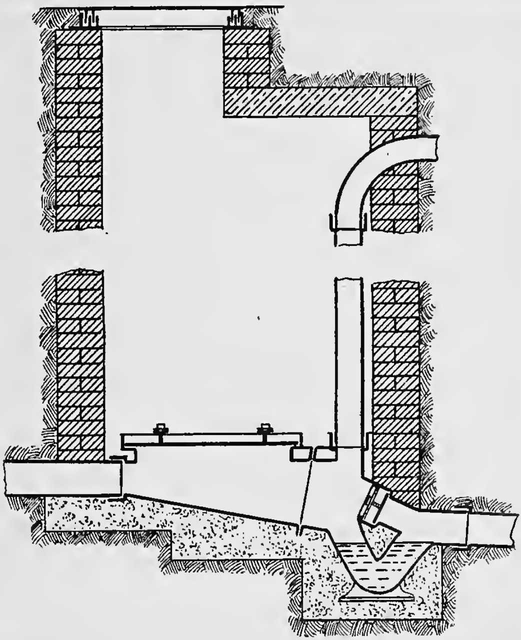


Fig. 272.

the drain. It will be seen that an air inlet socket is provided at A, and an access stopper at S. This type has been used by H.M. Office of Works on the drains of public buildings near the Thames at Westminster.

We may now revert to the question of intercepting chambers.

Fig. 270 shows a plan, and Fig. 271 a section, through a disconnecting chamber suitable for use under a street pavement where the building comes right up to the edge of the street. It is just wide enough from front to back to give room for a man to enter, and about 5 feet wide the other way at the lower part; part of this 5 feet width is arched over, reducing the size of the chamber to merely an access shaft in the upper part. Any deep manhole should have step irons, built in at vertical intervals of about 15 inches, the step irons being shown at S on plan. The fresh-air inlet is shown formed in a chase or recess of the wall, marked A.I. on plan, finishing with a grating at a reasonable height above ground, the grating being backed by a flap of mica to prevent back draught. An airtight cover is provided at C.

Fig. 272 shows a longitudinal section through a disconnecting chamber on an iron drain, with a closed channel. The cover-plate can be either bolted down, or fastened by bars and screws, as shown in Fig. 265, the latter being a more readily accessible method. The stopper of the cleaning arm is of similar construction. The surface cover can be of the ordinary airtight form, but as the channel cover is airtight, being provided with a prepared felt washer, the surface cover may take the form of an iron grating. The air inlet pipe to the drain is also shown. In contracting the size of the manhole at the top, an arch can be used instead of the stone slab shown.

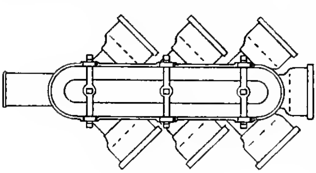


Fig. 273.

Fig. 273 shows the plan of the floor of an inspection chamber on an iron drain, receiving six branches, three on each side. The cover is held down by bars and bolts as before described, and known as pinching bars, or it could be secured by means of bolts. Fig. 274

shows a cross-section through the cover, the pinching bars passing through raised sockets at their ends. It will be observed that the cover is so shaped as to preserve the circular section of the pipe.

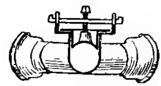


Fig. 274.

A form of intercepting or inspection chamber which is not often met with, is shown in section in Fig. 275. It is the form that would have to be used in connexion with iron drainage where there is a sub-basement and the sewer is at such a level that the drains are suspended from the ceiling of the sub-basement. It shows a bolted cover to the channel, and a similar one to the cleaning arm. The whole chamber is of iron and is carried by two of the floor girders.

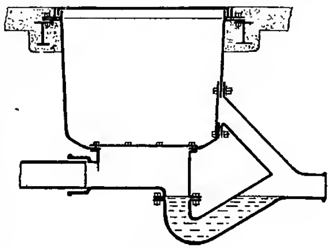


Fig. 275.

We come next to the question of ventilating drains. For many years it has been an established principle that there should be at least two untrapped openings to a system of drainage, an outlet at the highest point, and an inlet for fresh air at the lowest, that is to say, at the position of the intercepting chamber.

The objects of ventilating a system of drainage are: (1) to prevent bad air from accumulating in the drains, and (2) to divert any that may accumulate to places where injury to health cannot be caused.

As has been seen, every drain should have a good fall. The vitiated air which accumulates inside the drain, and is, owing to chemical decomposition, warmer than the atmosphere, and consequently more rarified and lighter, will rise to the higher end of the drain. If, therefore, an opening or outlet be made for this at the higher end, and an opening at the lower end to admit fresh air in its place, it has always been held that a current of air throughout the drain will be produced, preventing the accumulation of bad air.

There should be an outlet ventilating pipe at the upper end of the main drain, and of every long branch drain, these pipes being carried well above the roof, with a minimum of bends so as not to obstruct the current. The upper ends of these pipes should be finished in as exposed a position as possible, and protected at the top by a domical wire grating. It need hardly be added that the outlet should be well away from any windows or skylights. By carrying the pipe up in this way, an exhaust draught is caused by the passing of wind across the top. The air at so high a point being much more in motion than that close to the ground, is more rarified and gives less pressure down the top of the pipe than exists at the bottom, hence the up draught.

If the vent pipe is a vent pipe only, i.e. does not also serve the purpose of a soil pipe, it should be of galvanized cast iron, of the same diameter as that of the drain to which it is connected, and should be furnished with a rust pocket at its foot, the latter item having been already described and illustrated.

No matter how many outlet vent pipes there may be on a system of drainage, there should be only one inlet for fresh air, communicating with the intercepting chamber. If the latter is some distance from the building, and not near the road, an iron grating over the manhole will serve the purpose, but this is usually impossible to arrange. Therefore, one generally uses a galvanized iron pipe, with which there are two methods of dealing. Under either method the sectional area of the inlet should be approximately equal to the combined sectional areas of the outlets. Thus a 4-inch pipe should be used to supply only one 4-inch outlet, a 5-inch for two, a 6-inch for three, and so on.

One method of dealing with the fresh-air inlet pipe is to carry it up 3 or 4 feet from the ground and finish it with a mica flap inlet valve, placing the pipe well away from any windows in case the valve gets out of order and acts as an outlet. Fig. 276 shows a section through a good form of mica flap valve. It has a louvred front, and the flap of mica is set well back. It is hinged at the top and is shown slightly open at F in the sketch. This method is open to serious objection and formed one of the points of inquiry by the Intercepting Trap Committee. It is often placed in unsatisfactory positions, and finished with an inferior valve, which soon gets out of order, the flap becoming set, either opening or closing the aperture permanently. In the case of cottage property, one often finds the front grating of the valve kicked in, and the flap missing. On good class property this defect does not occur, but it is still indispensable that the valve should be of first-class quality if it is to remain efficient.

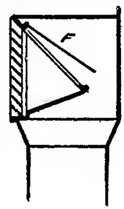


Fig. 276.

The second method is to carry up both inlet and outlets well above the roof. If an inlet is used at all, this is the only method that should be adopted in dealing with cottage property, and it is really a desirable one in all cases. At the same time it should be again pointed out that the Intercepting Trap Committee conducted experiments which satisfied them that an inlet is unnecessary; in other words, that a drain requires vent rather than ventilation in the sense of creating a current of air. We may therefore see an alteration in the by-laws of the future, either prohibiting, or making optional, the use of the air inlet. As matters at present stand, however, its use is compulsory.

Where expense has not to be considered, it is better to keep the rain water, generally speaking, separate from the sewage proper, in the drainage system. By this means the foul drainage can almost always be simplified, and the simpler it is in plan the better. At the same time, cases occur in which it is desirable to conduct the water from at least one rain-water pipe into the foul drainage, in order, say, to increase the flush of a branch drain. The necessity of an adequate water supply for the success of any drainage system cannot be over-estimated.

CHAPTER IX

THE BUILDING—ITS DRAINAGE.

(CONTINUED)

HAVING fully considered the principles underlying the design of a drainage scheme, we may next deal with the actual carrying out of the work.

An accurate block plan of the building must be prepared, and the position of all soil, waste, and rain-water pipes carefully marked on it, together with the position of any W.C. which is to be connected directly to the drain, such as a servants' closet on a ground floor, with no other closet over it. The arrangement of the drainage will, of course, depend on the character of the building. For example, with a terrace house, the main drain must necessarily pass under the building if the sewer is in the road in front, whereas in the case of a semi-detached or detached house the drains can usually be kept quite outside the plan of the building.

A few example plans may be given. Figs. 277 and 278 show block plans of two small terrace houses of different plan. The various inlets to the drain are lettered with distinctive letters and a reference table given to show their meaning. The same lettering will be adopted in further examples.

The heads of the gulleys under the rain-water pipes are not shown owing to the smallness of the scale.

In both the examples under notice the intercepting chamber is placed in the front garden and the fresh-air inlet carried up behind the pier which carries the front railings. Channel gulleys are shown taking the bath and sink wastes. In Fig. 277 the drainage from a yard gulley at the back is

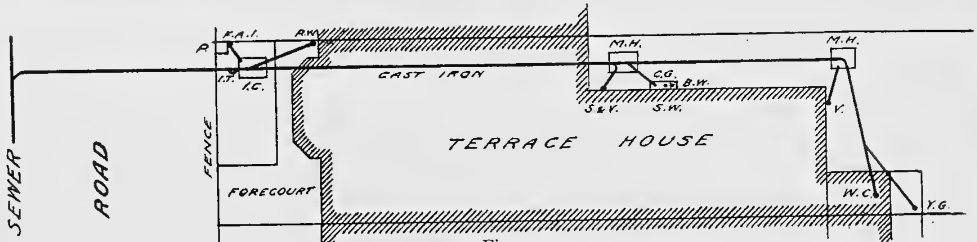


Fig. 277.

REFERENCE:— R.W. = RAINWATER PIPE
S.&V. = SOIL & VENT PIPE. V. = VENT PIPE S.W. = SINKWASTE PIPE.
C.G. = CHANNEL GULLEY. F.A.I. = FRESH AIR INLET. Y.G. = YARD GULLEY.
I.T. = INTERCEPTING TRAP I.C. = INTERCEPTING CHAMBER B.W. = BATH WASTE.
M.H. = MANHOLE. P. = PIER

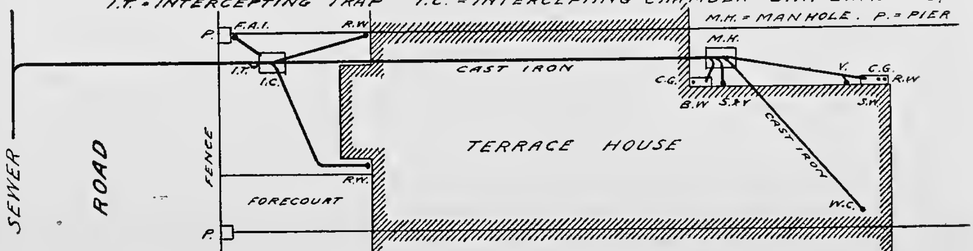


Fig. 278.

turned into the drain from the servants' W.C., in order to assist in flushing it. The vent pipe is shown connected to the manhole at the back, but if the manhole had a closed channel it would have to be joined to the drain. It would appear to have been better to put the vent pipe in the angle between the servants' W.C. and the main building, but it is shown otherwise owing to the existence of a skylight near that point.

In Fig. 278 the drain from the servants' W.C. is carried, in cast-iron pipes, under the back addition, for two reasons, (1) that the owner does not desire any manholes on the small grass plot at the back; and (2) that to proceed otherwise would mean two additional manholes, making four in all—rather a prohibitive item in the case of a small terrace house. In most cases, the soil pipe would be regarded as a sufficient vent pipe for the system, but an additional one might be added where shown, adjoining the entrance of the sink waste.

In Fig. 279 a pair of semi-detached houses are shown drained together, as is often done in the London district. It will be seen that a common passage leads to the tradesmen's entrances at the back of the houses, and that the main drain is laid under this. Its course is not quite straight from end to end, as to make it so would bring the back manhole under the fence. Inspection bends are placed on two of the rain-water drains in each case. By placing the back manhole farther from the street, the rain-water drain at the back of each house might have been given one change of direction instead of two, but in this case the foul drains would have had to enter the manhole with a very sharp curve, and the lesser evil has been chosen. It has been considered better, also, to connect the vent pipe to the drain from the W.C., a foul drain, rather than to the longer drain taking rain water only.

A detached corner house is shown in Fig. 280, separated from an adjoining house by a narrow passage. The peculiar placing of the sanitary fittings makes this case a difficult one

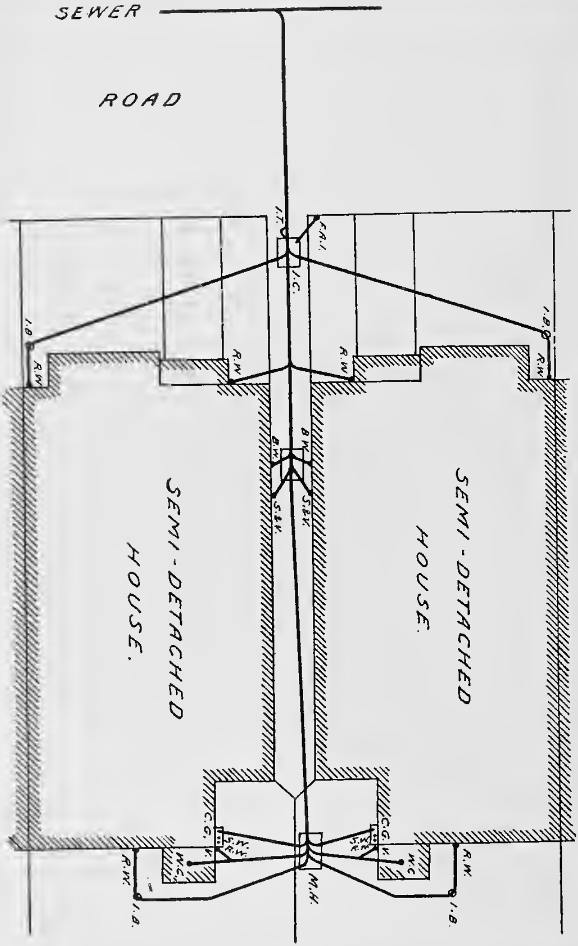

SEWER
ROAD
I.T.
F.A.I.
I.C.
I.B.
R.W.
R.W.
R.W.
I.B.
R.W.
B.W.
B.W.
S.&V.
S.&V.
SEMI-DETACHED HOUSE.
SEMI-DETACHED HOUSE.
C.G.
S.W.
R.W.
K.
W.C.
R.W.
I.B.
M.H.
C.G.
S.W.
R.W.
K.
W.C.
R.W.
I.B.

Fig. 279.

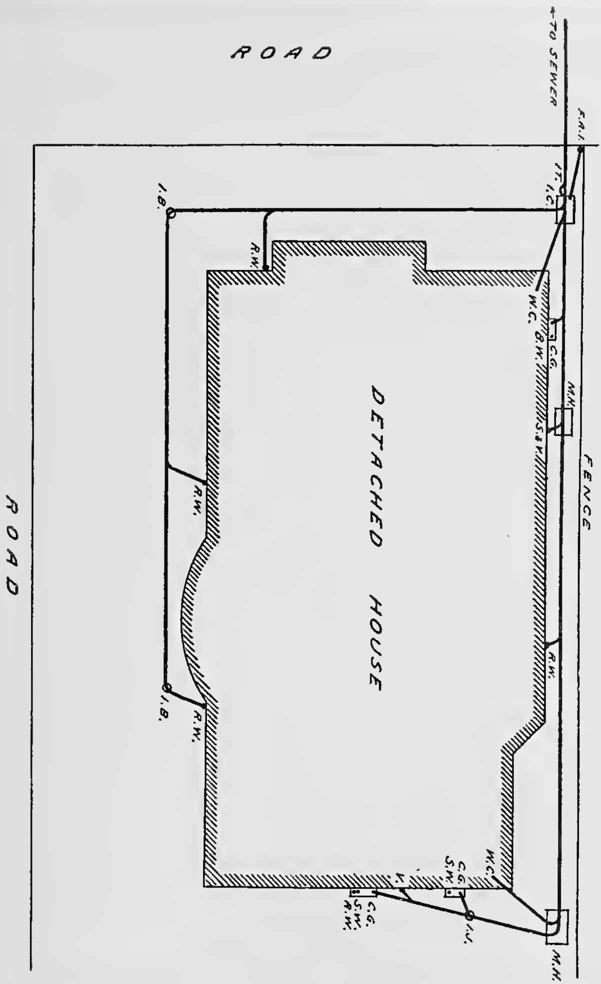

ROAD
TO SEWER
F.A.I.
I.T.
I.C.
I.B.
R.W.
W.C.
B.W.
C.G.
M.H.
FENCE
DETACHED HOUSE
R.W.
I.B.
R.W.
W.C.
C.G.
S.W.
V.
I.J.
C.G.
S.W.
R.W.
M.H.
ROAD

Fig. 280.

to deal with economically, owing to the narrowness of the passage. The bath waste and soil pipe might have communicated with the same manhole by placing the latter nearer the street, but the small space available between the manhole and the building would have caused very awkward junctions and the method shown is considered the better for this reason. It will be seen that the ground floor W.C. is not under that on the floor above, and the drain from the former is therefore taken direct to the intercepting chamber. An additional manhole might have been put at the back to take the two sink wastes and the rain water, but the increase in cost, over that of the arrangement shown, would not be justifiable. An inspection junction, I.J., is used at the connexion of the second sink waste. It will be seen that a good position is obtainable, in this example, for the vent pipe, right at the head of the system.

The next example shows a detached house, with a small stable, occupying the full width of the building plot, the sewer being in the road in front (Fig. 281). In this case, the drain has to run under the building, and is taken under the stable in preference to taking it under the house. At the back, there is a choice between taking the drain from the soil pipe under a scullery floor, or taking it round the outside at the increased expense of two extra manholes, and the former method is adopted since the whole length of this drain is under 20 feet, and the drain can be given an exceptionally good fall owing to the manhole having to take the drainage from a channel gulley in the area. The stable drainage is formed by shallow open channels leading through the wall to the yard gulley. It is better, as a rule, to keep the drainage from a stable distinct from the ordinary domestic drainage, but in this case it is difficult to do so and the point is not of great importance with so small a stable.

Fig. 282 shows a much more extensive system than those

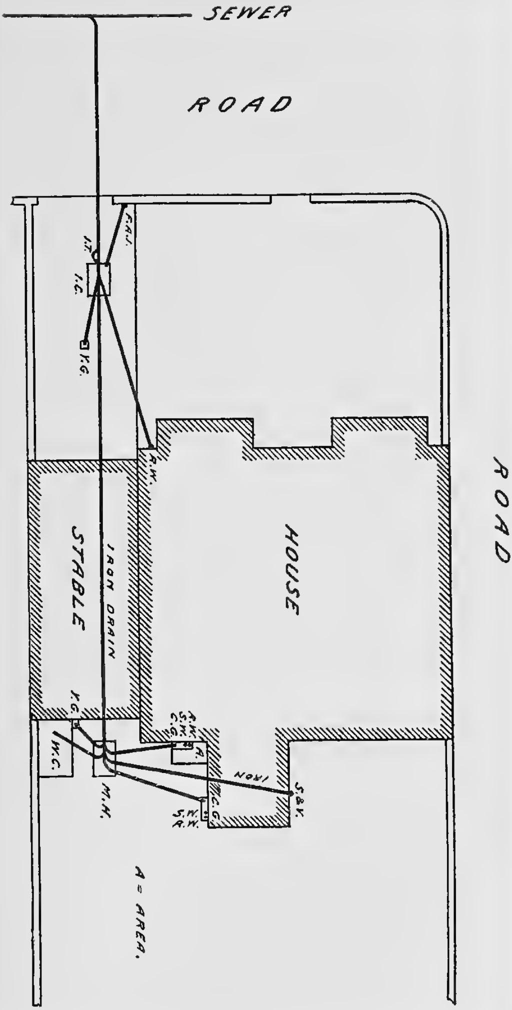


Fig. 281.

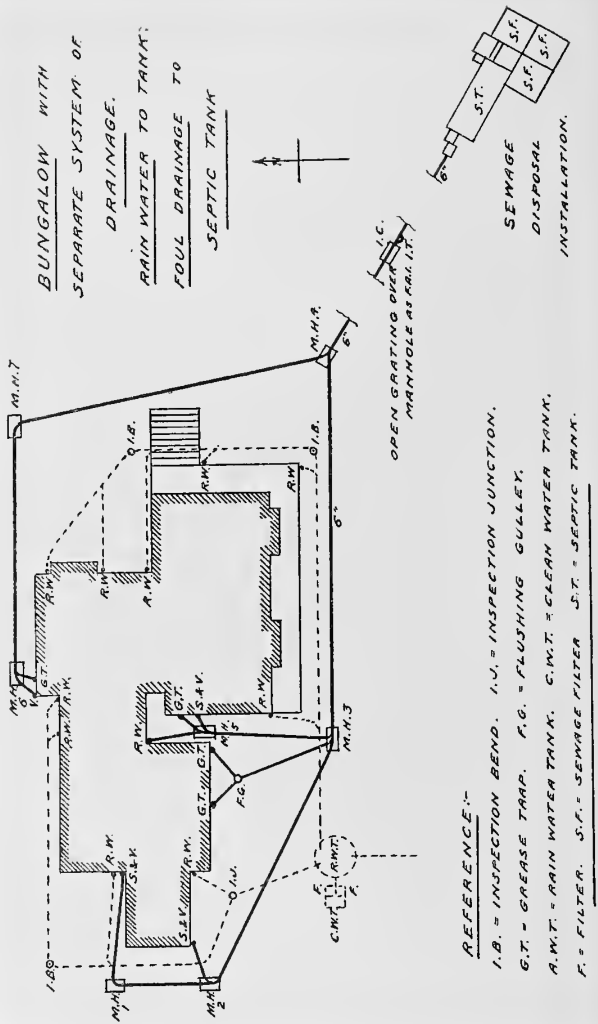
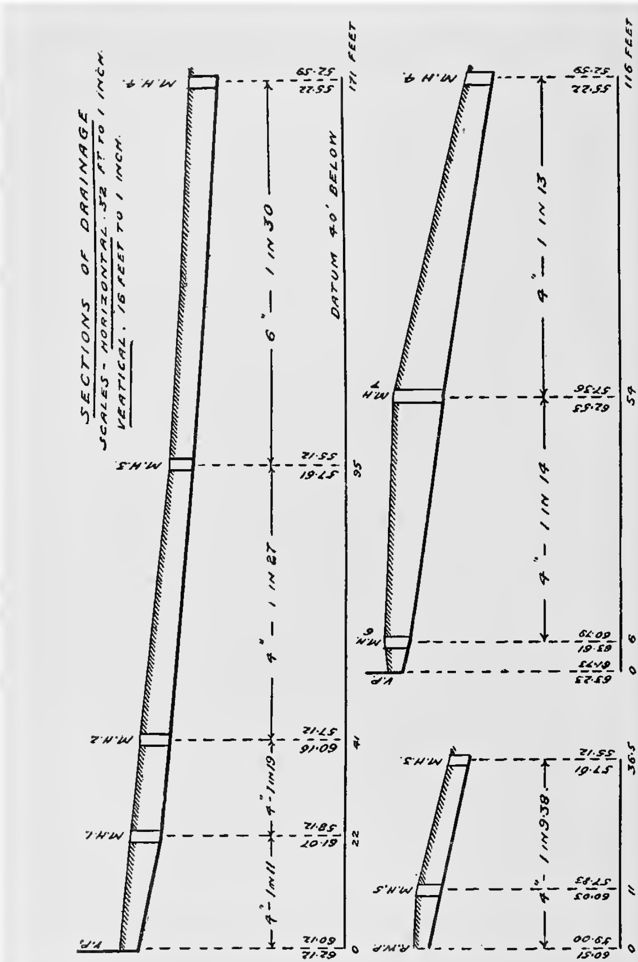

BUNGALOW WITH SEPARATE SYSTEM OF DRAINAGE.
RAIN WATER TO TANK: FOUL DRAINAGE TO SEPTIC TANK
OPEN GRATING OVER MANHOLE AS F.R.A.I. I.T.
SEWAGE DISPOSAL INSTALLATION.
REFERENCE:-
I.B. = INSPECTION BEND. I.J. = INSPECTION JUNCTION.
G.T. = GREASE TRAP. F.G. = FLUSHING GULLEY.
R.W.T. = RAIN WATER TANK. C.W.T. = CLEAN WATER TANK.
F. = FILTER. S.F. = SEWAGE FILTER S.T. = SEPTIC TANK.

Fig. 282.

already given, and illustrates the drainage of a fairly large bungalow on the separate system, with its own system of sewage disposal, the latter installation being situate some three or four hundred yards from the house. With the exception of those marked 6 inches, the drains would be of 4-inch pipes. As the septic tank system is used, grease traps are provided instead of channel gulleys, the former being of the lifting tray type, as a flushing grease gulley would not be permissible owing to the necessity of keeping grease out of the septic tank. At one point, to the south-east of the building, an ordinary flushing gulley is provided, taking the outlets from two ordinary grease traps, and flushed by an automatic flushing cistern placed high up in the scullery. The intercepting chamber, being some considerable distance from the house, is covered by an iron grating to act as a fresh-air inlet. It will be seen that a vent pipe is provided to the head of each of the principal branch drains.

Having prepared the plan of the drainage scheme, the next thing is the preparation of the working sections. The levels along the lines of the proposed drains must be carefully taken and the sections plotted, showing the existing surface of the ground. The method of taking the levels and plotting the sections is beyond the scope of the present work, but Figs. 283-285 give examples of completed sections after the lines of the proposed drains, positions of manholes, etc., have been added. They refer to the drainage of the bungalow shown in Fig. 282, Fig. 283 giving the section from the soil pipe in the N.W. corner, past manholes Nos. 1, 2, and 3, on to No. 4. Fig. 284 gives a section of the line running from N. to S., from the R.W. pipe to manhole No. 3, and Fig. 285 that from the vent pipe on the N. eastward and southward past manholes Nos. 6 and 7 to No. 4. These three sections form only part of the set which would have to be prepared for this case, but they serve as examples, and there is no advantage in repetition. The levels should be taken in reference to some


SECTIONS OF DRAINAGE
SCALES - HORIZONTAL. 32 FT TO 1 INCH.
VERTICAL. 16 FEET TO 1 INCH.
DATUM 40' BELOW
171 FEET
116 FEET
M.H. 4.
M.H. 3.
M.H. 2.
M.H. 1.
M.H. 7
M.H. 6
M.H. 5.
6" — 1 IN 30
4" — 1 IN 27
4" - 1 IN 19
4" - 1 IN 11
4" — 1 IN 13
4" — 1 IN 14
1 IN 9.38
4"

Figs. 283-285.

clearly defined Bench mark, the position and level of which should be shown on the sheet of sections.

It will be seen that against each ordinate on the sections two heights are figured, the greater reading being of course the existing surface level, and the less, the level of the proposed

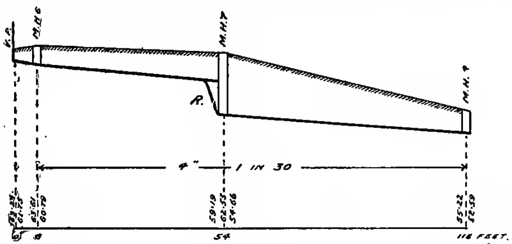


Fig. 286.

drain at that point. The highest end of the drain should be shown about 2 feet below the surface, and the line of drain drawn in such a position as will give a reasonable gradient without coming nearer to the surface than about 2 feet. The fall shown in the case of Fig. 285 is excessive, and it would be better to adopt the section shown in Fig. 286, which introduces what is termed a ramp or dip pipe in order to give a more reasonable gradient. The ramp is shown adjacent to the manhole at R, the drain being continued into the manhole to provide means of inspection and cleansing. The detail of such a ramp or dip pipe is shown in Fig. 287. A securely jointed stopper should be provided at S.S. If the ramp is not more than about 18 inches in depth, it can be formed in the channelled floor of the manhole.

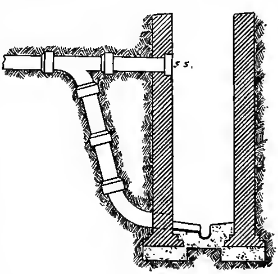


Fig. 287.

Before leaving this question of plans and sections, it may be pointed out that before the ground plan of any building is inked in by the draughtsman, the position of all the sanitary fittings, their waste pipes, and the drains to which they are connected should be finally determined. This can only be done successfully by a careful study of the proposed elevation, so as to select such a position for the soil, waste, and vent pipes as will allow them to be carried down without unnecessary bends. This point may appear of minor importance compared with the *tout ensemble* of the elevation, but whatever effect the elevation may have on the beholder, it can have none upon the health of the occupants of the house, and a badly arranged waste pipe may.

Having prepared the plan and sections, we may proceed with the setting out. The lines of the main drain and branches should be first of all pegged out on the ground before any excavation is commenced. The next point is the setting out of the gradients.

The only accurate method of securing a perfectly regular gradient is by the sight rail and boning-rod system. On either side of the proposed drain a drain pipe of good diameter, say 9 inches, is set up as shown at D.P. in Fig. 288. In each of these an upright post is planted, being well packed round with earth or sand. The sight rail, S.R., is then fixed to the two posts. By means of the sight rails an imaginary line is drawn, parallel to the intended gradient of the drain, and this can be easily fixed, no matter whether the gradient be steep or ever so flat. Sight rails are always fixed first at the

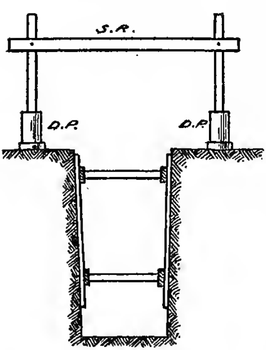
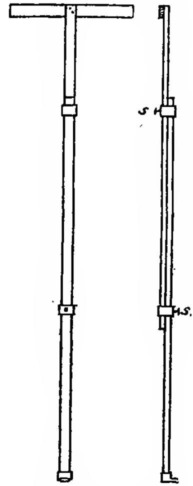


Fig. 288.

point at which the drain commences; next, at all changes of direction or gradient, and at any convenient intermediate point when desired. The posts should be well away from the edge of the trench to prevent disturbance by falling earth. The sight rail is an ordinary wooden straight edge, fixed level from one post to the other.



Figs. 289, 290.

Fig. 289 shows the elevation, and Fig. 290 a side view, of an adjustable boning-rod, or traveller. It is really an elongated T square, having the blade in two pieces, and capable of adjustment to any desired length by means of iron bands and clamping screws at S.S. At the foot is an iron shoe, projecting so as to enable it to be rested on the invert of the pipe.

The method of fixing the sight rails at the correct height can best be explained by the aid of Fig. 291. Two sets of sight rails

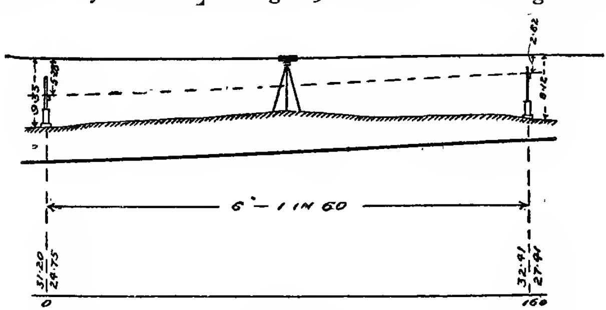


Fig. 291.

are shown in the section, and the level should be set up midway between them to eliminate any error of collimation in the instrument. Let the sight rail at the upper end of the drain be fixed at any convenient height, and a reading be taken on the upper edge of it. Assume this reading to be 2·62. If the gradient of the drain is to be 1 in 60, there will be a fall in 160 feet of $\frac{160}{60}$, or 2·66. The reading on a level staff held on the other sight rail must therefore be greater by 2·66, or 2·62 + 2·66, which equals 5·28, and it should be fixed at that level. Next take a reading on the level staff when held on the ground immediately under the centre of the upper sight rail. Assume this to be 8·12. Deducting the reading on the top of the sight rail (2·62) from this (8·12), we get 5·50 as the height of the upper edge of the rail above the ground. Next consider the levels of the ground and of the drain at this point. The difference between them, 32·41 – 27·41, or 5·00 feet, will give the depth of the drain below the ground at that point. If the sight rail is 5·50 feet *above* the ground, and the drain is to be 5·00 feet *below* the ground, the boning-rod must be set to a total length of 10·5 feet.

In laying the pipes to the exact line, the centre of the trench should be marked on each sight rail, and a plum-bob suspended from this point by a fairly stout cord. The pipe must be firmly bedded in the line joining these cords, its exact level being secured by the pipe layer inserting the shoe of the boning-rod upon the invert of the pipe and keeping the rod upright. The overlooker then applies his eye to the lower sight rail to see whether the top edge of the cross head of the boning-rod is above or below the line of sight from rail to rail. If it is above, the ground must be trimmed away and the pipe lowered until the true grade is reached. Should it be a trifle below, it should be gently raised and packed with dry firm material. If the ground has been inadvertently taken out to a depth appreciably greater than it should be, it must be made up again with concrete.

The trench should not be cut wider than is necessary to allow sufficient room for the pipe layer to work at the bottom. The length opened up at one time must be governed by the number of men at work, the nature of the ground, and the interference with access to the premises. Where the ground is bad from wet sand or other causes, or in passing close to walls and buildings where the foundations may be liable to disturbance by reason of the trench being kept open, it should only be cut in short lengths and with especial care.

As the excavation of the trench proceeds, the sides should be supported by proper timbering, fixed by competent timber men. Fig. 288 shows a method applicable to ordinary cases of moderately firm earth. Vertical planks about 9 inches by 1½ inches in section, and termed poling boards, are placed at frequent intervals, or close together, according to the nature of the ground, supported by horizontal timbers about 9 inches by 3 in section, and termed walings. The walings are kept apart by struts, about 4 inches square, wedged tightly between them. The struts should not be nearer together than about 6 feet, or they will interfere with the work of the pipe layer too much. In a very deep trench, the method of timbering is best carried out on the lines shown in Fig. 292, in which the polings are pointed at the foot and driven in. If the ground is very bad, the walings can be omitted, the trench being timbered by means of horizontal planks or sheeting, placed

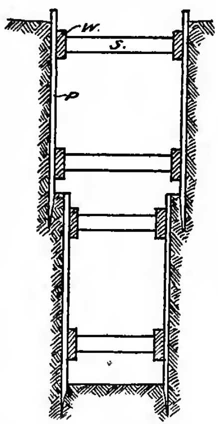


Fig. 292.

close together, secured by vertical polings about 9 inches by 3 in section, and about 6 feet apart, secured by strong struts as before described. Where the ground is very bad, it is usually advisable to leave the lower timbering in permanently.

If the bed of the trench is of good firm earth, and the local by-laws do not require a concrete bed to be used, the pipes can be firmly bedded throughout their length by forming grips or sinkings under each socket. This not only gives firm bed to the pipe, but enables the pipe layer to get his hand properly under the socket to make the joint. One sometimes finds pipes laid by placing a brick just behind each socket. This is a bad practice, as, though it enables the joint to be made properly, the pipe has no firm support throughout its length.

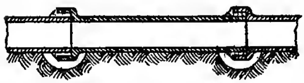


Fig. 293.

Where the ground is not too good, the pipes should be laid on a bed of concrete, which is afterwards added to, to produce the section shown in Fig. 294, the concrete being banked up and sloped off at the top. The thickness of concrete at the sides of the pipe should be not less than the outside diameter of the pipe. Where pipes are laid on concrete, it is better not to form grips under the sockets, as it is apt to disturb the setting of the concrete. Where the ground is exceptionally bad and wet, mere concrete alone is sometimes not sufficient. The usual method of procedure in such a case is to drive in timber piles at intervals along the sides of the trench, connect them by pieces of timber spanning the trench, and lay a foundation of elm planks from one to the other to carry the concrete. An alternative method would be to reinforce the concrete, by embedding in the middle of it old railway lines or tram rails.

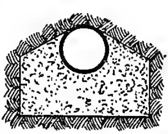


Fig. 294.

If the nature of the sewage permits the use of iron pipes, they provide the best way out of the difficulty. Timber piles, about 6 inches square, can be driven in at a distance apart equal to the outside diameter of the pipe, and the pipe can be supported on cross pieces, as shown in Fig. 295.

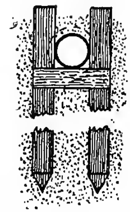


Fig. 295.

We may now revert to the case of the stoneware drain laid under ordinary conditions. As each pipe is laid, a "badger" should be drawn through in order to remove any cement which may have found its way through the joint. In its ordinary form, a badger consists of a semi-circular piece of wood having, preferably, a rubber ring projecting from its curved edge. A handle about 3 feet long completes its construction. An improved form of this appliance is shown in Fig. 296, consisting of two circular discs of wood, edged with rubber bands and connected by a steel spiral spring, which enables the badger to be drawn through a bend.

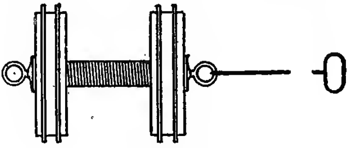


Fig. 296.

The drain having been laid and jointed, it should next be inspected and tested by the surveyor. He should walk along the trench, inspecting both pipes and joints, marking any defective joints or pipes with chalk as he goes. One must always be on the alert for scamped work. A case was brought to my notice in which the sockets of the pipes had been filled with sand, a thin coating of cement being put over its surface. A habit of prodding the joints with a strong knife brought the fraud to light. After the work has been completed not less than twenty-four hours, he should apply the water test, in order to determine the watertightness of the drain. The method of doing this will be fully dealt with under the heading of sanitary surveys.

If found all in order the trench can be filled in. This is a matter requiring careful supervision, as damage is easily done by falling stones or brickbats. For the first foot of depth over the pipes, the earth should be freed from stones ; after depositing it in the trench it should be well but carefully rammed or consolidated. The filling in should be completed in layers of not more than 1 foot in depth, each layer being well rammed. On completion, the drain should be again tested in order to detect any damage during the filling in. It is a good plan to make the contractor responsible for the drain standing the water test three months after completion, in order to ensure the use of cement in proper condition and of good quality.

The connexion to the sewer is a matter calling for mention. In developing an estate, junctions are often put in the sewer opposite the various plots. The mouth of the branch of the junction is sometimes closed by means of a piece of slate, but this is a slipshod and unsatisfactory practice. Proper junctions can be obtained for the purpose, having the branch temporarily but securely closed, as shown in Fig. 297. In this example, a cap is formed as part of the junction, a fairly deep triangular groove being formed round it. A few taps with an iron chisel readily detaches it, leaving the socket free for the connexion of the drain.

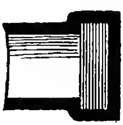


Fig. 297.

If a junction has not been put in, it is a frequent practice to remove two or three pipes in order to build one in. This can be obviated by the use of the special junction shown in Figs. 298-300.

One pipe only need be removed. From the plan given in Fig. 298 it will be seen that the junction has a very long socket, but, as shown in side elevation, Fig. 299, this socket is only applied to the lower half of the pipe. After the junction has been jointed to the two pipes A and B, the open space at S, due to the presence of only a half socket, is closed by a short piece of pipe having a double socket on its upper half only, as shown in section in Fig. 300.

In the case of country districts there may be no sewer, and the house may not be of sufficient size to justify the installation of a sewage disposal installation of its own. Recourse must then be had to a cesspool.

The usual official requirements as to cesspools are: (1) it

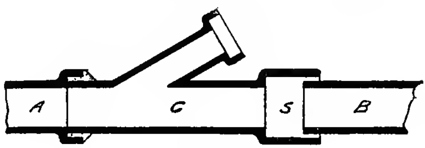


Fig. 298.

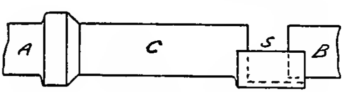


Fig. 299. Fig. 300.

shall be not less than 50 feet from a dwelling; (2) not less than 60 feet from any well, spring, or other source of water supply; (3) readily accessible for cleansing, and in such a position as will obviate the contents being carried through a building; (4) have no connexion with a sewer; (5) be disconnected from the drain by means of an intercepting trap; (6) be of brickwork built in cement, cement rendered inside, and backed with not less than 9 inches of clay puddle; (7) be covered, ventilated, and have means of access.

Fig. 301 shows a section through a good type of cesspool. It is of circular plan and domed over, built of brickwork, cement rendered, and backed by clay puddle; the floor is of concrete, falling to a sump or sinking in the middle, and with a foot of clay puddle below it. It has an access shaft covered by a stone slab or manhole cover at M.H.C. It is ventilated by forming a breathing chamber having a grating over it, at B.H.C. This is about 18 inches square on plan, and is con-

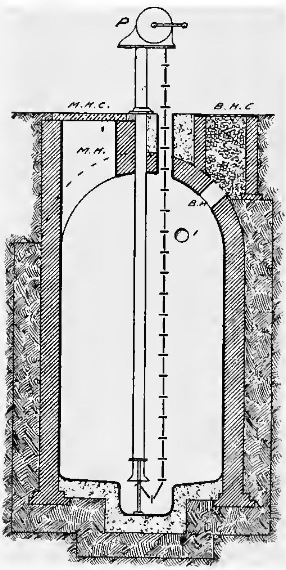


Fig. 301.

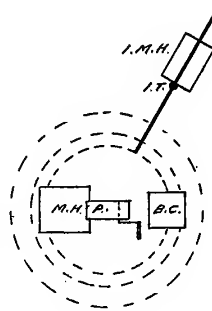
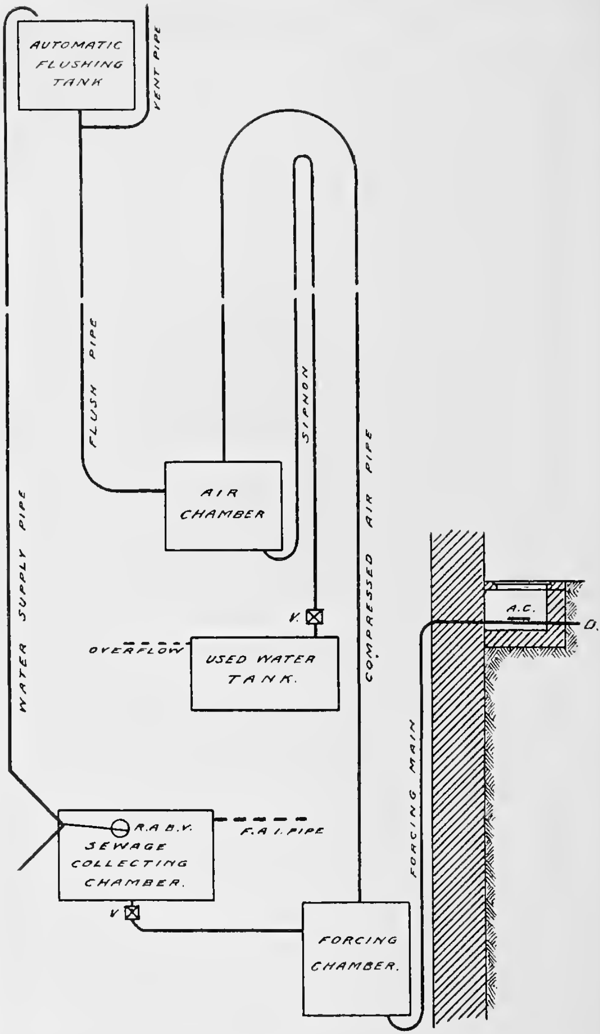


Fig. 302.

structed as follows: A short length of 9-inch pipe is built into the dome to form a breathing hole, B.H. Over this is placed a galvanized iron grating. The chamber is then filled with broken stone, such as road metal, and completed by a grating. The inlet is at I. In many cases it is desired to utilize the sewage for the kitchen garden, and this is best accomplished by the provision of a chain pump, such as shown in the figure at P. The essential part consists of the pump tube and an endless chain carrying circular iron discs at intervals of about 9 inches. These discs carry the sewage up the pipe when the handle is turned and discharge it from the mouth of the pump. Fig. 302 shows a plan of the ground above the cesspool, and gives the relative positions of the parts. It will be seen that an intercepting chamber is provided close to the cesspool. If some distance from any building, the cover of the intercepting chamber can be in the form of a grating, to act as a fresh-air inlet to the drains.

It is sometimes necessary to adopt means for the lifting of sewage from the drain into the sewer, as in the case of deep basements. It is possible to do this by the use of pumps, which are hardly applicable to any ordinary building, or by means of compressed air. In the latter case it is possible to get the requisite air compression either with or without an air-compressing plant. Relatively few buildings, and those only public institutions and factories, have the power to economically work an air compressor, and we will therefore deal first with the case not involving such plant. One of the best examples of this is that known as the Adams' Sewage Lift. The arrangement of the parts of the apparatus is shown diagrammatically in Fig. 303. The system is worked by means of an automatic flushing tank and the principle is very simple.

The flushing tank is placed fairly high up in the building, and the other chambers in approximately the positions shown. The drains discharge into a sewage-collecting chamber, from which the sewage flows to the forcing chamber, being prevented from returning by a non-return valve. When the sewage reaches a certain level in the collecting chamber, it opens the reverse action ball valve, R.A.B.V., and allows the automatic flushing tank to fill. The latter in due course discharges, expelling and compressing the air in the air chamber, which exerts a pressure on the sewage in the forcing chamber, and drives it



AUTOMATIC FLUSHING TANK
VENT PIPE
FLUSH PIPE
AIR CHAMBER
SIPHON
COMPRESSED AIR PIPE
WATER SUPPLY PIPE
V.
OVERFLOW
USED WATER TANK.
A.C.
D.
FORCING MAIN
R.A.B.V.
SEWAGE COLLECTING CHAMBER.
F.A.I. PIPE
V
FORCING CHAMBER.

Fig. 303.

up through the forcing main to the high level drain, D. The capacity of the automatic flushing tank is greater than that of the air chamber; sufficiently so to enable the water to not only fill the latter, but also to charge the siphon and so empty the water, after it has done its work, into the used water tank, from which it can be utilized for any other than domestic purposes, such, for example, as drain flushing. After the air chamber has been emptied of water in this way, it is re-charged with air from the vent pipe connected to the flush pipe, which is now empty. The sewage-collecting chamber is provided with a fresh-air inlet pipe, communicating with the outside air. An inspection chamber is provided just outside the building, with an access cap, A.C.

The Shone ejector is similar only in the sense that it is operated by compressed air. The compressed air is, however, derived from an air-compressing plant. The system is applicable not only to the drainage of deep basements, but also to the sewerage of low-lying districts. The ejector can be adopted for the raising of water, sewage, or sewage sludge, and is usually installed in a brick chamber. The apparatus can be made of any size or shape convenient for the special conditions for which it is required.

A diagrammatic section of an ejector is given in Fig. 304. The action of the apparatus is as follows: The sewage gravitates through the inlet pipe into the ejector, and gradually rises therein until it reaches the under side of the bell B. The air at atmospheric pressure inside this bell is then enclosed, and the sewage, continuing to rise outside and above the rim of the bell, compresses the enclosed air sufficiently to lift the bell, spindle, etc., which opens the compressed air admission valve, C.A.V. The compressed air, thus automatically admitted into the ejector, presses on the surface of the sewage, driving the whole of the contents before it, through the bell-mouthed opening at the bottom, and through the outlet pipe, to the high-level gravitating drain. The sewage can only escape from the ejector by the outlet pipe, as the instant the air pressure is admitted on to the surface of the liquid, the valve on the inlet pipe falls on its seat and prevents escape in that direction. The sewage passes out of the ejector until its level therein reaches the cup, C, and still continuing to lower, leaves the cup full until the weight of the liquid in the portion of the cup thus exposed and unsupported by the sur-

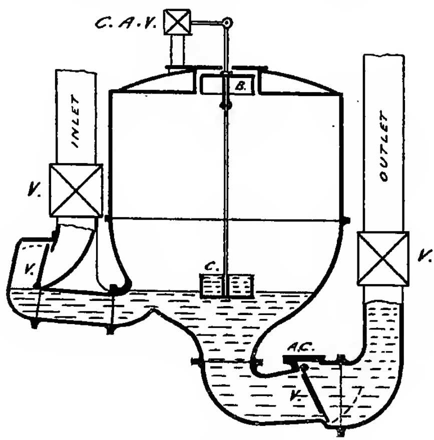


Fig. 304.

rounding liquid is sufficient to pull down the bell and spindle, thereby reversing the compressed air admission valve, which first cuts off the compressed air, and then allows the air within the ejector to exhaust down to atmospheric pressure. The outlet valve then falls on its seal, retaining the liquid in the outlet pipe, and the sewage flows into the ejector once more, driving the free air before it through an air valve as the sewage rises ; and so the action goes on, as long as there is sewage to flow.

The positions of the cup and bell floats are so adjusted that the compressed air is not admitted to the ejector until it is full of sewage, and the air is not allowed to exhaust until the ejector is emptied down to the discharge level. This method of draining basements has been very extensively adopted in the United States, particularly in Chicago, where the basements are, in many cases, of very considerable depth.

The general practice in draining stables is now very different to what it used to be, it being recognized that openings to a drain, inside a stable building, are as likely to be injurious to horses as they are to human beings in a domestic building. The floor should be of hard, non-absorbent material, such as Staffordshire blue bricks, adamantine clinkers, or granolithic concrete. The stable should be drained by laying the paving so that the floor falls to shallow surface channels, connecting to a main channel leading to a gulley outside the building.

In the case of a large stable, the main channel should be of iron, and covered with a grating, as shown in section in Fig. 305. The channel and grating should, of course, be protected against corrosion. The form of gulley used for stable work should be different from that of the ordinary yard gulley. It should have a perforated iron bucket to intercept particles of straw, horse dung, etc. The bucket is readily removable, like the tray of a grease trap. In other respects the drainage of a stable follows the general principles already given for domestic work. Such a gulley is shown in section in Fig. 306. It would have the usual iron grating over.

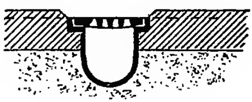


Fig. 305.

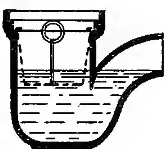
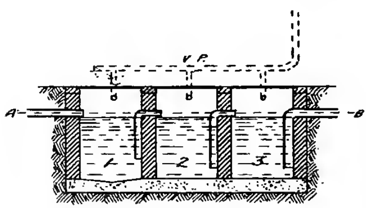


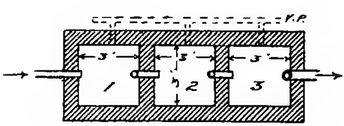
Fig. 306.

In the case of a garage a difficulty occurs that has not occurred in the cases already dealt with; that of the danger of petrol washings finding their way into the drainage system and possibly leading to explosions. In a small garage, attached to a building having a fair amount of land, the best thing to do is to lead the surface drainage of the garage to a soak away pit, dug well away from the building, but in the case of a garage in a crowded district this is difficult if not impossible. The local authorities usually require some special means to be adopted to intercept the petrol.

The requirements of the Public Control Department of the London County Council may be given as an example.



SECTION
Fig. 307.



SECTIONAL PLAN A-B
Fig. 308.

Figs. 307 and 308 show a section and plan of a special form of interceptor which they will accept as meeting the case, the example given being suitable for a garage taking six cars. It will be seen to consist of three chambers, each 3 feet square and 4½ feet deep, built of brickwork on a concrete floor.

Calling the chambers Nos. 1, 2, and 3, the only exit from No. 1 to No. 2 is through a considerably submerged pipe. The only exit from No. 2 to No. 3 is by a pipe submerged still more, while a similar pipe forms the outlet from chamber No. 3 to the drain. By this arrangement, the petrol is left to accumulate at the top of the sewage in each chamber, any vapour being carried off by the ventilating pipes shown by dotted lines. Probably other ingenious means could be devised to get over this difficulty, but the example given shows what is at present required for London garages.

In concluding this section a few words may be added on the repair of drains and on the remodelling of old drainage systems. In the ordinary way, on finding that a drain is leaky, one opens up the ground in order to expose the drain and so trace the leaky joints or cracked pipes. This necessitates the ground remaining open for at least a day or two, and often means taking up floors and so on.

A system of repair has been in use for some years by a London company, based on the following lines: The drain is first cleaned out and disinfected, the disinfectant being applied under pressure, so that it will pass through any defects and so disinfect the surrounding soil. Machinery is then passed through the drain, charged with liquid Portland cement, which, by means of compression, is forced into every flaw in either pipes or joints. The inside of the drain is said to be left free from any roughness due to this process, and the company is said to guarantee the drains to stand the water test on completion, on the principle of "no cure no pay". The system has much to commend it where a drain is only slightly leaky, and the uncovering of the ground is a matter of great inconvenience, but it would be an inadequate means of dealing with a very bad case.

The remodelling of old drainage systems is not a matter calling for a very extended notice. The principles which a new system should satisfy have been fully laid down in the preceding chapter, but it should be pointed out also that where, in remodelling a system, an old drain is discarded, the drain should be taken up and the trench disinfected before returning the earth. The extent to which an existing system is remodelled is a matter dependent entirely on the circumstances of each individual case. In some cases, sound but moderate proposals would be certain to be carried out, and sanitary progress thereby furthered, while an elaborate proposal might lead to nothing much being done, and progress thereby retarded.

For the cleansing of drains and the removal of stoppages, various tools are used, fixed to drain rods. The latter are of red malacca cane, obtainable in bundles, and having lengths of from 2 to 5 feet, the total length in the bundle varying from 30 to 100 feet. The rods are fitted with screws and sockets, so that they may be put together to form a long rod. Various tools are used for fixing to the end of the rod, including fixed and hinged badgers, double "corkscrews," spring hooks, etc., for the purpose of removing obstructions.

After the removal, the drain can be finally swept out by a circular brush of either bass or whalebone, affixed to the end of the rods.

CHAPTER X

SEWERAGE.

BY sewerage one means the system of sewers for the drainage of a district, not only as regards the wastes from the various sanitary fittings, but also the rain-water which falls on the area sewered and is not absorbed by the ground.

Little is known as to the early history of sewerage in England, but that sewers are of ancient origin is established by the fact that some of the main sewers constructed by the Romans can still be seen in Rome.

To enable an engineer to design a system of sewerage, many points have to be given consideration. These will be dealt with before going into the details of construction and arrangement.

The size of the main sewers is governed to some extent by the area to be sewered, but it must be remembered that the question of area must be taken in conjunction with the density of the population. Assuming the population per unit of area to be the same in two cases, the larger the area the greater must be the capacity of the main sewers.

The geological nature of the district needs consideration, since the more permeable the soil, the greater the amount of rain-water which it will absorb, and therefore the less the quantity to be carried off by the sewers.

The physical features of the neighbourhood form another point for consideration. It will be obvious that, in the case of an area which is shut in by hills, making it situate in the bottom of a basin, the rain-water from the surrounding hills will gravitate towards the area, whereas, if one imagines the reverse case to this, in which the land slopes away from the area in all directions, it will be seen that the rain-water will go from, instead of towards, the district.

The rainfall in the district is another factor. As has been pointed out in dealing with water supply, the rainfall varies tremendously in different parts of the country. Assuming two cases in which the geological nature of the districts is the same, the greater the rainfall the greater the quantity of surface water to be provided for in designing the sewers.

The population of the district also affects the question. Obviously, the more people there are on the area, the greater the amount of sewage to be provided for, but this point requires consideration from another standpoint. The sewers must be designed to take not only the present quantity of sewage, but also an estimated amount beyond that, in order to cope with the future development of the area and the increase in population. It is an easy matter to make a sewer a little larger than at present needed, but it becomes a very expensive item to take up one sewer and replace it by one of larger section. There are two ways of allowing for the probable increase. One is, to work from statistics giving the rate of increase in the past, and assume that it will go on at the same rate; the other, to assume a rate of increase equivalent to that of towns of similar size and subject to similar conditions. Whichever of these methods is adopted, it would be wise to design the sewers large enough for the estimated demand on them in about twenty-five years' time.

The water supply to the district requires to be considered, since all the water supplied to a house goes away again in a more or less impure state as sewage. Assuming, therefore, that the amount of water supplied per head per day is, say, 25 gallons, that quantity can be regarded as the amount of sewage proper, as opposed to surface water contributed to the sewers per head per day.

In some cases it will be found that water-closets are not in general use, their place being taken by earth-closets and privies. Provision must be made for their conversion to water-closets in due course, and for their consequently contributing their quota of sewage to the sewers. Again, although water-closets may be in use, the use of cesspools may be somewhat general; these must be looked upon as only a temporary expedient, and accommodation provided in the sewers for the quantity which is, for the time being, being received into cesspools.

Still another point to be regarded is the intended mode of disposal of the sewage, and the consequent position of the outfall or point of discharge of the sewers. These items will be governed largely by the nature of the land available for works of purification, its geological structure, position, extent, and value, but it may be pointed out that wherever a gravitation system is possible, without nuisance due to an unsuitable site for the disposal works, such a system should be adopted rather than incur the initial and annual expenditure incidental to pumping stations. If the sewage is to be subjected to land treatment, it is obvious that a sewage farm cannot be constructed just anywhere in the district, and the necessity for placing it on the outskirts may make a pumping station a compulsory item of the undertaking.

There are three methods of arranging a system of sewers, known respectively as the combined, separate, and partially separate systems.

The system known as the combined consists of a single sewer in each thoroughfare, there being also a single system of drains to each building. The one sewer therefore takes all the domestic sewage, rain-water on roofs and back yards, and the road drainage.

In the separate system there are two sewers, one for foul sewage and one for surface water; similarly, each house has two sets of drains, one for sewage and one for rain-water.

The partially separate system is a compromise between the two just described, and consists of two sewers, as in the separate system, but with only one set of drains to the building, the drains discharging into the foul sewer.

Each of the systems possesses certain advantages and disadvantages when one is compared with the other, but the question of individual preference and local conditions enters largely into the choice of system.

The quantity of rain-water to be dealt with per day is very variable, and it is difficult to design a foul sewer satisfactorily if it is liable to enormous fluctuations of volume of flow. If two sewers are used, the foul sewer can be relatively small, and the smaller a sewer is, so long as it is large enough for its work, the cleaner can it be kept. Again, if pumping has to be resorted to, the quantity to be pumped is reduced to a minimum by the exclusion of rain-water. It is quite unnecessary to incur considerable initial and annual expense in laying down a pumping installation of sufficient capacity to lift all the rain-water, as well as sewage, to a higher level; it is quite reasonable, if proper precautions be taken, to run the surface water to the nearest natural water-course. Further, if the foul sewage is undiluted with the bulk of the rain-water, its manurial value is retained.

On the other hand, while in rural districts, generally speaking, the rainfall is comparatively pure and so can be safely taken direct to the water-courses, in other cases it is of a very different nature. The first washings of a busy street, after a dry spell would give a liquid that could only be fairly regarded as foul sewage. Another drawback is that if there are two sewers in the street instead of one, there must be proportionately greater obstruction to traffic by repairs. It has been said that another drawback of the separate system is that there is a possibility of house drains, conveying foul sewage, being connected to the rain-water sewer; but this is hardly a valid argument, as the local authorities have ample powers of supervision.

The reason that the separate system has not been extensively adopted is that, generally speaking, the local authorities have no power to compel the provision of two sets of drains to the houses. This fact has led to the fairly extensive adoption of the partially separate system.

It will be noted that, so far as the sewers are concerned, there is no difference between the arrangement under the separate and partially separate systems respectively, these terms being applied to the sewerage and drainage taken together as a whole.

The sewage from the higher levels of a district is collected into subsidiary sewers of relatively small diameter, say from 9 inches upwards, and is discharged into main sewers at the lower levels. Where the levels of the district vary considerably, it may be necessary to use intercepting sewers, that is to say, subsidiary main sewers running on different contours and draining the areas above them, all discharging ultimately into the main outfall sewer. It often happens that the sewage from a low-level intercepting sewer has to be pumped up into the outfall sewer. Assume a town laid out on a hill sloping rapidly down to a river. If there were only one sewer, at the lowest level, it would be liable to be flooded by the surface water from the high levels; further, the sewer might be at such a level that the whole volume of sewage passing through it would have to be pumped up at the outfall. The method then adopted is to have more than one sewer to intercept the drainage above that level. Thus, in Fig. 309, the sewer on contour A would take the drainage from above its level, the sewer on contour B the drainage between the levels

A and B, and sewer C the drainage between B and the river.

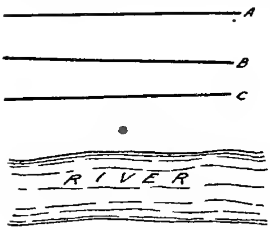


Fig. 309.

This is the arrangement in London, north of the Thames. The three sewers would then converge at some distance from the town, and the whole combined volume would be carried on in the main outfall sewer. Assuming, in Fig. 309, that it is necessary to keep the main outfall sewer at about the level of B, sewer A would discharge into B by gravitation, and the volume passing through C would be pumped up into B.

Small sewers are generally constructed of stoneware pipes, with either the ordinary cement joint, or one of the many patented forms of joint illustrated in the chapter on drainage. Stoneware pipes are obtainable up to 30 inches in diameter, but they are not often used of so large a size. Sewers of over 24 inches in diameter are generally constructed of brickwork or concrete. In this country there are only two principal forms of sewer in general use, the circular and the egg-shaped.

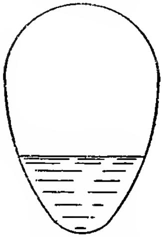


Fig. 310.

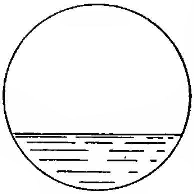


Fig. 311.

Their respective advantages and disadvantages may be briefly stated. The circular sewer of brickwork is stronger than the egg-shaped, and slightly less expensive to construct, but the egg-shaped has a great advantage from a hydraulic point of view. Figs. 310 and 311 show sections of two sewers, both having the same sectional area and both containing exactly the same quantity of water. It will be seen that the water is of greater depth in the egg-shaped sewer than it is in the circular; the greater the depth of the flowing liquid, the greater its velocity, therefore the egg-shaped sewer will, when compared with one of circular section, equal in area, and containing the same volume of liquid, be the more self-cleansing.

The object to be borne in mind in designing such a sewer is to give it the greatest possible hydraulic mean depth for small volumes of flow, and this condition is fulfilled by egg-shaped sections. Fig. 312 shows, diagrammatically, the method of drawing the section of the ordinary, or old egg-shaped type. The depth is one and a half times the greatest horizontal diameter. The top is a semicircle of radius R; the invert, or bottom, is a circular curve of one-half R in radius, and the top and bottom are joined up by circular curves of radius 3 R. The sketch shows the centres from which the arcs are struck.

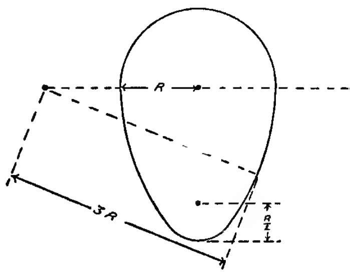


Fig. 312.

Fig. 313 shows, in the same way, the method of drawing the new egg-shaped type, which is also known as the metropolitan. The bottom is more pointed, giving still better conditions as regards the hydraulic mean depth. As in the last case, the depth is one and a half times the greatest horizontal diameter, but the radius of the invert is only half as great (i.e. one-quarter R) as in the

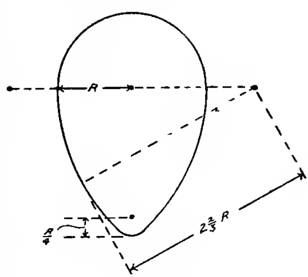


Fig. 313.

previous case. This necessitates, of course, a different radius for the connecting arcs; $2\frac{2}{3}$ R instead of 3 R.

Egg-shaped sewers can be constructed of brickwork, of concrete, or of partly the one and partly the other. Ferro-concrete has also been used with success. Fig. 314 shows one method of construction. The invert is formed of terra-cotta blocks which give a minimum of joints at this important point. They are moulded hollow as shown and are usually made with rebated joints. The inner ring of brickwork should be of either salt-glazed or blue Staffordshire bricks, both of which form a non-absorbent lining. The bricks should be specially made and moulded to the proper radius, so as to permit of thin joints of uniform thickness, instead of wedge-shaped joints as they would otherwise be. Between the inner and the outer rings of brickwork a thick line is shown. This represents a collar joint, consisting of a layer of asphalt, or neat cement, about $\frac{1}{2}$ inch in thickness, the object being to give a second line of defence against leakage. Sometimes the sewer is only lined with glazed or Staffordshire bricks up to the commencement of the covering arch, A-B, the arch being of ordinary pressed, or engineering, bricks. The outer ring of brickwork should be of pressed bricks in all cases, and it is not so imperative that the bricks should be moulded to the proper radius. Good cement joints are quite sufficient.

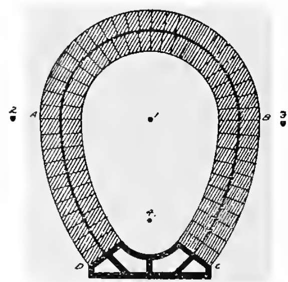


Fig. 314.

If the sewer is very large, the invert blocks may be built up of three pieces in the width.

The sketch (Fig. 314) shows the centres from which the arcs are struck, and from which the joints of the brickwork radiate. Concrete would, in any case, be put under the invert blocks, and if the ground is bad it would be put up the sides of the sewer also.

An alternative method of construction is shown in Fig. 315, in which the joints of the brickwork are not indicated. The sewer is partly in two rings of brickwork, and partly in one. Invert blocks are used, and the lowermost third of the height is lined with salt-glazed bricks, the remainder being of pressed bricks. The sewer is formed in an encasing block of concrete in this case, owing to unsatisfactory foundations.

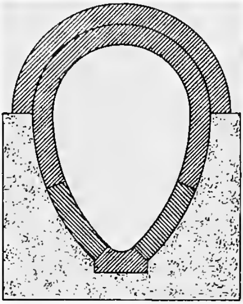


Fig. 315.

Difficulty sometimes occurs in regard to the rise of subsoil water as the work is being carried out.

Sometimes special invert blocks are used, having holes to admit the subsoil water to the spaces left in the hollow blocks and which form channels conducting the water to the lowermost end of the system. Another good method is that shown in Fig. 316. Below the concrete a small trench is cut to take a land drain of from 3 to 6 inches in diameter. The pipes are unglazed and are merely butt-jointed, without sockets. The trench is filled with broken stone. A third method, adopted where springs occur, is to place a pair of drain pipes on end, one on either side of the sewer, and fill them with gravel, leaving small openings in the sewer to allow the water to escape laterally to the top of the pipes and so down through them. The openings in the sewer are closed as the work proceeds.

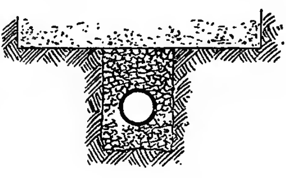


Fig. 316.

In ordinary ground, there is not much object in putting concrete under or around a sewer, but as less satisfactory ground is met with, so must such precautions be taken, additional measures of protection being taken in the case of very bad ground.

The methods of setting out the course, and gradients, of a sewer are similar to those adopted for a drain and described in the preceding chapter.

In the case of pipe sewers, grips should be cut under the sockets to permit the joint to be properly made and to permit the pipe to be supported throughout its length.

The timbering of the trenches also follows the same lines as given in Figs. 288 and 292, but for very bad ground the sizes of the timbers must be increased. Should the ground be very wet, it is desirable to leave in, permanently, the lowermost set of timbering.

In the case of running sand, small sewers should be of iron pipes supported similarly to that shown in Fig. 295. So also should they be treated where they pass above ground, with additional strengthening given by a cross timber above the pipe, and longitudinal timbers connecting the heads of the piles.

Where the sewer is very deep below the surface, it is not economical to lay it by means of an open cutting. In such a case tunnelling should be resorted to. For a simple case, the tunnel might be formed by excavation, timbering the work on lines similar to those shown in Fig. 317. The timbers shown would be of about the following sizes: longitudinal members 9 × 3 inches or 9 × 4 inches, other members ut 9 × 9 inches, at abo horizontal intervals of about 5 feet. If the tunnel is large, it is often

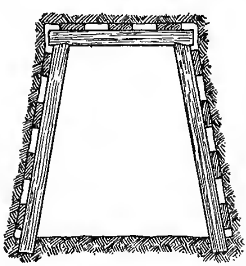
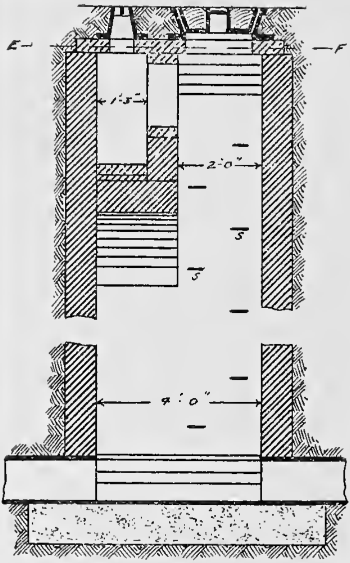


Fig. 317.

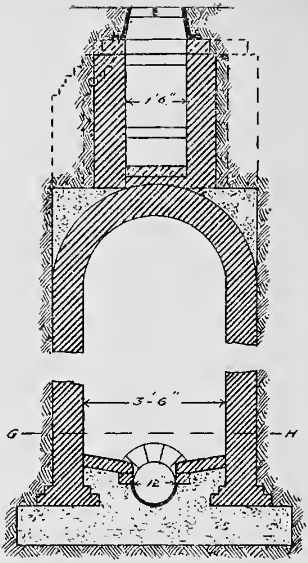
constructed by means of a compressed-air shield of the type used in the construction of tube railways, the tunnel being lined by means of cast-iron sections built up to form a circular lining, bolted together and well grouted, between and behind, with liquid Portland cement. Such a tube could be completed to form the sewer by lining it with fine concrete faced with neat cement, or the sewer might be constructed inside it in the ordinary way.

Sewers should be laid in straight lines between points of inspection, manholes being placed at all changes of direction and gradient. Manholes should also be put at the junctions of main and branch sewers, and also at storm overflows. Bends in small sewers should be formed entirely in manholes, but in sewers of large size, this is, of course, impossible. The forms of manhole vary with the size and type of sewer, and also with individual preference. Thus, with a small sewer, there is an opportunity of forming a reasonable benching at either side of the open channel. Figs. 318-321 show details of a ventilating manhole on a 12-inch pipe sewer. The plan of the floor is shown in Fig. 321, while Fig. 320 shows the position of the openings in the stone slab over the top. Figs. 318 and 319 show longitudinal and cross-sections respectively. An inspection of these details will show that the lower part of the manhole is 4 feet by 3 feet 6 inches, the upper part being reduced, by arching over, to a shaft of considerably smaller size. The benching is formed by means of Staffordshire blue bricks. Over the manhole shaft is a heavy iron cover, formed with hollows filled in with oak blocks, placed with their grain vertically, in order to give a good foothold for horses. Adjoining the top of the shaft, and over the arch, is a ventilating opening covered by a small but heavy iron grating. It will be seen that the floor of the small chamber under this grating is sunk somewhat, in order to form a dirt box, or receptacle for stones and other matters which may find their way through the grating.



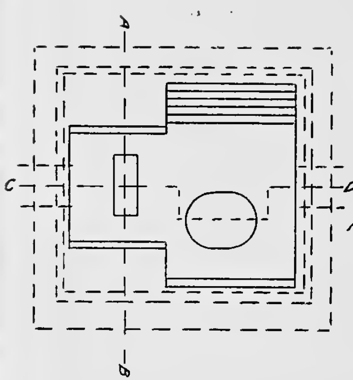
SECTION C-D.

Fig. 318.



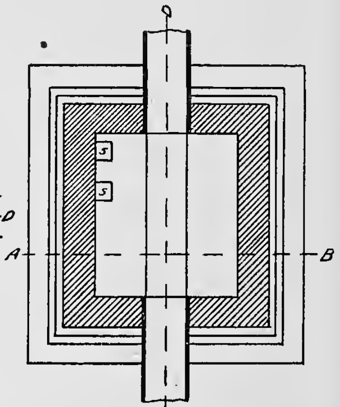
SECTION A-B

Fig. 319.



PLAN AT E-F.

Fig. 320.



PLAN AT G-H.

Fig. 321.

If it is not desired to have a ventilating opening at the level of the street, this part of the detail can be readily omitted.

Some engineers prefer manholes of circular plan on the ground that they are stronger, but they are rather more costly to construct. If circular they should be made tapering upwards.

In all manholes step-irons must be built in as shown at S, in Figs. 318 and 321.

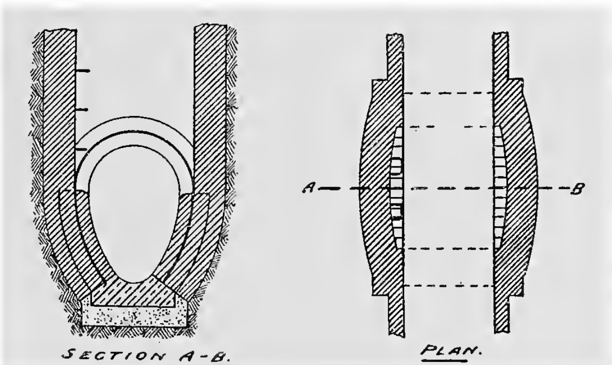


Fig. 322. Fig. 323.

In the case of a larger sewer, the base of the manhole is of different construction. An example of this is shown in Figs. 322 and 323. The latter shows the plan, and the former a cross-section, of a manhole on an egg-shaped sewer. It will be seen that, without making the base of the manhole of exceptional size, there is no appreciable benching, but merely enough to give a foothold. The curved shape of the walls on plan is to give greater strength.

In a street in which the traffic is very heavy, manhole openings in the roadway are apt to cause considerable interference with the traffic; and it is then a common practice to provide manholes with side entrances, the latter being accessible from the pavement. Figs. 324 and 325 show details of such a manhole. An access shaft leads down from the pavement to a short tunnel leading to the side of the sewer. The tunnel is best formed by arching over, or using ferro-concrete construction. The whole manhole can be formed of either brickwork or concrete, or partly the one and partly the other. A vent shaft is carried up to the roadway, in the form of a pipe, with a block of concrete or a stone slab around the top to support a heavy iron grating. The use of the vent pipe is very desirable in the case of a side entrance manhole, however much one may object to sewer openings at street level, as the large size of the manhole makes it a considerable receptacle for the accumulation of foul air.

I am well aware that if the Report of the Departmental Committee on Intercepting Traps is worthy of credence, there can be no disadvantage to health in putting openings at street level, since the Committee appears satisfied that the air in a sewer is generally better than that in the street above, but I prefer to adhere to the older view and experience that openings at street level are very liable to become offensive. Possibly they may be more offensive than injurious, but a smell can almost always be regarded as a danger-signal, and therefore surface openings should be kept at a minimum number.

Manholes should be from 75 to 100 yards apart, and if for any reason two manholes must be placed at a rather greater distance apart than this, a lamphole should be provided between them. A lamphole can be formed of 12-inch or 15-inch pipes leading vertically down from the street to the crown of the sewer, cased round in concrete and surrounded with a block of the same material, or a stone slab at the top, on which is placed a removable cover. A lamp can be lowered down the shaft thus formed, and any one in the next manhole on either

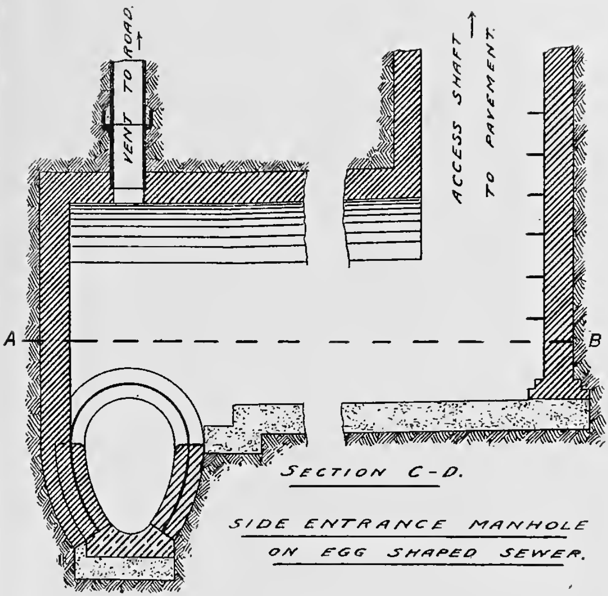


Fig. 324.

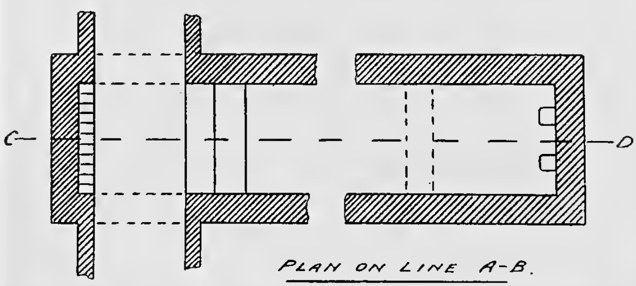


Fig. 325.

side should be able to see the light and also the condition of the inside of the sewer.

Where a sewer crosses a stream or similar feature by means of an inverted siphon, a manhole should be put at each end of the siphon. While a sewer should, if possible, be laid with sufficient gradient to ensure the flow through it being a self-cleansing one, sewers should not be given an excessive fall, owing to the excessive wear and tear caused thereby. The

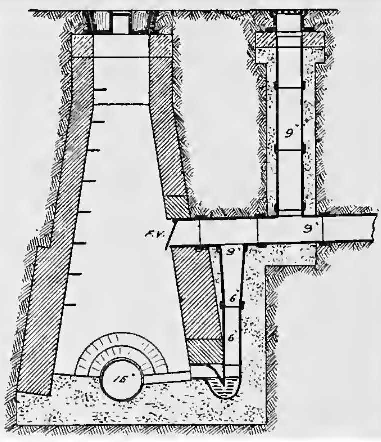


Fig. 326.

difficulty can be overcome by the use of a ramp similar to that shown in Fig. 287, but it is more usual, in the case of a sewer, to form it somewhat as in Fig. 326. When the flow is small, it passes down the taper pipe and reaches the manhole through a trap, the object of which is to form a water cushion for the falling solid matters, which would otherwise tend to deposit at the foot. A flap valve, F.V., is provided at the end of the sewer proper, to facilitate inspection, and to give relief in times of excessive flow, as after a heavy shower.

Ramps should be avoided as far as possible, as the splashing they involve tends to release objectionable gases. They can be in most cases avoided by the judicious use of intercepting sewers.

Where a bend occurs in a sewer, it should have a rather greater fall in its length than the uniform fall of the straight lengths it connects, to allow for increased friction. Where a small sewer discharges into a larger one, their inverts should not be at the same level, that of the smaller being above that of the larger, in order to prevent sewage standing in the smaller, and the consequent check on the velocity of its flow.

There must be no right-angled junctions on a sewer in the same way that there should be none on a drain. All branch sewers should join the main with a bend pointing in the direction of flow. In the case of pipe sewers, this is easily effected by the use of proper stoneware junctions. In the case of an egg-shaped or other form of brick or concrete sewer, the junction is effected by the use of specially made stoneware junction blocks, built into the sewer at the required positions. Where large main sewers join, a special form of construction becomes necessary, the form depending on the special condition to be met in each case. Figs. 327-331 give details of what is known as a bell-mouth junction between three egg-shaped sewers. The construction will be fairly evident from the figures. The walls of the sewer are thickened around the junction as shown in Figs. 327 and 328. The former shows a plan and the latter a longitudinal section. The remaining figures show cross-sections of the junction at three different points. This example will give an idea of the method of construction in any somewhat similar case.

Road gulleys should be placed at intervals of from 40 to 75 yards, according to the longitudinal fall of the road. They can be of iron, stoneware, artificial stone, or of brickwork. They can also be either circular, square, or rectangular on plan,

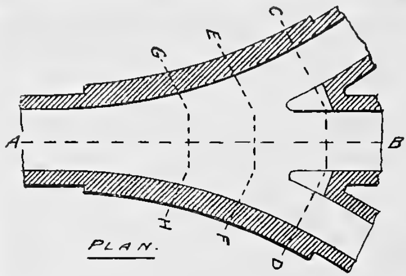


Fig. 327.

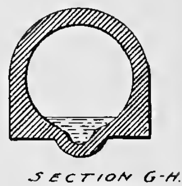


Fig. 331.

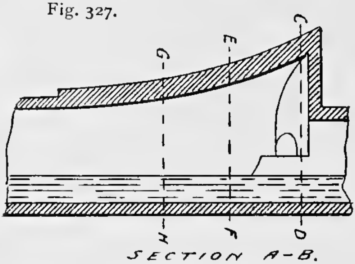


Fig. 328.

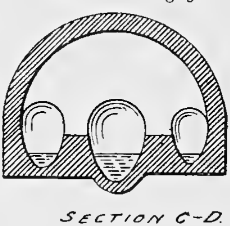


Fig. 329.

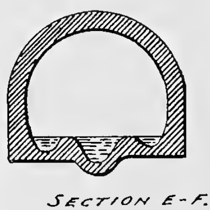


Fig. 330.

but the general principles given for the design of any sanitary fitting will apply; that is to say, there should be a minimum of angles and corners. Fig. 332 shows a section through a well-known type of stoneware gulley. The trap is formed in one piece with the main body of the gulley, and an access stopper is provided to the drain leading to the sewer. In the example shown, the stopper is of iron, fitting into an iron frame with an airtight joint and secured by means of gunmetal thumb screws. The part below the trap is for the purpose of intercepting the mud, which is removed at more or less frequent intervals.

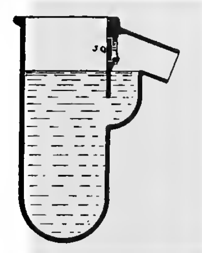


Fig. 332.

One of entirely different construction is shown in Figs. 333 and 334, a type required to be used by one of the District Councils in the neighbourhood of London. It is built of brickwork, lined inside with cement, covered by a stone slab, and surmounted

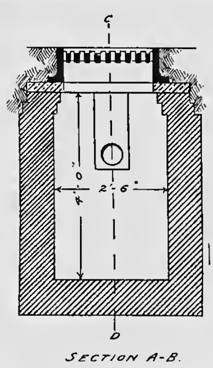


Fig. 333.

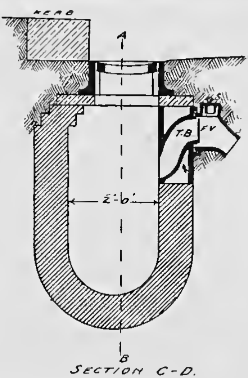


Fig. 334.

by the usual heavy iron grating. Fig. 333 shows a longitudinal section and Fig. 334 a section at right angles to the kerb. The trap is formed by means of a stoneware trapping block, T.B., in two pieces, a light flap valve being added at F.V. if desired. There is no direct access to the drain from the gulley, but an access stopper exists just under the roadway surface as shown.

Flushing is often necessary in the case of sewers. For example, if a sewer is designed for prospective requirements and will, for some time, receive much less than its ultimate quantity, it should be provided with means of flushing. So also, if it is of a very flat gradient, insufficient to cause it to be self-cleansing.

There are many means of flushing. Automatic flushing tanks have been dealt with under the heading of drainage, and large tanks of that kind, built of brickwork and of course always placed underground, are often used. Such a tank should always be provided at the upper or dead end of each section of sewers.

Any flushing arrangements should have for their object the maintenance of an effective velocity through the sewers for a sufficient time to remove any deposits and cleanse the sewer.

One of the simplest ways of flushing is by damming back the sewage and then liberating it when it has attained a sufficient head, or depth, in the manhole. Special flushing gates, sluices, etc., are fixed in manholes for the purpose. An old-fashioned method was to use a board across the outlet of the manhole, fitting into grooves at its ends and lower edge, but a few inches away from the mouth of the outlet. The sewage accumulated behind the board, which was then pulled up by means of chains in order to liberate it. This had the advantage that if the sewage was allowed to rise to above the top edge of the flushing board, it simply flowed over and through the sewer. If a sluice or gate is used, a sort of inverted ramp should be provided as an overflow in case of neglect to open the sluice, the manhole end of the ramp being always open.

The arrangement of the base of the manhole when a flap valve, F, is used is shown in Fig. 335. The floor is slightly sunk in front of the outlet, to permit of the flap readily opening. A strong chain is attached to the flap and fastened loosely near the top of the manhole. The chain shown in the sketch is unnecessarily heavy, but a strong one is essential. The overflow is omitted, but the mouth of it would be about at O, and the pipe would pass down to join the outlet sewer a few feet from the manhole. Flap valves sometimes have floats attached to them which are intended to lift them automatically when the sewage reaches a certain height, but the plan is not very reliable.

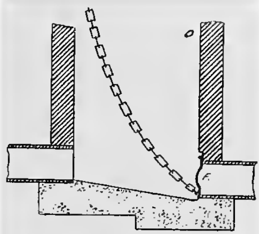


Fig. 335.

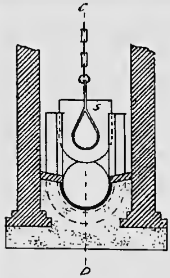


Fig. 336.

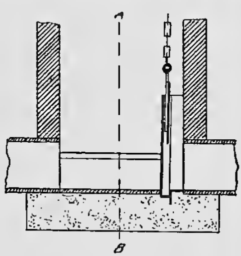


Fig. 337.

Tipping tanks are also used for flushing sewers, but they are only suitable for small volumes of flow.

Another method is shown in Figs. 336 and 337 which show a longitudinal and cross-section respectively, of the base of a manhole fitted with a sluice valve, S. The latter is merely an iron plate or door, fitting into a grooved frame of iron and capable of being rapidly opened by the pull of a chain from above. The frame in the example shown is fixed a little away from the outlet so as to allow the sluice to form an overflow. The sections show the sluice open.

For properly cleansing the sewers it is necessary to introduce plentiful supplies of water, and to do it systematically. In dry weather, more frequent flushings are, of course, necessary, and in times of epidemics disinfecting liquids should be added to the water.

Where a river is near, it is generally possible to obtain an ample supply for flushing, and on the sea-coast many towns use sea-water with more or less beneficial results. Water which has to be bought from water companies may be taken from the street hydrants, and admitted to the sewers through manholes or lampholes. Storm water may be collected and used with advantage. Before the use of automatic flushing tanks became general, an ordinary tank was often used. It was constructed of brickwork or concrete, with cement lining, with a capacity of from about 1500 to 1800 gallons. It could be filled from hydrants in about twenty minutes, and its contents were then allowed to pass out through a 9-inch pipe, this taking only about three minutes, and producing a powerful scouring effect. Automatic arrangements for flushing are, however, much more satisfactory than those requiring manual attention.

Where the combined system of sewerage is in use, it is possible, to some extent, to arrange for the discharge of excessive rainfall without designing the sewers to carry the whole of it; in fact, it is out of the question to do so. The method adopted is, to put in at suitable points what are termed storm overflows, by means of which the rain-water, after it passes a certain height in the sewer, runs off through relief sewers to some natural outlet or river. This water, being the last brought into the sewer and forming the upper layers of the liquid, is comparatively pure, the first part of the rainfall, which was polluted, having been carried down the sewer, flushing and cleansing it on the way.

There are many forms of storm overflow and a few of the principal will be briefly described. A relief sewer may be run close alongside the main sewer at a suitable point and a special manhole formed. When the sewage reaches a certain height in the main sewer, it is permitted to pass over a weir into the adjoining relief sewer, which discharges direct into a river or other water-course.

Another method is to lead a relief sewer direct from the main sewer to the river as shown in Fig. 338. It will be seen from the sketch that no water can enter the relief sewer until the water level in the main sewer is quite abnormally high and the sewage therefore diluted to an allowable extent. A flap valve is shown at the river end of the relief sewer, to prevent back flow when the river may be abnormally full of water.

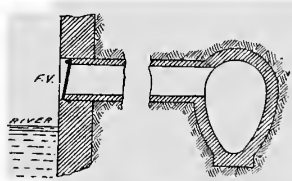


Fig. 338.

Where a separate rain-water sewer exists, one must not lose sight of the fact that the first washings of streets, roofs, and back-yards are usually very foul and quite unfitted for discharge into a river. When only a small quantity is flowing in the rain-water sewer it will have only a small velocity, but when the sewer is fully charged, as after a storm, the water will have a high velocity.

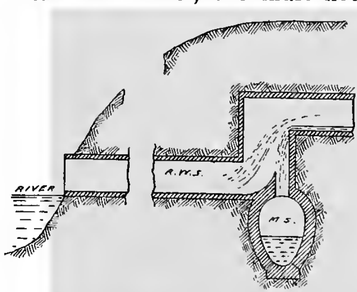


Fig. 339.

The leap weir is designed on this fact, as will be seen by reference to Fig. 339. When only a small quantity is flowing it will not have the velocity necessary to bridge the gap in the top of the main sewer, M.S., and will therefore fall into the latter, but if the rain-water sewer, R.W.S., be flowing fairly full, it will have a velocity of flow sufficient to leap the weir at the far side of the gap, hence the term leap weir. It is obvious that the success of this method depends entirely on the care and skill with which the width of the gap and the depth of the top of the weir below the invert of the rain-water sewer are calculated.

Another form of leap weir is the following: An iron plate, fixed so as to be adjustable, is placed on the invert of the rain-water sewer, over the mouth of an opening leading to a small foul sewer to carry off the first flow of rain-water (Fig. 340). When only a small quantity is passing along the rain-water sewer, it will all go to the foul sewer through the opening, but when there is considerable velocity, very little, and that only from the lowermost part of the flow, will be intercepted in this way. A rather more elaborate form of leap weir, with means of adjusting the gap, is that introduced by Mr. Silcock, and illustrated in the well-known work on Sanitary Engineering of which he is joint author. The arrangement is shown in Figs. 341 and 342.

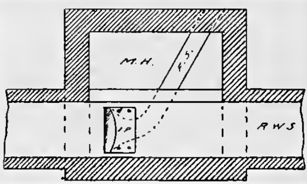


Fig. 340.

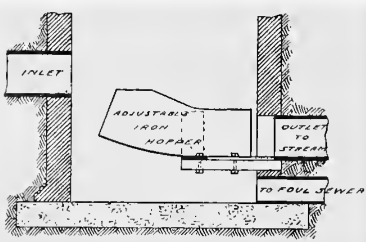


Fig. 341.

The former shows a longitudinal section and the latter a plan. At a special manhole, on the rain-water sewer, an adjustable iron hopper is interposed between the inlet and outlet. When the flow is good, the water leaps the gap between the inlet and the hopper and is thus conducted to the rain-water outlet, but if the flow is slight, the water falls clear of the hopper and passes away through a foul sewer below. The sketches are somewhat diagrammatic, and are intended only to show the principle. The hopper is built up of iron plates riveted together. The drawback to this type of overflow is that a high velocity is apt to carry the whole flow to the river or stream, and so interfere with the regularity of working of the sewage purification works, which are required, by the regulations of the Local Government Board, to be kept in full working. On the other hand, the overflow first described, with the weir, is open to the objection that the greater the rainfall notwithstanding the weir, the greater the volume passing to the sewage works, since a large quantity flows past the weir, even though the latter is at a lower level.

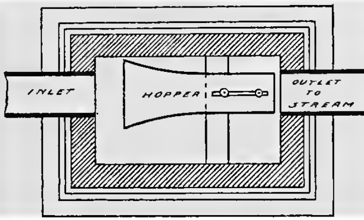


Fig. 342.

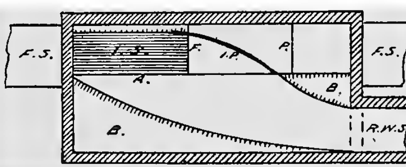


Fig. 343.

This difficulty is overcome by a form of overflow introduced at Birmingham by Mr. Lloyd Davies, and shown on plan in Fig. 343. The level of the storm-water overflow must, in all cases, be such that only the excess beyond six times the average dry weather flow is diverted, under the regulations of the Local Government Board, and this type diverts all above this stated quantity. A horizontal flat plate, F.P., is fixed across the foul sewer, F.S., at the required height to cut the flow into two parts; one that below six times the dry weather flow, and the other, that above it. On the flat plate is fixed a vertical curved plate of iron, I.P., which diverts the upper flow into the rain-water sewer, R.W.S. At the entrance to the manhole is an inclined wire screen, I.S., with an upright triangular side at A. This screen forms a sort of basket, which prevents rags, paper, and other rubbish collecting at the edge of the flat plate, or passing into the rain-water sewer.

Where a sewer has to cross a stream, railway cutting, or other similar feature, an inverted siphon has often to be used. They are objectionable features and should be avoided wherever possible. They usually consist of two sloping lengths meeting a flat length between them. They should be formed of wrought-iron pipes, treated with the Angus Smith or other process, and should be laid in duplicate. There should be a good manhole at each end, and if the length is great it is wise to carry up a vent shaft at the middle to prevent the siphon becoming air-locked. There is always a tendency to blockage in the flat length, and it is usual to adopt some device to check this, such as putting a permanent large chain through from end to end, so that it can be pulled backwards and forwards to stir up the silt. The object of laying them in duplicate is that, in case of trouble, the sewage can readily be diverted from one to the other.

Where sewers cross bridges, they should be of iron or steel pipes, owing to the vibration. Sometimes they are accommodated between the girders of the bridge, and if this is impossible, they are fixed to brackets at the side.

We come next to the question of the ventilation of sewers, one of the most vexed questions in connexion with sewerage work. The Report of the Departmental Committee on Intercepting Traps would appear to show that ventilation of the sewer is a thing that is in most cases unnecessary, but, though it is a fact that some towns have no system of ventilating the public sewers, it is undoubtedly the case that foul air is under some circumstances, if not all, generated in sewers, and that steps should be taken to prevent its accumulation. Whether ventilation is needed in the sense that currents of air should be induced, is very doubtful, it being probable that all that is needed is a sufficiency of vent pipes or shafts.

The space above the sewage in a sewer is always filled with air, watery vapour, or gas, or a mixture of them. There is no such thing as a special sewer gas. The gaseous contents of a sewer are a mixture of gases of a highly complicated and composite character, and whether dangerous or not, it is a highly offensive mixture, which should not be emitted into streets at low levels, especially in the midst of a dense population. The effect of a bad smell is not the same on all individuals. Some can submit to it with impunity, while others are very adversely affected. Not only is this so, but the fact remains that a bad smell is offensive and should be prevented if means there be of so doing.

Much evidence was taken by the Committee referred to as to the nature and effects of sewer air, such evidence as was taken leading to the expression of opinion in the report that, in effect, the air of the sewer was generally better than that in the street above. Many previous investigators have experimented on the effects of sewer air, their results showing that exposure to the gases of decomposing sewage caused a predisposition to infection, vomiting, purging, and a febrile condition, increase in blood pressure, acceleration of the pulse, and so on. At King's Norton, some years ago, the local authority was ordered to pay £3500 damages in connexion with negligence which caused death from blood poisoning, a case of a defective sewer ventilator communicating with the chimney of a house.

At Dublin, in 1905, two men were suffocated in a sewer; at Rotherhithe, in the same year, one man met the same fate; and in 1907, at Southwark, six men were overcome and narrowly escaped death. Several medical writers have recorded their opinion that typhoid fever is undoubtedly caused in some cases by inhaling sewer air. Our present knowledge of the science of bacteriology is no doubt very far from perfect, but Dr. Andrewes, in the thirty-sixth Annual Report of the Local Government Board, makes this very guarded statement: "Though the organisms which I have been able to detect in sewer air are not in themselves known to be prejudicial to health, . . . yet their value is evident as indices of the possible presence of more harmful sewage-borne microbes".

Sufficient has probably been said to show that it is desirable to prevent the accumulation of sewer air, and its emission at points at which it is likely to do injury.

For many years a section of the municipal engineers have aimed at ventilating the public sewers through the medium of house drains, but this has been checked by the existence of by-laws requiring the use of the intercepting trap.

Various allegations have been made against the offending trap, which may be briefly summarized and answered as follows:—

1. It is said that the interceptor is virtually a small cesspool, containing putrefying sewage, and polluting the air of the intercepting chamber. The answer to this is that the matter lies in the hands of the sanitary authorities, who should demand the use of a trap to their approval, since attention to this point has, in some towns, been the cause of no trouble arising from the interceptor. Even if a bad form of trap be permitted, the air of the intercepting manhole need not be

foul (nor, in practice, does one often find it so), since the sanitary authorities have power to require drains to be ventilated, and efficient means of ventilation are always available.

2. It is said that the interceptor impedes the free flow of the sewage through the drain. The best of interceptors does this to a small extent; so also does every bend on the drainage system, and if the principle of interception be correct, both are unavoidable. Further, with good construction, both are almost negligible quantities.

3. It is said that the interceptor causes a diminution of the limited fall available for the drain. As a good interceptor only uses about 2 inches of the fall, the answer to this is that the argument does not apply to ordinary cases of drainage, but only to a small proportion of cases, in which, interceptor or no interceptor, supplementary means of flushing should be provided for the drain.

4. It has been said that interceptors do not effect their supposed object, that of forming an effectual barrier between the air of the sewer and that of the drain. The Committee before referred to appear satisfied that they do.

5. Interceptors are alleged to cause waste of water in flushing. Water used in flushing is like money well spent The disadvantage of most drainage systems is the insufficiency of water available for the purpose.

6. The air inlet to the drain, rendered necessary by the use of the trap, becomes a nuisance. If a low fresh-air inlet is used, this is undoubtedly often the case, but it is an avoidable nuisance, as it can be carried up above the roof. Further, the Committee expresses its opinion that the inlet can be dispensed with without detriment.

7. It is alleged that the use of the interceptor makes the effectual ventilation of sewers and drains impossible. This argument only applies if it is desired to use the drains to ventilate the sewers, the fundamental principle of which is

absolutely sound. To do this, however, would necessitate, for the safety of the public health, perfect sewers, perfect drains, perfect, regular, and systematic inspection, perfect maintenance, all traps proof against siphonage and evaporation (practically an impossibility), and the reconstruction of about 75 per cent of existing drainage systems.

8. Lastly, it is alleged, and the allegation is undoubtedly one of fact, that the interceptor sometimes becomes blocked. With well-designed traps blockages are of fairly rare occurrence, and may be due to several causes, such as defective fixing, faulty stoppers of the cleaning arms becoming loose and falling into the mouth of the trap, inadequate flushing, excessive size of trap or drain for the work it has to do, insufficiency of fall to the drain, and lack of automatic flushing, and lastly, the presence, in the drain, of some article which has no business there. As an example, old scrubbing brushes, tin cans, and even articles of clothing have been found to be the cause of the blockage. The chief cause of trouble, however, is faulty design of the intercepting trap, the design of which should undoubtedly be standardized after extensive experiments.

The proving of defects in one thing is no proof of the efficiency of the proposed alternative, and the interceptor should only give place to something more efficient. If the trap is done away with at all, its use should remain optional.

This matter has been rather fully dealt with, but no apology is needed in face of the importance of the matter. The interceptor has many adherents and many opponents, either of whom hold strong views on the matter, and it is doubtful if the Report of the Departmental Committee has made any converts either the one way or the other.

The necessity of ventilating sewers is by no means a newly recognized matter. That it was appreciated by the Romans we know by the writings of Justinian (555 A.D.).

The amount of ventilation necessary is a point about which difference of opinion exists, but the tendency of opinion is towards vent rather than ventilation as effected by air currents. There is quite a connexion between the nature of the air in the sewer and the condition of the sewer itself; that is to say, it may reasonably be expected to be more offensive in an old sewer than in one of first-class modern construction, lined with glazed bricks, regularly and systematically flushed, and not too large for the work it has to do.

Let us consider the systems at present in use in this country for the ventilation of sewers. They include open gratings over manholes, a combination of open gratings and vertical shafts, vertical shafts only, cremation in special forms of gas lamp, deodorization of the air, connexion to mill chimneys, and many patented systems involving more or less complicated apparatus. The three systems first mentioned are those most largely used, the others being rarely met with. About 80 per cent of the towns in England ventilate their sewers by means of a combination of surface gratings and vertical shafts, and about 15 per cent by vertical shafts only.

The use of open gratings dates from about 1834, when the first gulley trap was introduced. The system is open to considerable objection owing to the more or less frequent offensive emanations from the gratings. Complaints on this ground led to gratings being closed one by one, and the substitution of vertical shafts, it being thought that the high shafts would act as outlets and the remaining gratings as inlets. Some valuable investigations were, however, carried out by Mr. E. G. Mawbey, M.I.C.E., the Borough Engineer of Leicester, and by the late T. De Courcy Meade, M.I.C.E., City Engineer of Manchester.

Mr. Mawbey carried out thousands of tests, at all times of the year, in Leicester, and came to the conclusion that surface gratings are unnecessary, vertical shafts alone being sufficient. He found that the shafts gave both inward and outward air currents, but usually the latter, which were in all cases the more vigorous. In a thousand tests, he found the average upward current to be 162 feet per minute, and the average downward current to be 34·6 feet per minute.

Mr. De Courcy Meade's experiments corroborate the results obtained by Mr. Mawbey, Mr. Meade pointing out that the shafts act indifferently as both inlets and outlets, the air currents being governed by the difference in temperature between the internal and external air, the flow of sewage, the construction and character of the sewer, etc. All the conditions are liable to be neutralized and reversed by the direction and force of the wind, while the heat of the sun, of course, affects the draught through any particular shaft.

In the face of these results there has been a growing tendency, in recent years, towards the use of vertical shafts alone. These may be erected against the sides of buildings, but local authorities find a difficulty in obtaining the necessary permissions. An owner runs a serious risk in granting such a permit, since if the shaft is not thoroughly well constructed and maintained, there is the possibility of danger to health by reason of defective joints. Further, the settlement of the building, and consequent settlement of the shaft, may lead to a fractured pipe or broken joint at the foot of the shaft, allowing the soil around to become impregnated with sewer air. In some few instances shafts have consequently been erected against buildings, but not attached to them. All iron vent shafts should have rust pockets at their feet.

Sewer vent shafts should be carried up independently of buildings, either along the kerb or in the centre of the roadway, to a height at least equal to that of the ridges of the roofs of the abutting houses. High lamp standards have been used as vent shafts in some places, notably at Southport. In some cases the shafts have been carried up beside, and attached to telegraph poles, but there is a risk of damage to the joint at the foot by reason of the motion of the pole in a high wind.

The sizes of the shafts depend on the size of the sewer, but they vary from 4 to 12 inches in diameter, as a rule, and are put at from 100 to 200 yards apart. The system of ventilating by detached shafts is simple, sound, calls for a minimum of attention, and, compared with more elaborate systems, inexpensive.

The system of cremating sewer air in special forms of gas lamp is an expensive one, and not altogether satisfactory, but a gas lamp ventilator may be useful at isolated points at which it is difficult or inadvisable to put an ordinary open shaft. An example of this system is the Webb lamp, which resembles an ordinary incandescent street lamp, with a cluster of three burners. The heat rays are focussed on to the sewer air in the neck of the lamp by means of heat reflectors.

Systems of deodorization are of many forms, the two best known being the "Reeves" and the "Caink" systems. In the former, recesses are formed in the manhole of the sewer, containing two vessels, charged with chemicals which mix continuously, forming gases which purify the sewer air. In the Caink system an apparatus is used in the form of an air filter and deodorant. It is complicated and unsuitable for other than deep sewers, but is said to work efficiently.

In some few towns the connexion of the sewer to mill chimneys has been adopted, but with little success. The draught is so great near the chimney that it tends to unseal the neighbouring traps, while 200 yards away it has no effect at all. The system is obviously of limited application, since there must be a mill chimney near before one could think of using it. It is interesting to note that the first attempt in this direction was made on the main sewers of London by Sir Joseph Bazalgette, who used a furnace in the tower of the Houses of Parliament with but poor results.

An interesting mechanical system is that known as the "Shone and Ault," which ventilates both sewers and drains by one operation, without necessitating the abolition of the interceptor. Fans, driven by any motive power, draw the air through the sewer and discharge it at suitable points, forcing it through a filtering and deodorizing medium in its passage to a vertical outlet shaft. The admission of air is rigidly controlled at all known inlets to the sewer, and the amount of vacuum caused is carefully graduated in order to avoid any tendency to unseal the traps, which are provided with relief valves. The system approaches the ideal for a new and perfect system of sewerage, but, in the case of an old system, the presence of unauthorized inlets would be a great bar to success. The air is drawn down the soil and ventilating pipes of the house drains, and so away from the building, and, being a mechanical system, it is practically independent of atmospheric conditions. On the other hand, the system is an expensive one to instal and maintain, the metal fittings are said to be liable to be acted on by the acids in the sewage, and the valves to be liable to fouling after storms.

It will be seen from the foregoing that there are many systems for the ventilation of public sewers without trespassing on private rights by ventilating them through the house drains.

We may next approach the question of sewerage from another point of view; namely, the volume of sewage to be carried by the sewers, and the determination of their size.

The volume of dry weather flow in any sewer, if only sewage be admitted, may be assumed to be equal to the amount of the water supply, say 25 to 30 gallons per head per day. The volume carried is not, however, uniform throughout the day; so much so, in fact, that one-half of the sewage due to the whole twenty-four hours often flows off in from six to eight hours. This is owing to the varying quantities of water used in houses at different times of the day. In making provision for the maximum dry weather flow of sewage, it is usual to assume that one-half the daily quantity is discharged in from six to eight hours. If, therefore, we take the daily quantity at 25 gallons per head, the maximum flow will be at the rate of $12\frac{1}{2}$ gallons per head in, say, six hours, or about 2 gallons per head per hour.

The amount of rainfall which it is necessary to provide for in the sewers is a difficult matter to determine, and is often underestimated. The amount the sewer should receive below storm overflows is arbitrarily fixed by the Local Government Board at six times the dry weather flow, but the amount to be received above such overflows must be estimated. As excessive rainfalls occur but seldom, it is unusual to go to the expense of providing for them in order to avoid possible damage from the sewers overflowing at very rare intervals, though where such damage might be great the expense would be justified.

No hard and fast rule can be laid down in reference to the probable amount of storm water which will reach the sewers. It must depend on the area of the district, the relative porosity of the soil, and the general fall of the area in question.

A simple rule giving a fair estimate of the maximum amount of rainfall likely to reach the sewers is that the quantity in cubic feet per second will vary from $400\sqrt[3]{A^2}$ to $1000\sqrt[3]{A^2}$, in which $A =$ the area of the district to be drained in square miles. The value of the numerical coefficient must be judged. It can be taken as 1000 for a district well built over, well paved, and with a good natural fall, and as 400 for a more sparsely covered district, containing a larger percentage of garden ground, and of less natural fall. Between those two cases there is a large margin, and the figure must be carefully judged, taking the before-mentioned points into account and also the relative average rainfall. It must be clearly borne in mind that no hard and fast formula can be laid down for rainfall and storm water.

In the case of the partially separate system, it is necessary to determine what proportion of rainfall is likely to enter the foul sewer, that is to say, that falling on roofs, back yards, etc. This is often taken as equal to one-eighth of an inch of rainfall per hour, on 100 square feet per head of population.

Where the combined system of sewerage is in use, another point to be considered is the necessity of not allowing the proportion between the rainfall and the sewage proper to fall below a certain minimum. There are two reasons for this; firstly, the sewage passing out at the storm overflows must be sufficiently diluted, so as not to pollute the river or stream into which it discharges, and secondly, in any case, allowance should be made for the admission of a sufficient volume of storm water to flush out the sewers. This point is settled to a certain extent by the Local Government Board's requirement that six times the dry weather flow should be carried below storm overflows, but this requirement is not a complete settlement of the point, since the dry weather flow at some times of the day is far in excess of that at others.

Even when the separate system is used, sufficient rain-water should be allowed to enter the foul sewer to adequately guard against sluggishness of flow.

Before considering the determination of the sizes of sewers, the question of available velocity must be dealt with. It will have been seen, from the formula given for drains ($V = C\sqrt{RS}$), that velocity depends on the inclination S, and the hydraulic mean depth R. As regards the gradient to be given to the sewer, one is largely bound by the physical features of the district, and the position of the point of outfall, but the hydraulic mean depth depends on the sectional form and sectional area of the sewer, which one is free to vary. The point to be kept in mind is that the velocity in the sewer must be such, if possible, as to make it self-cleansing, and, at the same time, carry off the maximum quantity of sewage for which it is intended; further, that it must carry off the estimated minimum flow with a self-cleansing velocity if possible. If the flatness of the district makes this difficult, the inclination should at least be sufficient to give a self-cleansing velocity with the assistance of flushing.

A small sewer, say 12 inches and less in diameter, should have a velocity of flow of not less than 3 feet per second to keep it free from deposit; a sewer from 12 to 24 inches in diameter $2\frac{1}{2}$ feet per second, and larger sewers 2 feet per second.

The smallest sized sewer should not be less than 6 inches in diameter, and then only where there is no chance of its being extended higher up.

To enable one to calculate the sectional area requisite for a sewer, one has settled, let us suppose, (1) the minimum volume to be discharged, that is to say, the dry weather flow; (2) the maximum volume the sewer is to carry; (3) the velocity required in the dry weather flow to make the sewer self-cleansing; and (4) the available gradient.

It is usual to design sewers so that they are only partially full when taking their maximum estimated volume. Engineers variously assume them as flowing either two-thirds or three-fourths full when carrying their estimated maximum.

Various sets of tables are obtainable, giving the velocity and discharge of sewers of various sizes, according to their inclination, and these, of course, furnish the most ready method of arriving at the size necessary for any particular case. If tables are, for any reason, not available, the size must be determined by the principle of trial and error, assuming a size, and finding, by calculation, whether it fulfils the necessary conditions, and if not, trying another size until the right one is obtained. An example will show what is meant.

Example. Find the diameter to be given to a circular sewer to discharge the sewage of a population of 20,000 persons, together with the unavoidable rainfall under the partially separate system. The available fall is 1 in 850. The sewer to have a self-cleansing velocity when carrying its dry weather flow.

First determine the volumes to be carried.

Assume the sewage proper at 25 gallons per head per day, and the unavoidable rainfall as $\frac{1}{8}$ inch per hour on 100 square feet per head.

Dry Weather Flow.

As there are $6\frac{1}{4}$ gallons to a cubic foot, 25 gallons $= 4$ c. ft.

$$20{,}000 \times 4 = 80{,}000 \text{ c. ft. per day.}$$

About one-half of this must be estimated to pass through the sewer in six hours.

$$\therefore \frac{80{,}000}{2 \times 6 \times 60 \times 60} = 1\cdot85 \text{ c. ft. per second} = \text{D.W.F.}$$

Maximum Flow.

Find the discharge due to $\frac{1}{8}$ inch of rainfall per hour on 100 square feet per head.

$$= \frac{20{,}000 \times 100}{8 \times 12 \times 60 \times 60} = 5\cdot783 \text{ c. ft. per second.}$$

The total flow will therefore be :—

Sewage proper	1·85	c. ft. per second.
Unavoidable rainfall	5·783	,, ,,
Maximum flow	7·633	,, ,,

The maximum flow of 7·633 c. ft. per second should be carried by the sewer when flowing not more than two-thirds full, and our calculations must also have regard to the fact that the sewer must be self-cleansing with a flow of only 1·85 c. ft. per second.

Using the formula already given for drainage,

$$V = C\sqrt{RS}$$

assume that a sewer of, say, 2 feet 3 inches diameter is somewhere near the requirements, and calculate the velocity and discharge when it is flowing only, say, one-third full.

When flowing one-third full, the H.M.D. of a circular sewer is ·186 D.

The fall is given as 1 in 850.

$$\begin{aligned} V &= C\sqrt{RS} \\ &= 100\sqrt{(\cdot 186 \times 2\cdot 25) \times \tfrac{1}{850}} \\ &= 2\cdot 218 \text{ ft. per second.} \end{aligned}$$

The velocity under this condition is therefore a self-cleansing one.

Next find the discharge when one-third full.

$$Q = AV.$$

From the table given in Chapter VIII, $A = \cdot 229\ D^2$.

$$\begin{aligned} \therefore Q &= (\cdot 229 \times 2\cdot 25^2) \times 2\cdot 218 \\ &= 2\cdot 513 \text{ c. ft. per second.} \end{aligned}$$

This also is all right so far, as the dry weather flow is only 1·85 c. ft. per second.

Now see if the same sewer will discharge the maximum amount of 7·633 c. ft. per second when flowing two-thirds full.

In this case the H.M.D. = ·291 D.

$$\begin{aligned} V &= C\sqrt{RS} \\ &= 100\sqrt{(\cdot 291 \times 2\cdot 25) \times \tfrac{1}{850}} \\ &= 2\cdot 775 \text{ ft. per second.} \\ Q &= AV. \end{aligned}$$

From the table before referred to, $A = \cdot 556\ D^2$.

$$\begin{aligned} \therefore Q &= \cdot 556 \times 2\cdot 25^2 \times 2\cdot 775 \\ &= 7\cdot 812 \text{ c. ft. per second.} \end{aligned}$$

This is so little beyond the estimated maximum of 7·633 that there is no need to try the next size smaller. It will be seen therefore that a sewer of *2 feet 3 inches diameter* will meet the case.

There is sometimes a difficulty in sewering a district, owing to the levels being such that a gravitation system is out of the question. Pumping stations can in such case be provided, or the case may be met by the provision of a series of Shone ejectors, or the Adams' sewage lifts, both of which have been described. For use in connexion with a sewerage system the Adams' lift is of a modified form, but the principle is the same as in the example described.

CHAPTER XI

SEWAGE DISPOSAL.

A MOST interesting branch of the subject of drainage and sanitation is that of sewage disposal or purification. The problem is by no means a simple one, and the effectual purification can only be accomplished by the earnest collaboration of the engineer, the chemist, and the bacteriologist. Very few, if any, men can be regarded as combining a thorough knowledge of these three professions—in fact, the science of bacteriology is hardly out of its infancy, and it has been truly said that the engineer who poses as a chemist, or the chemist who poses as an engineer, usually makes a conspicuous fool of himself.

Much has been written on this part of the subject, but a large part of it, if not the bulk, has not had the merit of impartiality.

Many years ago the condition of our streams and rivers was exceedingly bad, owing to the discharge of crude or only partially purified sewage, and it became necessary to pass the Rivers Pollution Act of 1876, Section 3 of which provides that local authorities and other parties shall use the best practical and available means to render harmless the sewage discharged into streams and rivers.

It is necessary, therefore, to see that the sewage, before being discharged into streams, is purified, and not clarified only; that is to say, not only shall the matters in suspension be removed, but the organic impurities also, so that secondary decomposition shall not set up after the effluent water has commingled with the water in the stream.

Sewage is a very complex substance, its composition varying tremendously. It is obviously the fact that there must be a great difference, for example, in the composition of the sewage from a purely residential district and that from a large manufacturing town, owing to the sewers receiving the waste liquids from the trades and manufactures, which in themselves, again, differ in nature in one town from those in another.

It is difficult, therefore, to give anything very definite as to the chemical composition of sewage. The Rivers Pollution Commissioners, in 1876, published a table of compositions of sewage, for both water-closet towns and privy midden towns, but the latter are so rapidly becoming obsolete that they hardly call for notice now. An abstract of the table referred to is given below as regards water-closet towns, i.e. towns discharging principally ordinary domestic sewage into the sewers :—

Average Composition of Sewage.

Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
						Mineral.	Organic.	Total.
In Parts per 100,000.								
72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	39·11
In Grains per Gallon.								
50·54	3·287	1·543	4·692	5·410	7·462	16·926	14·357	31·283

the remainder being water.

It is also difficult to define the meaning of the word "harmless" as used in Section 3 of the Rivers Pollution Act,

1876. The Local Government Board has often been asked to prescribe a standard of purity for sewage effluents. The Board has, however, always refused to do so, on the ground that each case should be dealt with on its own particular merits.

In 1898 a Royal Commission was appointed to investigate the whole question of Sewage Disposal, and this Commission issued many Reports. The eighth, issued at the end of the year 1912, deals with the question of standards of purity of effluents.

A brief summary of the conclusions of the Commission on this point is as follows:—

"The law should be altered, so that a person, discharging sewage matter into a stream, shall not be deemed to have committed an offence under the Rivers Pollution Act, 1876, if the sewage matter is discharged in a form which satisfies the requirements of the prescribed standard, the standard being either the general standard, or a special standard which shall be higher or lower than the general standard, as local circumstances require or permit.

"An effluent, in order to comply with the general standard, must not contain, as discharged, more than three parts per 100,000 of suspended matter, and with its suspended matters included, must not take up, at 65° F., more than 2 parts per 100,000 of dissolved oxygen in five days. This general standard should be prescribed either by Statute or by Order of a Central Authority, and should be subject to modifications by that authority after an interval of not less than ten years.

"In fixing any special standard, the dilution afforded by the stream is the chief factor to be considered. If the dilution is very low, it may be necessary for the Central Authority, either on its own initiative or on application of the Rivers Board, to prescribe a specially stringent standard, which should also remain in force for a period of not less than ten years.

"If the dilution is very great, the standard may, with the approval of the Central Authority, be relaxed or suspended altogether. Relaxed standards should be subject to revision at periods to be fixed by the Central Authority, and the periods should be shorter than those prescribed for the general or for the more stringent standards.

"With a dilution of over 500 volumes, all tests might be dispensed with, and crude sewage discharged, subject to such conditions as to the provision of screens and detritus tanks as might appear necessary to the Central Authority."

Nothing could show more clearly than the foregoing that no hard and fast rule can be laid down as regards standards of purity. Many of the Rivers Boards and County Councils have established their own standards of purity for effluents, but in the face of the recommendations of the Royal Commission in this, their eighth, Report of 1912, such standards may probably disappear.

The whole question of sewage disposal is one in which there has been a vast amount of experimental work going on for years, and is one of the greatest importance to the public at large. The prompt and effectual removal of the excremental and other refuse from the midst of our communities is of the utmost importance, but no one system of disposal can be applied indiscriminately, and the system which is applicable to one district may not be by any means the best for another, differently situated or conditioned. The work of the Royal Commission on Sewage Disposal is so important that its Reports will be dealt with somewhat fully towards the end of this chapter.

Let us consider the methods which are available for the purification of sewage.

In all cases the purification of sewage is due to bacterial agency, and it is therefore well to consider, at the outset, what bacteria really are.

Bacteria are divided into two classes, namely, the parasitic, needing a living host, and the saprophytic, living on dead matter, but some exist indifferently as both parasites and saprophytes. We have to deal with the saprophytic organisms, which are subdivided into anaërobic, living without air, and aërobic bacteria, living with air. Anaërobes and aërobes are both obligate and facultative; that is to say, obligate anaërobes cannot live, or at least do not act, in the presence of free oxygen, while facultative anaërobes can. Similarly, obligate aërobes need free oxygen, but facultative aërobes are able to exist without.

Bacteria are minute vegetable growths, varying in size from about one-fifteen-thousandth to one-twenty-five-thousandth of an inch in diameter; they increase usually by division, occasionally by spore formation; their multiplication is exceedingly rapid and is interfered with by cold. Moisture is necessary for their successful working.

Most of the solids in suspension and solution in sewage are composed of oxygen, hydrogen, nitrogen, and carbon Different bacteria separate the many complex forms in which these elements occur into simpler combinations, liquefying part of the suspended matter and freeing the other portion as gas—nitrogen, hydrogen, methane (or marsh gas), and carbon dioxide. When sewage has been purified by micro-organisms, the effluent should show an appreciable quantity of nitrates. If this is so, it indicates that those substances liable to putrefaction have been first of all broken down by anaërobes, ammonia being largely formed, that the nitrogen of the ammonia has then been incorporated with oxygen by anaërobic-aërobic action, and that finally, in contact with aërobes more oxygen has been added.

Let us next consider the various methods in use for the treatment or disposal of sewage.

They are :—

1. Discharge into the sea or a tidal estuary.

2. Land treatment.
3. Sedimentation tanks, followed by filtration.
4. Chemical precipitation, followed by filtration.
5. Bacterial processes only :—
   (*a*) With definite anaërobic stage, involving the use of a so-called septic tank.
   (*b*) With bacteria beds only, and no tank.

No matter what treatment is adopted, the primary object is purification. Sewage works should be kept free from nuisance; the production of sludge, or sewage mud, must be avoided as far as possible, owing to the difficulty of getting rid of it; and lastly, the expenditure, both capital and annual, should be kept as low as possible consistent with efficiency.

In the case of towns on the sea-coast, discharge into the sea or a tidal estuary furnishes an efficient and economical means of disposal. Great care is necessary in selecting the position for the outfall, and careful observations of the nature of the prevailing currents should be made over a fairly large area. The observations are made with the help of floats, the directions taken being carefully recorded with the aid of a theodolite or prismatic compass, so that the course of the current may be plotted on a plan. The sewage should be discharged into favourable currents, on the ebb tide, and tanks must, of course, be provided for storage during the times of exceptionally high tides.

There are two methods of applying sewage to land for the purpose of purification, known as irrigation and filtration respectively. The two systems were formerly known as broad irrigation and intermittent downward filtration, but these names are falling rapidly into disuse.

It is very difficult to draw a hard and fast line between the two systems, but, generally speaking, it can be said that irrigation is the system in which the sewage is applied to an area of land continuously for a certain time, the area being then rested while agricultural operations proceed. This system is best carried out by laying the land out to a fall of about 1 in 100 and passing the sewage over it in a thin sheet.

On the other hand, filtration is generally carried out by levelling the plots, underdraining them, enclosing them with earth walls or banks, flooding the area with sewage, and allowing it to soak away, thus passing alternate layers of sewage and air through the soil. In both systems ridges and furrows, as shown in Fig. 344, are sometimes used, the advantage being that the roots of the crops absorb the sewage without the crops themselves being fouled.

The sewage carriers, in the case of land treatment, require to be carefully arranged and constructed. The main carriers

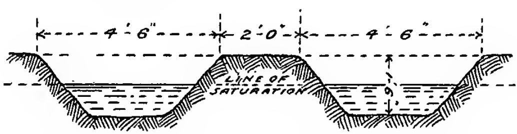


Fig. 344.

or channels can be of concrete, and the minor carriers can either be similarly constructed, or may consist of grips, or channels, just cut in the ground. Fig. 345 shows what is known as the catch-water system, applied to an area of rough and irregular surface. The minor carriers are carefully formed along contours, at vertical intervals of about 2 feet 6 inches as shown. The inlet to the main carrier is controlled by a meter chamber, to measure the quantity applied at one time. The entrance to the minor carrier, at its junction with the main, is controlled by a small sluice. A manhole is shown on the subsoil drain, for the purpose of sampling the effluent passing through the drains.

A most important point in reference to the land treatment is the nature of the soil. A good loamy soil is the best, and clay or peat about the worst. Sand or gravel are of little use for the purpose, but peat and clay should only be used when there is a fair amount of vegetable soil above them, of at least 6 or 9 inches in depth. Good soils for purification purposes are alluvial drift and gravel, oolitic sandstone, Bunter sandstone, magnesian limestone, and old red sandstone.

The bulk of the purification is effected in the first foot or so of depth, but it is necessary to have an underlying soil of

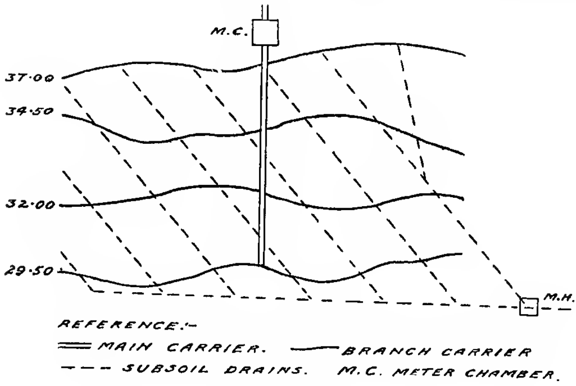


Fig. 345.

a porous nature in order to carry off the effluent. The action of an earth filter is partly mechanical, partly chemical, and partly biological. The destruction of organic impurities in sewage is brought about by a process of active fermentation or decomposition, termed nitrification, caused by bacteria, the organic matters being resolved into soluble nitrates, products having no smell, colour, or injurious properties. Nitrification ceases if the treatment of the land with sewage is not conducted intermittently, and if irrigation or filtration is carried on without care and without a knowledge of the laws which require to be considered there is a risk of the pollution of subsoil waters and streams.

It is easy to see why a non-porous soil is unsuitable for sewage purification—although the sewage may be to some extent mechanically strained, the absence of free oxygen in the soil prevents purification.

It is a very general practice now to work a sewage farm on the principle of one section being given up to irrigation and another to filtration, and to change them over once a year; that is to say, to use in alternate years for filtration the areas given up during the preceding year to irrigation. This enables the land to be well worked up and aerated, especially if the ridge and furrow system is adopted, and the ridges and furrows levelled once a year. Italian rye grass is a favourite crop on sewage farms, the reason being that it grows so rapidly and closely that weeds are kept down—an important point in land treatment.

That no hard and fast rule, or definite figure, can be given as to the area required for any particular case of land treatment will be evident from the following extract from the Fourth Report of the Royal Commission: "We doubt whether the most suitable kinds of soil, worked as a filtration farm, should be called upon to treat more than 30,000 to 60,000 gallons per acre per twenty-four hours at a given time (750 to 1500 people per acre), or more than 10,000 to 20,000 gallons per acre per twenty-four hours calculated on the total area of irrigation (250 to 500 people per acre). Soil not so well suited, worked as surface irrigation, or combined surface irrigation and filtration, 25 to 50 persons per acre."

The sewage in the foregoing cases is regarded as settled in tanks before applying it to land. It is also impossible to lay down any hard and fast rule as regards the proper proportions between the area being irrigated at one time and the surplus resting or aerating, but the Commissioners suggest that fourfifths of a surface irrigation farm, and two-thirds of a filtration farm, should be at rest. The Commissioners in effect also express their inability to say whether slow or rapid alternations of work and rest are advisable.

The Commissioners lay much stress on the fact that the success or failure of a sewage farm lies largely with the management, and point out that there is much temptation to try and grow remunerative crops, pointing out that the farming operations should be relegated to the background, and the production of a good effluent come before everything else.

It is seldom that a farm has no aids to purification in the way of screens, sedimentation tanks, or other works, but such features will be dealt with later. It is also advisable to have an artificial filter of broken stone or other suitable material, to help matters forward in case of emergency. This filter should have a dose of sewage now and then in any case, to keep it in condition.

The land drains should not be of less diameter than 3 inches, and there is no advantage in putting them deeper than from 4 to 5 feet below the surface.

For irrigation, shallow earth carriers are usually formed with stop boards fixed on semicircular iron plates, with handles, to be used as a means of damming the sewage at any point and so causing it to overflow the sides of the carrier. The main carriers are of concrete or brickwork, with penstocks or valves controlling their outlets.

It will be obvious that if the areas are interchangeable for both irrigation and filtration, the whole must be underdrained.

We may next consider the various principal mechanical and artificial processes in connexion with sewage treatment.

Various foreign matters find their way into sewage, such as road metal, rags, brushes, corks, etc., and it is desirable in all cases to remove them by screening. There are many forms of screen, the commonest form consisting of a framework carrying a series of flat bars at intervals of about $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, the screen being inclined at an angle of about 30° to the vertical and the bars bent over at the top in the direction of the sewage flow. The screen is kept clear by frequent raking, either by hand or machine. In large works mechanical devices are almost always used for keeping the screens clear. Where the screens are at a good depth below the ground, they are generally in duplicate, sliding vertically, so that they can be readily raised and cleaned. Other forms of screen are endless bands of copper-wire netting, and circular, revolving, perforated plates.

Where screening is not adopted, the coarse mineral matter should be intercepted in a detritus or grit chamber. Often both screens and detritus chambers are used. The detritus tanks are relatively small and should be in duplicate, so that one can be in use while the other is being cleansed. They can be constructed of concrete.

Sedimentation, or settling, tanks are not unlike what is now well known as a septic tank, the difference lying in the fact that in the former the sludge is much more frequently removed than in the latter. They may be worked on a continuous or intermittent principle; that is to say, the sewage may continuously flow through them at a very low velocity, or they may be filled and allowed to stand for a time before being emptied. They should be in duplicate to facilitate cleansing; should have a depth of about 6 to 8 feet, and a total capacity of about 50 per cent of the dry weather flow. They are usually of concrete.

Some years ago the use of similar tanks, for the purpose of expediting settlement of the solids by the aid of chemicals, was very general, but in recent years the idea of the septic tank has caused the principle of chemical precipitation to fall rather into the background. The Reports of the Royal Commission, however, are so favourable in their mention of this practice, that it is a point calling for more than passing mention.

If suitable chemicals are added, the settlement of the solids is considerably expedited, but the process gives rise to rather a large proportion of sludge, a substance which is not easily disposed of. When the septic tank was introduced, it was thought that the sludge trouble was disposed of, and that the new process would produce none. This, however, has proved a fallacy, and the sludge trouble still remains with us.

Chemical treatment dates from the year 1740, when it was first introduced in Paris.

The system is one calling for rather more attention during working than some of the later systems. The tanks can be worked on either the continuous or the intermittent principle, are usually of rectangular plan, from about 6 to 8 feet in depth, and usually of concrete. The rectangular plan has some drawbacks, principally that they require a fair amount of fall, and in recent years they have often been made in the form of sectors of a circle, grouping the controlling valves at the centre. In the "Dortmund" tank, for example, the group of tanks forms a vertical cylinder with the floor shaped like an inverted cone. In a later form, the "Candy" tank, the circular plan is retained, but the floor is level. The sewage enters, in this case, near the floor and the effluent leaves the tank near the top. The sludge is siphoned out by an ingenious arrangement which utilizes the hydrostatic pressure in the tank itself, the process taking only about a quarter of an hour, so that the tank need not be put out of use.

Like all sewage tanks, the precipitation tank should be of watertight construction. The chemical precipitant is added to the sewage, and in the ordinary way is well mixed by passing it into a tank containing baffle plates, or else is mixed by the aid of a wheel of somewhat the same form as a paddle wheel.

The total tank accommodation should be equal to about 50 per cent of the dry weather flow of sewage, and the tank should be at least in duplicate. The available site may make it more convenient, in some cases, to have several small tanks rather than two or three large ones.

The inlets and outlets of precipitation and settling tanks are usually weirs. About 3 to 6 inches from each end scum boards are placed right across the tank, extending down into the sewage to prevent a current across the surface from weir to weir. In the case of a rectangular tank, the floor is usually made to fall about 1 in 50 towards the inlet end, as the larger proportion of sludge is precipitated at that end. This is not with the idea of discharging the sludge by gravitation, as sufficient fall for that is not often available, nature having to be aided by the use of squeegees, perforated pipes, etc.

Although inlet and outlet weirs are provided, it is desirable to empty precipitation tanks at fairly frequent intervals, and this is often done by means of a floating arm to the outlet pipe. The open end of the outlet pipe is held up by floats, there being a swivel joint at the junction of the floating arm and main outlet pipe. When the liquid rises to the required level, the outlet comes into operation, a sluice valve being closed when the level of the sludge is reached.

Very many chemicals have been used for the purpose of precipitating sewage. One of the oldest methods is to add lime in the proportion of about 6 to 10 grains of lime to 1 gallon of sewage. Where an excess of lime is used, the effluent becomes too highly charged with it, resulting, when turned into a stream, in the precipitation of organic matter and injury to fish life. Other chemicals are, therefore, often used in conjunction with the lime, such as sulphate of alumina or sulphate of iron. The lime treatment is particularly good for sewage containing brewery and dyeworks wastes, but is unsuitable for small works owing to the expense of the machinery necessary for grinding the lime, mixing it with the sewage, and so on.

Another well-known precipitant is alumino-ferric, a material rich in alumina and iron. About 10 to 20 grains to the gallon of sewage is needed as a rule. The material can be obtained in the form of blocks, which can be suspended in wire cages, making the system very suitable for small works. Other processes of precipitation utilize ferozone (a material containing alum, copperas, and magnetic oxide), herring brine, clay, carbferalum, etc., but it is unnecessary to give an extended notice of their use.

Electrolytic methods have been tried in connexion with sewage treatment by precipitation, but not on any large scale.

Any preliminary treatment, such as sedimentation, precipitation, or sceptic tanking, may be followed by either land or artificial filtration. The method of treating the sewage on land has already been dealt with, and the construction of artificial filters will be presently referred to.

While, as has been pointed out, the treatment of sewage on land only is a bacterial process, it was not recognized as such until comparatively recent times, when the subject of bacterial treatment was being seriously taken up, and everything being done in the way of utilizing, to the utmost, the value of bacteria for the purpose of purification. The credit of being the first to put to practical use the fact that certain bacteria possessed the power of liquefying organic matters, is due to Mr. Scott-Moncrieff, who introduced an upward flow bacteria bed in 1891. The bed was formed of coarse flints and the effluent then passed through a series of trays, a method only applicable on a small scale. Notwithstanding this, the name of Mr. Scott-Moncrieff will always be associated with the subject of purification, owing to his valuable experimental work and influence on details.

A few years later, about 1896, the septic tank was introduced by Mr. Cameron, of Exeter, the sewage being run into a long, covered, watertight tank, where it became subject to the liquefying, or as has more recently been alleged, the gasifying influence of anaërobic organisms. It was thought that the sludge problem had been solved and that all the sewage would be absolutely liquefied, but, unfortunately, this has been shown to be far too sanguine a view. In many cases there is not very much less sludge than from a precipitation tank. The effluent from the tank is then passed on to artificial filters.

A year or so before the advent of the septic tank, Mr. Dibdin, then chemist to the London County Council, was experimenting on their behalf in regard to filtration. The Council laid down a filter of one acre in extent, composed of a depth of 3 feet of coke breeze and 3 inches of gravel, through which over a million gallons of sewage was filtered per day. The outlet of the filter was closed and the sewage allowed to run on to the filter until it was full. The latter was then allowed to stand full for an hour, and finally emptied and drained dry. This was the origin of the contact method of working bacteria beds—a method adopted with the septic tank when that was introduced, and largely adopted since.

A common method of working contact beds is on an eight hours' cycle: 1 hour filling, 2 hours standing full, 1 hour emptying, and 4 hours aerating or resting, which allows of three fillings in 24 hours. In many places a practice of two fillings a day is adopted.

Septic tanks can be either open or closed, there being but little to choose between them from the point of view of the digestion of the solids. From the point of view of nuisance by smell, a closed tank is the better, and the increase in cost is amply justified. In the case of a small tank for, say, a county house, the point is of no great importance if a suitable position is obtainable for the tank, far enough away from both house and roads.

Following the introduction of the septic tank came the work of Colonel Ducat and Mr. Dibdin, both applying crude sewage to the filter, the former on the continuous and the latter on the contact system. Mr. Dibdin's first installation of contact beds for the treatment of crude sewage was laid down at Sutton, the system becoming known as the Sutton system in consequence. There is a strong tendency to clog the filter in such a method, and though many attempts have been made to purify sewage by aërobic processes alone, the general consensus of opinion is in favour of the use of preliminary tank treatment of some sort.

The alternative to a contact bed is a continuous, percolating, or trickling filter, in which the effluent can be better aerated than in the former. The volume of air which can follow the filling and emptying of a contact bed is merely the volume of the charge of sewage, whereas with a percolating filter a thin layer of sewage is followed by any desired volume of air before a fresh application of the tank liquid. The details of filters will be dealt with later.

Valuable experimental work has been done in recent years by Dr. Owen Travis, of Hampton, who introduced a very novel successor to the ordinary form of septic tank, and which he has termed the Hydrolytic tank. Dr. Travis' conclusions have been the cause of much discussion among engineers, chemists, and bacteriologists engaged in sewage purification research, since his theories tended to somewhat disturb others that had become fairly well established. The so-called soluble organic matter in sewage has been found to be largely colloidal in nature, and the greatest importance must be attached to its removal owing to its putrefactive tendency. The term colloid is applied to matters in the nature of jelly, as opposed to crystalloids. Dr. Travis alleges the so-called liquefaction of the solids in the septic tank to be really a gasification, and points to the larger volume of sludge in support of his view.

Mr. A. E. Collins, M.I.C.E., the City Engineer of Norwich, in a paper read before the Institution of Municipal and County Engineers, states that he has been forced, against his own prejudices, to the conclusion that the Hampton experiments have proved the prevailing practice of sewage disposal to be one of error, pointing out that the liquid portion of the sewage is not appreciably benefited by a tank operation, and is, in fact, when such operation is a long one, injuriously affected by saturation with gases evolved by decomposing sludge. This contains solids which require eliminating and treating, from the coarse suspended matters down to infinitesimally small colloidal particles, ordinarily regarded as solids in solution. These latter are only depositable when brought into very intimate contact with surfaces. The action of the ordinary septic tank is such that sludge is formed below, and part is forced up by gasification to form a thick scum, until a relatively small channel remains, through which the sewage, often with solid fæces and unaltered paper, goes direct to the effluent channels, and so on to the filters, the accumulating sludge causing an increasingly foul character in the effluent.

Mr. Collins ably summarizes the principles of the hydrolytic tank thus:—

1. To exclude from any prolonged tank operation as large a proportion of the liquid as possible.

2. To effect the sedimentation of the depositable contents of the sewage in such a way as to avoid the rising floor of sludge, by substituting therefor a disappearing floor of liquid.

3. To separate the hostile forces of deposition and gaseous eruptions by limiting these operations to their own separate compartments.

4. To prevent undue accumulations of scum and sludge by periodically withdrawing that proportion which the special method of operating the tank may dictate.

5. To correct the frequent outrush of disturbed deposited

matters, the result of gaseous eruptions, by the re-deposition and removal of such solids in an additional chamber known as a hydrolising chamber.

6. To submit the entire volume of liquid to the attracting influences of self-cleansing surfaces, in order to abstract as large a proportion of the finer suspended and colloidal parts as possible; and

7. To continuously maintain the predetermined capacity of the tank.

A brief illustrated description of the essential parts of the Norwich installation is given later.

Mr. Dibdin, the pioneer before referred to, has also done further valuable experimental work in recent times, with a view to showing that sewage could be treated by aërobic processes only. Continuing his original idea of contact beds, he brought out a primary contact bed containing large horizontal slabs of slate, separated from one another by means of cross pieces. He claims that crude sewage can be considerably purified in such beds, and that the sludge which accumulates in them can be periodically flushed out with water.

The slate bed has proved to be of considerable value as a preventative of smell and nuisance, and it seems fairly well established that they do not lose their liquid capacity to any appreciable extent. The Commissioners state that the slate bed sludge differs from ordinary sewage or septic tank sludge in that it possesses only a slight odour, resembling that of seaweed.

Having now outlined the lines along which the question of sewage purification has advanced, the details of the parts of such systems may be investigated.

The submitting of an effluent to one contact bed only is termed a single contact process, and does not give a sufficiently high degree of purification. If the effluent is passed through two contact beds in succession, the process is known as double contact, which is the usual, and if through three beds, triple contact, which is unusual. A very usual depth for contact beds is about 4 feet, but they range from about $2\frac{1}{2}$ to 6 feet. The usual water capacity is about one-third of the gross capacity, the other two-thirds being occupied by the filtering medium. The quantity which can be properly purified per day, however, depends on the strength of the tank effluent and the condition of the filter, and ranges from about 50 to 100 gallons per cubic yard of filtering medium per day. The beds must be watertight and the total area should be divided up so that the maximum size of a single bed does not exceed about two hours dry weather flow, which ensures quick filling and emptying, and satisfactory working generally. In the case of double contact, it is usual to place the second bed at such a level that the first bed can be readily discharged on to it. A finer material is used in the second than in the first, since the object of the first is to "take the rough off," so to speak. A common practice is from $1\frac{1}{2}$ to 3 inches gauge for the first beds, and $\frac{3}{4}$ to $1\frac{1}{2}$ inch for the second, although much finer material is often used.

The floor and walls are usually of concrete, and the drains on the floor are arranged in one or other of the following ways :—

1. Some form of false floor made of specially shaped tiles.

2. Semicircular channels in the floor, covered by perforated tiles.

3. Semicircular tiles with perforations on the top or back of the semicircle.

4. Interlocking tiles forming drains in section like an inverted V. In either case the drains are laid to fall to main effluent channels.

The floors of continuous or percolating filters are formed in the same way.

The inlets and outlets of contact beds are usually controlled by means of automatic gear, a description of which is beyond the scope of this introduction to the subject.

The percolating filter is distinctly different from the contact bed so far as the method of working is concerned. The outlet is allowed to remain open, and the tank liquid is applied in the form of a fine spray, by automatic or other means, so arranged that alternate layers of sewage and air pass through the filter.

The pros and cons of the two methods have been summarized by Dr. Barwise, the Medical Officer to the Staffordshire County Council, as follows:—

With contact beds the sewage need not be so carefully distributed, whereas with percolating filters the sewage must be carefully and intermittently distributed by expensive means.

With contact beds the size of the filtering medium need not be so carefully graded, whereas in the other case it should not exceed from $\frac{1}{4}$ to $\frac{3}{4}$ inch diameter or gauge.

Contact beds must have watertight walls, whereas percolating filters are often formed with walls of very open construction, often above ground, or with no walls at all.

Double contact is required to give results approaching that obtained from one percolating filter.

With contact beds the oxidation is limited, as the air supplied only equals the volume of sewage treated, while the air supplied to percolating filters may be as much as five or six times the volume of sewage, thereby giving greater oxidation.

With contact beds the sewage, being stagnant, has a greater tendency to plug the bed up, while, in the other case, such little plugging as there is is on the surface, and the filter does not deteriorate if well made.

Lastly, percolating filters will do about four or five times the work per day that can be done by contact beds of equal area.

Various materials are used for the filtering medium, including hard furnace clinker, hard coal, coarse gravel, broken granite, coke breeze, and burnt ballast. The last two, however, are liable to disintegration, and their use is not always advisable.

The walls of percolating filters may be of concrete, dry rubble, or brickwork, either solid or honeycombed. The floor may also be of concrete. Sometimes both floor and walls are formed by a simple excavation in clay, but the clay is apt to work up and choke the drains.

There are many forms of sprinkler for applying the sewage over the top of the filter. The original form was the fixed distributor, which varied in form from wooden troughs with notches in the sides, and iron troughs with holes perforated low down in the sides, to perforated sheets of corrugated iron with projecting points on the under side of the holes, the latter being known as the Stoddart system. Fixed spraying pipes were next introduced. For small installations, horizontal pipes with holes in the sides, and, in larger cases, such as at the Birmingham sewage works, 3-inch pipes, 9 feet apart, with vertical jets 4 feet 6 inches apart. This latter system is one to be greatly condemned on sanitary grounds. The spraying up into the air of partly purified sewage, the germs of which can be taken up by every wind that blows, is a practice that must soon become obsolete, as it cannot but be a nuisance at times.

The next innovation was the revolving sprinkler operated by the sewage on somewhat the same principle as the lawn sprinklers in such common use. This form consists of a central column carrying radiating pipes with perforations on one side only, the column and its arms revolving by reason of the reaction of the jets. In some cases very large distributors of this kind have been used, the arms being given support on rails. The arms, if long, must be supported by steel stays or guy ropes.

Another type of sprinkler is the Fiddian, the radiating arm being in the form of elongated water wheels of small diameter with long buckets of small section round the circumference, fed by a pipe parallel to the distributing wheel.

The great drawback of all the revolving sprinklers is that they necessitate filters of circular plan, and are therefore by no means economical in the utilization of space. From the latter point of view, the rectangular filter is the best, and ingenuity has therefore been devoted to the production of power-driven distributors, self-reversing, and fed by siphonage from an effluent channel alongside the filter. The first reversible power-driven distributor was designed in 1902, by Messrs. Wilcox & Raikes, for use at Hanley, and is said to be very efficient. It consists of a perforated iron pipe the full width of the filter, 60 feet, fed with sewage by siphonage from a central channel, and drawn backwards and forwards by a wire rope driven by an electric motor, the motion of the rope being automatically reversed as required.

Septic tanks can, as already stated, be either open or covered, and are usually constructed of concrete or ferro-concrete. Their usual capacity is from about one to one and a half days' dry weather flow, which can include the capacity of the adjoining detritus tank, the latter having room for say two to three hours' dry weather flow. Both the inlet and the outlet are either submerged or protected with scum boards. The usual shape is rectangular and the usual depth about 6 to 7 feet, the length being about three or four times the width. For large works the tanks should be at least in duplicate to permit of cleaning out and repairs.

One of the greatest troubles in sewage works of any size is the disposal of sludge. The principal methods are the following:—

1. Conversion into a marketable manure, as is done at Kingston-on-Thames, where "Native Guano" is produced, and at Glasgow, where "Globe Fertilizer" comes from.

2. Barging it out to sea—a cheap process for places conveniently situate for so doing. This is done in the case of London, Manchester, Southampton, and other places.

3. Pressing into cakes in special presses, afterwards disposing of it to farmers if it has any manurial value, mixing it with house refuse and burning in a refuse destructor, or burying it in the ground.

4. Shallow burial of the crude sludge in the ground. V-shaped trenches, about 2 feet wide, and about 1 foot deep, have wet sludge run into them, and immediately covered over by shovelling back the earth. The land is allowed to absorb the sludge, and is then ploughed up, being used either for crops or more sludge.

5. Lagooning or air drying. In this method large earth tanks are excavated, from 1 to 6 feet deep, and filled with sludge, which is allowed to evaporate and drain away until the remaining matter can be dug out and dumped on waste land. This is a poor method and is condemned by the Royal Commission as undesirable.

6. Covering flat land with a layer of a few inches of the wet sludge. This rapidly dries, but the system is unsuitable for strongly smelling sludge.

7. Burning the sludge in a refuse destructor. Many attempts have been made to burn wet sludge in combination with other matters, such as house refuse, but without success. If carefully carried out, however, pressed or dried sludge can be dealt with in this way.

8. In some few places where the sewage is of an unusual nature, works have been installed for the recovery of valuable constituents such as fat. Mr. A. E. Collins, the City Engineer of Norwich, who is well known as a pioneer in municipal engineering, successfully installed a system on these lines at the sewage works of that city. The sludge is first submitted to a "wet carbonizing" apparatus, where it is changed from a

mucilaginous to a granular character. It is then passed through filter presses, and the cake is dried and passed on to a de-greasing apparatus, where the grease is extracted with benzine. The refuse is then dried to less than 10 per cent of moisture, and sold for manure.

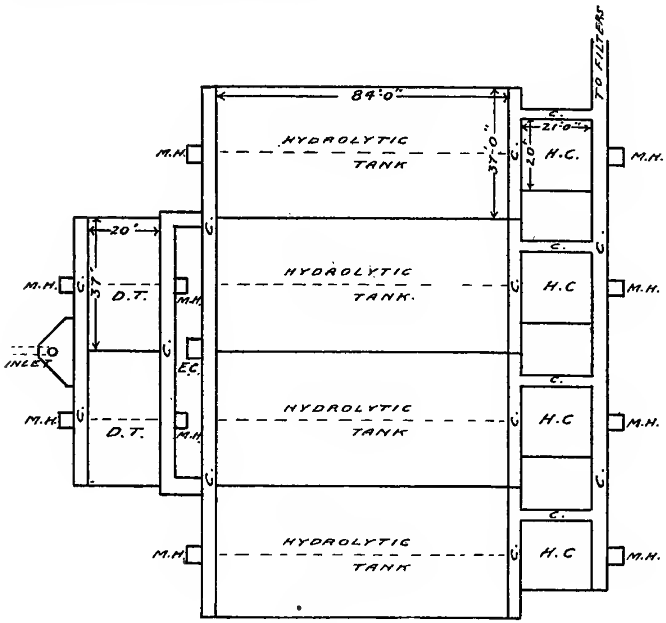
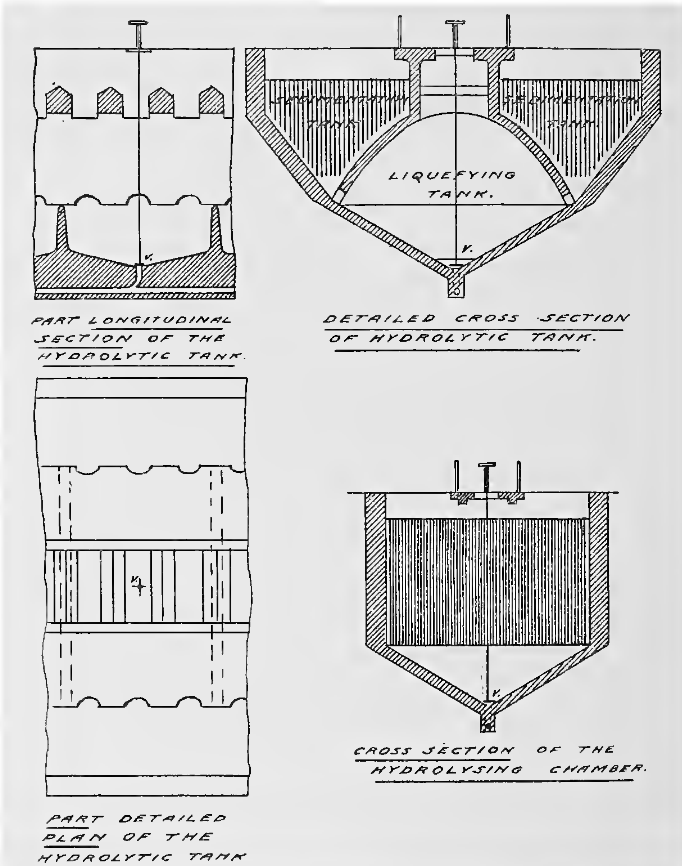


Fig. 346.

It is considered beyond the scope of the present work to deal largely with the methods of arranging sewage works on a large scale, but one example may be given, that of the installation of Travis' tanks at Norwich, before referred to. Fig. 346 shows an outline plan of the tanking part of the installation. The sewage passes through a detritus tank (of the same section as the hydrolytic tank), then into a hydrolytic tank, and afterwards part of it through an adjoining hydrolysing chamber. The effluent then passes on to filters in the usual way. The detritus tanks have an average depth of about 20 feet, and the hydrolytic and hydrolysing tanks a maximum depth of about 22 feet. The bulk of the liquid passing through the hydrolytic tank passes on to the effluent channel direct, the fouler matters passing through the hydrolysing chamber before reaching the same channel. The sludge is conducted, by drains running longitudinally under each hydrolytic tank, to a chamber E.C. from which it is elevated and disposed of. Figs. 347-350 show details of the tanks. From Fig. 348 it will be seen that the tank is divided into three compartments by a longitudinal arch-shaped division, that shape being used for constructional reasons, the upright walls at the centre being kept apart by buttresses, shown in section in Fig. 347 and on plan in Fig. 349. The arch has openings at its base and at the top for liquid communication, the former in the form of segments of a circle, and the latter between the buttresses. The two side compartments are devoted to sedimentation and the centre one to sludge reduction. Each hydrolytic tank is divided into six compartments, one of which is shown in Fig. 347, their floors falling to a central point at which there is a valve guarding the sludge outlet. On starting the tanks at work, sewage entered by the side chambers only, the first volume flowing into them passing through the segmental openings into the central chamber, which became gradually filled. As the sewage continued to flow, it rose equally in all the chambers until the level of the weirs at the end was reached. On the tank becoming thus full, the proportion of liquid carried by each chamber is settled by the width of its weir. The lower portion of the flow in the side chambers forms a disappearing floor into which the depositing solids fall, and by which they are conveyed to the central liquefying tank.



Figs. 347-350.

It will be seen that the principle of excluding the bulk of the liquid from a prolonged tank operation is accomplished by this arrangement.

It is, however, necessary to add a description of the colloidal properties of the tanks, and the method of dealing with colloidal matters. It has been pointed out that the colloidal matters should be brought into intimate contact with self-cleansing surfaces, and, with this object in view, about five-eighths of each hydrolytic tank is provided with "colloidors" in the form of wood splines or strips, as shown by the vertical lines in the sedimentation tanks in Fig. 348. These are hung vertically, and are only placed in the side chambers. The deposits of colloidal matter on these splines, when their weight overcomes the power of attraction, fall away into the central chamber, to be reduced by anaërobic action. A travelling scum board, fitted with long bass, such as is used for brooms, sweeps the tops of the colloidors as it passes up and down.

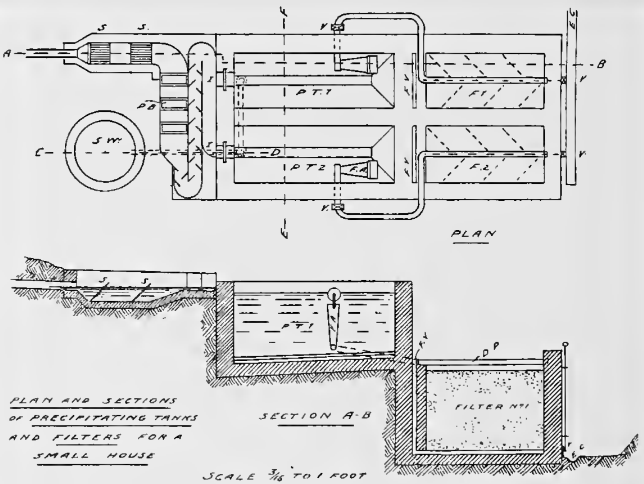
The tank is so arranged that the flow through the central, or liquefying chamber, is much slower than through the side chambers, the sewage taking ten hours thirty-two minutes to pass through the former, and three hours forty-five minutes to pass through the latter. In the case of the detritus tank, which is of similar section, the times are sixty-five minutes and twenty-three and a half minutes respectively, and in the hydrolysing chamber three hours thirty-six minutes.

The scum forming on the surface in either of the chambers is systematically drawn into scum channels. This point is particularly worthy of note, as the scum has always, hitherto, been considered a desideratum in a septic tank, whereas under this system it is alleged to be a detriment, on the ground that it prevents the free escape of the gases which are generated.

The cross-section of the hydrolysing chamber, through which the contents of the liquefying tank pass, to finish them off so to speak, is as shown in Fig. 350, the bottom of the chamber being formed in the same way as those of the other chambers. The liquid enters towards the bottom of their chamber and flows forward and upward to the outlet weir. It will be noted that this installation makes an exceptionally good provision for the removal of the sludge.

The system has the conspicuous merit of being based on sound principles, though expensive to instal.

One or two examples of small installations may now be given for the disposal of the sewage of country houses, or small institutions which are not connected to public sewers.



Figs. 351, 352.

Figs. 351-354 show details of a chemical precipitation system. Fig. 351 shows a plan of the scheme. The sewage enters at A and passes through two screens; it then passes along an iron channel containing three precipitating boxes or cages, P.B., containing, say, blocks of alumino-ferric. It passes along a further length of channel, in which are a series of baffle plates to thoroughly mix the precipitant with the sewage, which then enters, through either of two inlets, I, precipitating tanks, P.T.1 or P.T.2. The effluent from these is conveyed by floating arms, F.A., to distributing pipes lying over the centres of the filters. Each filter is ventilated by a filter vent, F.V., and the effluent passes down through the filter and out through a valve, V, into the effluent channel, E.C. The sludge from the precipitating tanks passes to a sludge well, S.W., the entrance to which is controlled by the valve, V, shown in Fig. 353. The inlets to the precipitating tanks are in the form of sluices, shown in Fig. 354, that of the precipitating tank, P.T.2, being shown closed and that of P.T.1 being shown open. The sludge can be removed from the sludge well by means of

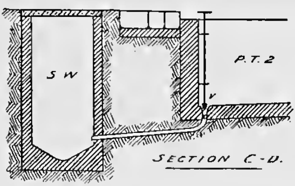


Fig. 353.

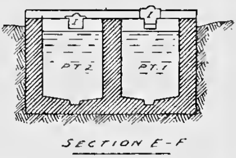


Fig. 354.

an ordinary farm yard, or chain, pump, and conveyed to the kitchen garden by a trough or channel.

In Figs. 355-357 a septic tank installation is shown, the system involving the use of a covered septic tank and successive filtration. Such a system is applicable to the case of a house on a hill-side, or any position in which a good fall is obtainable. The sewage enters at A, passing through the inlet chamber, I.C., and the grit chamber, G.C., from which it enters the septic tank. The tank, as shown in Fig. 356, is covered and ventilated, and has two manholes for access. Both inlet and outlet are submerged, and the sewage passes into the ponding chamber, P.C., from which it can circulate through the circulating chamber, C.C., as shown in Fig. 357. It will be noted that there are non-return valves, V.V., between the

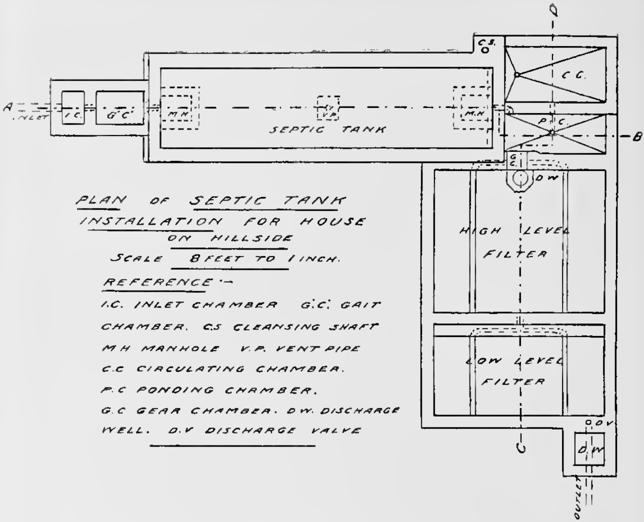
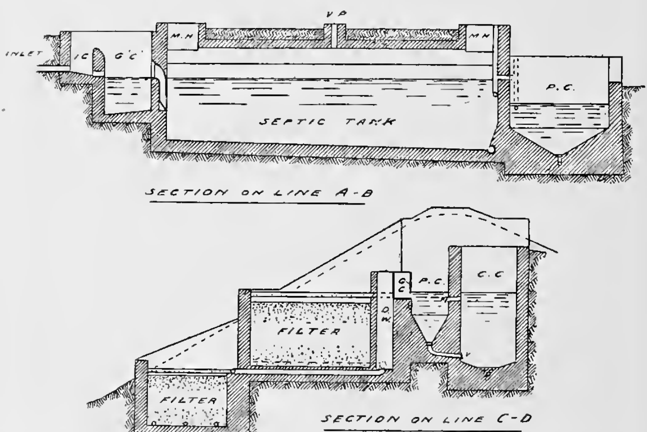


Fig. 355.



Figs. 356, 357.

ponding and circulating chambers. From the ponding chamber the tank liquid passes into the automatic gear in the chamber G.C., and thence into two distributing pipes over the top of the high-level filter. The effluent from this filter is collected in drains on its floor, leading to the discharge well, D.W., adjoining the ponding chamber, and from there it is permitted to pass to the low-level filter, from which the final effluent is discharged into the nearest water-course. The sludge from the septic tank is collected through a special form of perforated

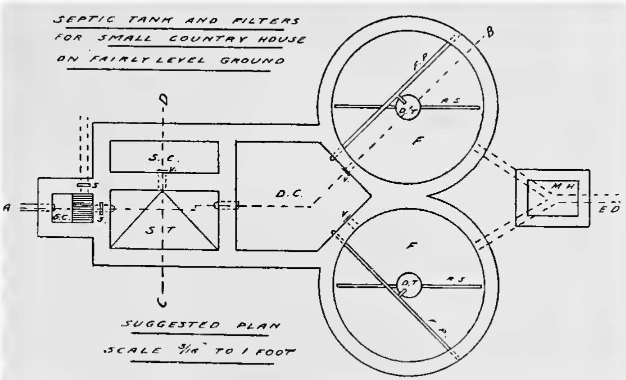
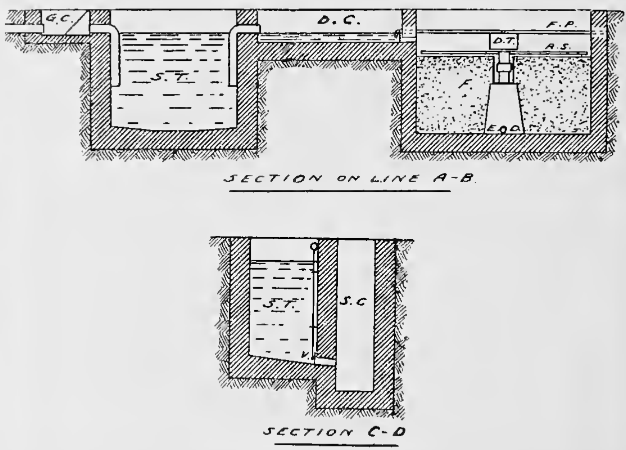


Fig. 358.

pipe, P.P., and led to a cleansing shaft, C.S., the floor of the circulating chamber connecting with the same pipe. From the cleansing shaft the sludge can be led in any desired direction.

This example involves a covered tank and a good fall. The next applies to a case in which the land is flat, and the open tank can be put at such a distance from the house and road as not to permit of nuisance from smell. See Figs. 358-360.

The sewage enters a grit chamber, G.C., in which is a screen. From the grit chamber an overflow or emergency drain is shown in dotted lines, the entrance to it being controlled by a small sluice, S. The sewage passes from the grit chamber, past a sluice S, to the septic tank, S.T., the inlet being submerged. The floor of this falls, leading past a valve, V, to the sludge chamber, S.C., from which the sludge can be removed by pumping or other means. The outlet for the liquid from the septic tank is submerged, and leads to a dis-



Figs. 359, 360.

tributing chamber, D.C., a very shallow chamber as shown in Fig. 359.

Adjoining the distributing chamber are two filters, F, of circular plan. In the centre of each is a collecting or dosing tank, D.T., which actuates a rotary sprinkler, R.S. The dosing tank is fed from the distributing chamber by a feed pipe, F.P., and the chamber can be flushed out by means of a valve, V, leading direct to the filter.

The filtered effluent passes from the bottom of the filters into the effluent drain, E.D., a manhole being placed near the filters for the purpose of sampling the effluent from them.

The three examples just given will serve the purpose of showing the methods of treating varied conditions from varied points of view. It is beyond the scope of this work to go into the details of the automatic gear used by the Septic Tank and other Syndicates, and it is, perhaps, wise to point out that any such scheme as the foregoing should be left, as regards its details, in the hands of a specialist firm.

If an open septic tank is used near a house or a road, there is likely to be nuisance from smell. This difficulty is to a large extent obviated by using covered tanks, but an alternative method is to put, between the septic tank and the filters, a chemical precipitation tank.

During the last quarter of a century the question of sewage disposal has been in a rather chaotic condition, and the Royal Commission, before referred to, was appointed to consider the following points:—

1. (*a*) What method or methods of treating and disposing of sewage (including any liquid from any factory or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and

(*b*) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage.

The Commission pursued its investigations for seventeen years and issued ten Reports, the last being published in the year 1915.

The work of the Commission has been very thorough throughout, and its conclusions give the latest official opinions on this important subject. It is therefore proposed to give a brief summary of them.

The First Report was issued in 1901, and contained the following conclusions :—

1. No land is entirely useless for purification of sewage, but in the case of stiff clay or peat lands the power to purify sewage seems to depend on the depth of the top soil. The use of such lands for the purpose is always attended with difficulty, and, where the depth of top soil is very small, say 6 inches or less, the area of such lands which would be required for efficient purification would, in certain cases, be so great as to render land treatment impracticable.

2. The Commissioners express themselves as satisfied that it is practicable to produce by artificial processes alone, either from sewage, or from certain mixtures of sewage and trade refuse, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance.

3. Generally speaking, in effluents from sewage farms, there are fewer micro-organisms than in effluents from artificial processes, but both classes of effluent usually contain large numbers of organisms, many of which appear to be of intestinal derivation, and which might, under certain circumstances, cause disease. Such effluents must therefore be regarded as potentially dangerous.

4. It is of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers. In the present state of knowledge, and especially of

bacteriology, it is difficult to estimate these dangers with any accuracy. The general protection of our rivers is a matter of such grave concern that it demands the creation of a separate Commission, or a new department of the Local Government Board, which shall be a supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, when appeal is made to them, shall have power to take action in cases where the local authority has failed to do so.

The Second Report, issued in 1902, dealt with the experiments being carried out by the officers appointed by the Commissioners.

The Third Report, 1903, dealt principally with the question of trade wastes :—

The Commissioners recognized the diversity of practice, on the part of local authorities, as to receiving or refusing trade wastes, and the fact that manufacturers were thereby hampered, and also that the cost of purification of such wastes by the manufacturer would be more costly than their purification by the local authority.

The local authorities should be under obligation to take trade wastes.

The Commissioners therefore conclude that the law should be altered, so as to make it the duty of the local authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers of the local authority if he wishes to do so.

In each district it would probably be desirable that the local authority should frame regulations which should be subject to confirmation by a central authority. The regulations could provide definite standards as regards preliminary treatment, with power to vary them or dispense with them. The

Commissioners say: "Although the duty of receiving trade effluents should, we think, be imposed on the local authority, cases may arise in which they should be wholly or partially relieved of it," and so they go on to recognize the fact that some tribunal should be set up to deal with disputes between the parties. The idea of the Commissioners is a Central Board possessing adequate technical knowledge, such as the Supreme Rivers Authority referred to in their First Report.

The Commissioners also recommended that, for the due protection of rivers, Rivers Boards should be formed, and that these boards should be empowered to determine, subject to appeal to the central authority, certain of the differences between local authorities and manufacturers. Further, that a part of the duty of such Rivers Boards should be the inspection of public water supplies.

The Fourth Report was issued in 1904, dealing with the pollution of tidal waters, particularly in reference to the contamination of shell-fish. In this Report the Commissioners suggest still another new Government Department in the form of a controlling authority, although they express the view that the work could be adequately done by the central department, presumably the central authority before referred to, since a later paragraph in the Report says that the necessary power of control over the pollution of tidal waters, and over waters, foreshores, pits, ponds, beds, and layings where shell-fish are grown, fattened or stored, should be vested in the Rivers Boards, subject to appeal to a central authority.

The Fifth Report, which was issued in 1908, is a rather more important one, and calls for a more detailed notice. The most important of the conclusions of the Commissioners are as follows:—

"It is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and there is no essential difference between the two processes.

"We find that it is generally desirable to remove from the sewage, by a preliminary process, a considerable proportion of the grit and suspended matters, before attempting to purify the sewage on land or filters."

The Commissioners go on to say, in reference to sedimentation tanks, that if the tanks are worked on the intermittent principle, two to three hours' quiescence should be sufficient for any ordinary case, whereas in the continuous flow system the time taken in passing through the tank should be from ten to fifteen hours, the tanks being cleaned out once a week.

As to septic tanks, the Commissioners conclude that the actual amount of digestion of the solids depends on the character of the sewage, size of tanks, and frequency of cleansing. Further, that the liquor issuing from septic tanks is, bacteriologically, almost as impure as the sewage entering the tanks, and that the septic tank system is really no better than chemical precipitation or simple sedimentation.

As regards digestion of sludge, and quality of tank liquor, a closed tank possesses no advantages over an open one, but there is less risk of nuisance if the tank and the feed channels to the filters be covered in.

By passing septic tank liquor through tanks of a size sufficient to hold about one-quarter of the day's flow, with the addition of from two to three grains of lime per gallon to the liquor, the suspended solids in the liquor are materially reduced, a considerably larger quantity of the liquor can be treated per cubic yard of filter, and the offensive character of the liquor is largely destroyed.

It is generally desirable to subject sewage containing certain trade waste, and strong sewage, to chemical precipitation, which facilitates subsequent filtration.

In precipitation on intermittent lines two hours' quiescence is usually sufficient, and with continuous flow such a velocity through the tank that the sewage will remain in it for eight hours.

Within ordinary limits, the depth of a contact bed makes practically no difference to its efficiency per cubic yard, but the Commissioners advise a depth not greater than 6 feet, and not less than 2 feet 6 inches.

In the case of percolating filters, the greatest efficiency can be got from fine material by making the filter shallow, rather than deep. With coarse material, however, the Commissioners consider that the same efficiency is obtained from either shallow or deep filters assuming the same quantity of liquid to be treated per cubic yard in each case.

Taking into account the gradual loss of capacity of contact beds, a cubic yard of material, arranged in the form of a percolating filter, will generally treat about twice as much tank liquor as a cubic yard of material in a contact bed.

Percolating filters are better adapted to variations of flow than contact beds.

Effluents from percolating filters are usually much better aerated than effluents from contact beds, and apart from suspended solids, are of a more uniform character; but the risk of nuisance from smell is greater with percolating filters than with contact beds, and with percolating filters there is apt to be nuisance from flies.

There is no essential distinction between effluents from land and effluents from artificial filters, though the effluents from particularly suitable soils contain only a very small quantity of unoxidized organic matter and are of a higher class. On the other hand, effluents from unsuitable soils are often very impure.

All the trade effluents of which the Commissioners have had experience interfere with or retard processes of purification to some extent, but they are not aware of any case where the admixture of trade refuse makes it impracticable to purify the sewage upon land or by means of artificial processes, though special preliminary treatment may sometimes be necessary.

The nuisance from smell at sewage works is apt to be considerably greater where the sewage contains brewery refuse, and less where refuse of a kind containing iron salts and tarry matters is dealt with.

If a sufficient quantity of good land, to which the sewage can pass by gravitation, can be purchased for about £100 per acre, land treatment would usually be the cheapest method of sewage purification.

Where the liquor to be treated contains much suspended matter, coarse filtering material is the better, but where the preliminary treatment has effectively removed the greater part of the suspended matter, fine material is the better.

As a general rule, special stand-by tanks (two or more) should be provided at the works, and kept empty for the purpose of receiving the excess of storm water which cannot properly be passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks, our experience shows that in storm times the rate of flow through these tanks may usually be increased to about three times the normal dry weather rate without serious disadvantage.

Special filters which are only used in times of storm are not usually efficient, and should not be provided. Any extra quantity in times of storm should be treated on the ordinary filters.

The stand-by tanks should hold about one-quarter of the daily dry weather flow, and provision should be made for filtering about three times the normal dry weather flow.

If separate sewers are provided, the local authority should have power to enforce the provision of separate drains. Moreover, the powers of the local authority in this matter should not necessarily be limited to new streets and new houses.

As a general rule, the expense of altering existing drains should fall on the local authority, and there may be instances in which it would be equitable that they should bear some portion of the additional cost even in the case of new roads.

The Report also makes some reference to the standards of purity for sewage effluents, but that point is more fully dealt with in a later Report.

Another point dealt with is that of the proposed Central Authority, the Commissioners pointing out that the conditions of different cases vary to such an extent that the necessary control cannot, in their opinion, be provided by any direct enactment which could be enforced by the ordinary courts.

Since the date of the appointment of the Commission considerable developments have taken place in regard to the disposal of sewage, and the Commissioners have every reason to think that further changes will occur in the future, making it necessary for the proposed Central Authority to keep in close touch with all such changes and from time to time report on them.

It will be seen from the foregoing that the Royal Commission has been doing good work, its Fifth Report being of exceptional value.

The Sixth Report, issued in 1909, deals with the disposal of liquid refuse from distilleries, and need not be referred to further, as the matter is hardly one of general interest.

The Seventh Report was issued in 1911, and is also of a special nature, dealing with nuisances due to excessive growths of green seaweeds in sewage-polluted estuaries, with special reference to Belfast Lough.

The Eighth Report, issued at the end of 1912, deals with standards and tests for sewage and sewage effluents discharging into rivers and streams. Its chief provisions have been referred to in the opening part of this chapter.

The Ninth Report, issued in 1914, deals with (1) the discharge of manufacturing wastes which for any reason could not be taken into sewers, and (2) the disposal of domestic refuse in rural areas. In dealing with (1) the Commissioners make detailed recommendations in regard to the advisability of altering the existing law. In dealing with (2) they find that "in rural areas the main fact governing the question of the removal of excremental matter and domestic waste waters is the abundance or the scarcity of the water supply". Shortly, they recommend that with an abundant supply, piped to the houses, water carriage is the most satisfactory system; in other cases the Commissioners state that, under proper supervision, a system of dry closets may be open to little objection on sanitary grounds, provided the closet is constructed so that its contents can be conveniently and frequently removed. The domestic waste water is best distributed over the gardens.

The Final Report, issued in 1915, is merely a careful resumè of the Reports previously issued.

Owing to the great importance of this part of our subject at the present time, it has been thought well to give a fairly extended notice of the most important conclusions of the Commissioners. It is not so much a question of where we stand, as in what direction we are moving.

CHAPTER XII

THE MATERIALS USED IN SANITARY WORK.

UNDER this heading it is proposed to give short descriptions of the composition, properties, and manufacture of the principal materials used in the various branches of sanitary work.

Bricks.—The principal use of bricks, from our present point of view, is for the construction of manholes and sewers, and for these items bricks should fulfil the following conditions :—

1. They should be non-absorbent unless protected by a non-absorbent facing, such as cement rendering.

2. They should have smooth faces.

3. They should be uniform in size, shape, and texture.

4. They should have sharp arrises or edges.

5. They should be free from flaws, stones, and lumps of lime, the last named being liable to expand and split the brick.

6. They should ring well when two are struck together.

7. They should be strong and require repeated blows before breaking.

8. They should stand handling and cartage well without injury.

Bricks are blocks of clayey earth, baked or burned. Their quality depends on (1) the chemical composition of the earth used; (2) the amount of preparation it has undergone; and (3) the temperature at which burned, and the care with which the burning is carried on.

A good brick earth is generally composed of silica and alumina, together with a small quantity of lime or iron, or both, which act as a flux to fuse the particles together, giving silicate of alumina. Small percentages of other substances are also contained, such as magnesia, potash, soda, and manganese, which give the colour to the brick. The colour is also dependent on the temperature at which burned; for example, the well-known Staffordshire blue brick owes its colour to a fairly large proportion of oxide of iron, which is, by a high temperature, converted from the red oxide to the black. A small proportion of iron, and a moderate temperature, give a brick of from an orange to a deep red colour, while bricks free from iron burn white. Magnesia gives a yellow colour.

Brickmaking processes may be divided into four heads: (1) the preparation of the earth; (2) moulding; (3) drying; and (4) burning.

In the preparation of the earth the clay is first exposed by unsoiling or removing the earth above it, then dug, freed from stones, weathered by exposing in heaps to the action of the elements, ground in some cases, and tempered, which consists practically of kneading.

The brick may be moulded by hand or by machine. In the former case a wooden mould is used, in the form of a box without a top or bottom. It is placed on a stock board which has a raised piece on it to form the frog or indentation on one side of the brick. The clay is forced into the mould and the top made flat by passing a straight-edge across the top of the mould.

Machine moulding can be carried out in three ways:—

1. By forcing the clay through an opening in the form of a plastic band, cutting off the bricks by means of descending wires, which of course give a brick without a frog. The marks of the wires can always be seen on a wire-cut brick.

2. By moulding the brick from powdered clay under great pressure, such bricks having usually a frog; and

3. By moulding the bricks in the ordinary way and then subjecting them to compression under a piston.

Pressed bricks of the last two classes have very true surfaces and hard edges.

Before the bricks are ready for burning they must be dried, which can be done either indoors or out.

The burning can be accomplished in two ways, either in a clamp or in a kiln. The former method gives an inferior quality of brick, unsuitable for sanitary work, the clamp consisting of a stack of raw bricks built up over a rough system of flues formed by bricks already burned, on a properly drained floor covered with burned bricks.

Kilns are of two principal kinds, the intermittent and the continuous. The former is known as the Scotch kiln, and consists of a low, rectangular, roofless building, with a wide doorway at each end, and fire-holes along each side. Flues are formed with bricks from side to side, the kiln is loaded, and the doorways bricked up. The whole charge of bricks is then burned, allowed to cool, and then the kiln is emptied. The best-known example of the continuous kiln is the Hoffmann, of which there are many forms, differing only in detail. They are chamber kilns, circular, oval, or rectangular on plan, having chambers which are separated by removable doors. In some chambers the bricks are being placed, in some they are drying, some burning, some cooling, and some being unloaded. This system is now in use in all the large brick yards, and gives a regular supply independent of weather, the kiln being roofed.

The best bricks for sanitary purposes are pressed red bricks, blue Staffordshire bricks, and hard bricks salt glazed on the exposed faces, like the surface of a drain pipe. The salt glazing is obtained by the vaporization of common salt in a special kiln, which covers all exposed faces with a thin film of glass.

Stone.—Stone is not largely used in sanitary work, but is useful in the form of slabs for the tops of manholes and similar situations, for which the Yorkshire sandstone is the best fitted.

Terra-cotta.—This material is sometimes used for special invert blocks to egg-shaped sewers, and consists of well-burned clay—generally a mixture of clays. It has a hard vitrified outer skin, which is usually indestructible by acids and which must not be interfered with, such as by chipping adjoining edges to make them even in surface, as this exposes the softer inside structure of the material. Terra-cotta is almost always moulded hollow, with diaphragms or webs connecting the outer walls of the blocks, with a view to reducing the shrinkage, the hollows being then filled with fine concrete.

Cement.—Cements are of two principal varieties, the natural and the artificial. The former are burned from natural lumps of a clayey or stoney nature, and the latter are burned from a mixture of materials. Further, the cements can be divided into those suitable for internal and those for external work.

The principal cements for outside or underground work are Portland and Roman, and the principal for inside use are Plaster of Paris, Keene's, Parian, and similar cements. The best and strongest cement is Portland, so called from its resemblance in colour to Portland stone. It is made from a mixture of chalk and clayey materials. In some parts of the Medway, and on the Thames side, a mixture of chalk and river mud is used. In recent times new methods of manufacture have been introduced, reducing the time taken in production from about a month to half a day, the most approved of these methods being the following:—

The measured proportions of chalk and clay are thoroughly combined by passing them through a set of three wash mills, forming what is termed slurry. It is then passed through very fine screens, being in itself of such a fine nature that 95 to 97 per cent of the slurry will pass a screen having 32,400 holes to the square inch. The slurry is then elevated, by pumping, to storage and mixing tanks, in which it is kept in motion by mechanical stirrers. Here the mixture is sampled and chemically tested to see if it is of the desired composition, and if all is in order, it is conveyed or conducted to a special form of kiln, to be dried and burned. The kiln is of extraordinary shape, about 6 feet in diameter and 130 feet long. It is fixed with its length inclined to the horizontal. The slurry enters at the upper end, and is dried by the rising hot gases, probably in about the first sixth or seventh of the length of the kiln, and issues at the lower end in a stream of fine clinker. A temperature of about 2800° F. is kept up at the lower end of the kiln, the flames being fed by pulverized coal injected by an air or steam blast. The clinker falls into coolers, and is afterwards taken to the mill for grinding. This mill is of cylindrical form, lined with plates lapping one over the other like roof tiles, and contains a number of hard steel balls. The rotation of the cylinder reduces the clinker to a fine powder, when it passes through perforations in the mill and is ready for further grinding. This is effected in another cylindrical mill containing specially hard pebbles from Dieppe, and known as a tube mill. This grinds the cement to such a degree of fineness as will allow it to pass through a sieve having 40,000 holes to the square inch. To make the cement ready for immediate use, a special apparatus is attached to the end of the tube mill, which subjects the cement to a charge of superheated steam at great pressure, this method superseding the old-fashioned method of spreading the cement over a wooden floor for a month or so to properly aerate it.

Portland cement for sanitary work should be of the very best quality. Most of the specifications one meets with are out of date, and it is desirable, therefore, to give here the chief provisions of the specification laid down by the British Engineering Standards Committee.

The specification commences with preliminary clauses covering the following points, i.e. (1) Composition and preparation of the cement; (2) samples for testing and by whom to be taken; (3) samples for testing and how to be taken; (4) sampling large quantities; (5) facilities for sampling and identifying; and (6) cost of sampling and testing. It then prescribes the following important tests:—

(*a*) *Test for Fineness.*—The residue on a sieve of 32,400 meshes per square inch shall not exceed 18 per cent, and on a sieve of 5776 meshes per square inch shall not exceed 3 per cent, the diameter of the wire for the finer sieve being ·002 inch, and of the coarser sieve ·0044 inch.

(*b*) *Test for Specific Gravity.*—The specific gravity, when fresh burnt and ground shall be not less than 3·15 or 3·10 provided the vendor satisfies the purchaser that the cement has been ground for not less than four weeks.

(*c*) *Test for Chemical Composition.*—The cement shall comply with the following conditions as to its chemical composition. The proportion of lime to silica and alumina shall not be greater than the maximum, nor less than the minimum ratio (calculated in chemical equivalents) represented by $\frac{CaO}{SiO_2 + Al_2O_3} = 2{\cdot}85$ or $2{\cdot}0$ respectively. The percentage of insoluble residue shall not exceed 1·5 per cent; that of magnesia shall not exceed 3 per cent; and the total sulphur content calculated as sulphuric anhydride shall not exceed 2·75 per cent. The total loss on ignition shall not exceed 2 per cent, unless it can be shown that the cement has been ground for more than four weeks.

(*d*) *Test for Tensile Strength* (*Neat Cement*).—The cement shall be tested by submitting briquettes of neat cement to a tensile stress. (The method of gauging or mixing the cement is stipulated and then follows): Breaking. The briquettes shall be tested for breaking at 7 and 28 days after gauging, six briquettes for each period, and the average of each six taken as the result. The shape of the briquette and of the jaws for holding it are standardized and illustrated in the specification. The briquettes are to be 1 inch thick, 3 inches long, and 1 inch at the middle, increasing to 1¾ inch at either end. The load must be steadily applied, increasing at the rate of 100 lb. in 12 seconds. After 7 days the average breaking stress must be not less than 400 lb. per square inch of section. The average breaking stress after 28 days must show an increase on the figures for 7 days of not less than :—

25 per cent	when	the 7-day test	is above	400 lb.	and	not above	450 lb.
20	,,	,,	,,	450	,,	,,	500 ,,
15	,,	,,	,,	500	,,	,,	550 ,,
10	,,	,,	,,	550	,,	,,	600 ,,
5	,,	,,	,,	600			

(*e*) *Test for Tensile Strength* (*Cement and Sand*).—The briquettes are in this case to be made of one part of cement to three parts of washed Leighton Buzzard sand, by weight, mixed, etc., in the manner prescribed in the specification, and be tested in a similar manner to that prescribed for neat cement. Breaking: a similar number of briquettes, and similar periods before testing, are prescribed as for neat cement. The average breaking stress of the cement and sand briquettes seven days after gauging must be not less than 150 lb. per square inch of section. The average after 28 days must be not less than 250 lb. per square inch of section, and the increase must be not less than :—

25 per cent	when	the 7-day test	is above	200 lb.	and	not above	250 lb.
15	,,	,,	,,	250	,,	,,	300 ,,
10	,,	,,	,,	300	,,	,,	350 ,,
5	,,	,,	,,	350			

(*f*) *Test for Setting Time.*—The specification prescribes three qualities of cement under this heading, termed quick, medium, and slow respectively :—

Quick.—Initial setting time not less than two minutes.

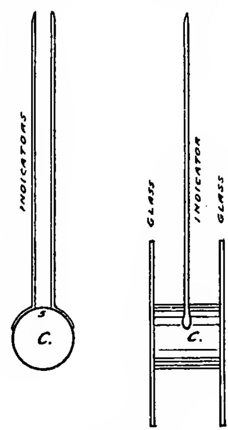
Final setting time not less than ten nor more than thirty minutes.

Medium.—Initial not less than ten minutes, and final setting time not less than half an hour nor more than two hours.

Slow.—Initial not less than twenty minutes, and final setting time not less than two hours nor more than seven hours.

The initial and final setting times are to be determined by the Vicat needle apparatus. The cement is held by a split ring 3·15 inches in diameter and 1·57 inch high, resting on a glass plate. The needle has a square end, ·039 inch square, and with its carrier, etc., weighs 10·58 ounces. The needle is repeatedly brought into contact with the surface of the cement, and the initial setting time is that period after gauging the cement at which the needle fails to pierce the cement completely. The final setting time is that period after gauging at which the needle fails to make an impression on the surface of the pat of cement.

(*g*) *Test for Soundness.*—The cement shall be tested by the Le Chatelier method. The apparatus consists of a small split cylinder of brass or other suitable metal ·0197 inch in thickness, forming a mould $1\frac{3}{16}$ inch in diameter and 1 ^{3} inch high. On either side of the split are two indicators with pointed ends, the distance from these ends to the centre of the cylinder being $6\frac{1}{2}$ inches. (Fig. 361 shows a front view of the apparatus, C being the cylinder, split at S., Fig. 362 shows a side view of the apparatus between two sheets of glass.) In conducting the test, the mould is to be placed



Figs. 361, 362.

upon a small piece of glass, and filled with cement, gauged in a mode as prescribed for section (*d*) of these tests, care being taken to keep the edges of the mould together. The mould is then covered with another glass plate, a small weight is to be placed on this, and the mould is then to be immediately placed in water at a temperature of 58° to 64° F. and left there for twenty-four hours. The distance separating the indicator points is then to be measured, and the mould again placed in water at 58° to 64° F., which is to be brought to boiling-point in twenty-five to thirty minutes, and kept boiling for six hours. After removing the mould from the water and allowing it to cool, the distance between the points is again to be measured. The difference between the two measurements represents the expansion of the cement which must not exceed the following limits: Ten millimetres when the sample has been aerated for twenty-four hours in the manner hereinafter described, or, if the above test has failed, 5 millimetres after seven days' aeration in the same manner.

Clauses 8, 9, and 10 of the specification deal with non-compliance with tests, copies of vendor's tests and analyses, etc., and delivery respectively.

Space precludes the inclusion of the full specification herein, but the foregoing are the chief points of interest. The best thing to do in specifying Portland cement for important sanitary work is to say that it is to conform, in all respects, with the requirements of the specification of the British Engineering Standards Committee. Further, the quality as regards setting should be stated. The quick setting cement of the standard specification is useless for ordinary building work and for practically all the works referred to herein.

Roman cement is burned from modules found in the London clay. It is used to a limited extent, its rapid setting properties fitting it for work between tides or similar cases, but it has no great ultimate strength. It is said to resist, even before setting, water and the tendency to being washed away better than other cements.

Keene's, Parian, and similar cements are suitable only for such purposes as wall linings for inside work. Both are manufactured from plaster of Paris, Keene's by the addition of alum, and the Parian by the addition of borax.

Sand.—There are three kinds of sand—river sand, sea sand and pit sand. The best for use in mortar or concrete is the pit sand, which is sharp and gritty. It should be clean and free from earthy matters. River sand is granular, and not so satisfactory as sand which would help to form a compound of a crystalline character when mixed with lime or cement. Sea sand is not a desirable thing to use, as the excess of salt it contains makes it always damp and retards setting of the mortar or concrete. When sand is not available, permissible substitutes for it are crushed furnace ashes, or blast furnace slag run into water.

Mortar.—For sanitary work, cement mortar is almost always used, composed of Portland cement and sand. It should be mixed dry, the ingredients being carefully turned over together two or three times before the water is added. The proportions range from one part of cement to one of sand, to one of cement and four of sand. In some cases neat cement is desirable, but for jointing drain pipes, joints of brick sewers, and similar work one of cement and two of sand is a good proportion. Not more should be mixed than is immediately required, as mortar which has commenced setting should not be re-mixed.

Concrete.—As will have been seen, concrete, which is really an artificial stone, is largely used in sanitary work. There are two chief varieties of concrete, lime concrete and cement concrete; but the former is now but little used, cement concrete being desirable for any work required to be waterproof. Bituminous concrete is also sometimes used, this being a compound of tar pitch with broken stone, the former taking the place of cement. Concrete consists of two parts, the matrix or mortar, and the aggregate, or broken stone, etc., which the matrix binds together. The matrix may be of neat cement, but is more often of one part of cement to one or two of sand, the cement being best Portland and the sand clean sharp pit sand. The aggregate may be of broken stone, broken bricks, Thames ballast, coke breeze, or furnace slag, the three first named being those suitable for concrete for sanitary work. The stone or brick is broken to pass through screens having meshes of varying size; from about $\frac{3}{4}$ inch up to $2\frac{1}{2}$ inches.

For heavy retaining walls a screen of the largest size mesh might be used, for ordinary watertight work, such as the construction of a septic tank, a gauge of 1 inch is a fair one, and for thin slabs of concrete the finest gauge. The use of Thames ballast is rather common. This material is of uncertain quality. It used to contain about a reasonable amount of sand for the making of concrete, but now very often contains far too much. It all depends on the part of the river from which it is obtained and must therefore be regarded with caution. If broken stone or brick is used, it should be clean and freed from fine stuff by rejecting any part which passes through a finer screen than the gauge specified.

The proportioning of the matrix and aggregate is a matter of greater importance than is generally recognized. The proportion of the former should be just such as will fill the voids between the pieces of the aggregate. This is readily found by filling a watertight box with the broken stone and then filling up the spaces with water; this can be poured off and measured and compared in bulk to the quantity of aggregate in question. The proportions having been settled, the ingredients should be carefully measured in gauging boxes and tipped on a boarded platform. They should then be turned over carefully about four times to thoroughly incorporate them in the dry state. After this, clean water should be added through a rose, and the whole turned over again at least three times in its wetted condition. Concrete should not be tipped from a height, or the heavier particles will separate from the lighter. It should be gently lowered into position, deposited in layers not more than 1 foot thick, and each layer well rammed. If any layer has set before the next is added, the former should be brushed over with liquid Portland cement (or cement grout) before a fresh layer is put on.

Stoneware and Fireclay Pipes.—The relative advantages of these two kinds of pipe have been already referred to. They are both manufactured, by machine, in the same way. The machine is arranged so to extend through two floors of the building.

On the upper floor is a steam cylinder, working a steel ram up and down. Below the ram is a hopper or funnel, formed in the floor and into which the clay is charged. Connected to the outlet of the hopper, and situate in the room below, is the steel pipe mould, having a core inside it, the socket being lowermost. There is a space between the core and the mould, which, if filled, and the mould and core then removed, would leave the partly finished pipe. At the lower end of the mould is a small platform which can be readily raised or lowered, and on this is the socket part of the core. The clay is charged into the hopper and the ram allowed to rapidly rise and fall, so as to make the mould compactly filled; clips, holding the platform to the base of the mould, are then released, and the ram allowed to slowly come downwards. This causes the pipe to descend out of the mould, following the movable platform downwards. When a sufficient length of pipe is through the mould, it is cut off by a thin steel wire to a length rather greater than its ultimate length. It is then taken to a revolving table, cut to its true length, trimmed up, and the grooves on the socket and spigot formed. The platform is brought up to its original position, re-clamped, and the operation goes on again and again. Bends are formed by the pipe moulder taking the lower end of the pipe, as it issues from the mould, and pulling it round to the desired curve. Junctions are formed of two pipes moulded as just described, a hole being cut in the side of the one, and the other cut to fit, the moulding being carefully completed by hand. More complicated pieces of stoneware are moulded in two halves and then put together, the joint being carefully made good.

The next step is to dry the articles, which is generally done in a drying shed, often over a kiln. They are then stacked in a dome-shaped kiln, having fire holes around its base, and burned for about three to four days, according to the composition of the clay. While in the kiln they are, when sufficiently burned, glazed by the vaporization of common salt, applied either at the fire holes, or at the top of the kiln. The heat decomposes the salt into a gaseous vapour which coats every atom of exposed surface in the kiln, and forms an alloy with the surface of the clay. For this reason the salt glaze cannot be chipped off the pipe without taking off also a piece of the pipe itself. An alternative method of glazing, of greater expense, and with many disadvantages, is that known as lead glazing. This is applied, after the pipes or other articles have been burned and removed from the kiln, by coating them with a mixture containing, among other things, oxides of lead and tin, silica, china clay, and borax. This forms, when burned in another kiln at a temperature of about 1000° F., a thin surface coating of a glassy nature, but one which does not combine with the material of the pipe, and can be readily chipped off.

Stoneware pipes, if required to be of "tested" quality, are tested by means of a hydraulic press, the objects of the test being to ascertain their powers of resistance to absorption, percolation, and pressure.

Cast Iron, Wrought Iron, and Steel.—The manufacture of these materials is too large a matter to be dealt with fully in a work of this kind, but the difference in composition and properties can be dealt with. The main difference in composition is in the proportion of carbon contained. Cast iron contains from about 2 to 6 per cent, wrought iron from 0 to ·15 per cent, and steel from ·12 to 1·5 per cent.

Cast iron is obtained by smelting the ore in blast furnaces and running the metal into moulds termed pigs. The pig iron should be re-melted in order to obtain a good quality of iron. There are three kinds of cast iron, white, grey, and mottled, which contains both the grey and white varieties. White and mottled cast iron are less liable to rusting than the grey variety, but the last mentioned is the material which, for its greater toughness, is used for structural castings.

Cast iron is crystalline in fracture, gives but little resistance to tension, but great to compression. It is lacking in toughness and elasticity, being hard and brittle.

Wrought iron is obtained from cast by a series of processes, the object of which is to remove the carbon and the impurities which made the cast iron brittle. Wrought iron is of fibrous structure, very tough and ductile, easily forged and welded but not fusible, and gives high resistance to tension, though but little to compression.

Steel may be produced by adding carbon to wrought iron, or by removing a portion of the carbon from pig iron. There are a large number of processes by which this may be brought about. Mild steel is a material which is superior to wrought iron for all ordinary structural uses, principally in that it is stronger and more uniform in texture. It has great tensile strength, and has greater resistance to compression than wrought iron, with a harder surface. It is also more elastic in nature. Mild steel is forgeable and weldable, like wrought iron. Given pieces of the same bulk, cast iron of good quality will last much longer than wrought, because of the rapid way in which commercial wrought iron goes to pieces by flaking, a process which does not apply to cast iron.

Iron Pipes.—Cast-iron pipes are formed in a mould having a core in the middle. They can be cast horizontally, vertically, or in an inclined position. All three methods are in use, but the vertical method is best, though perhaps less convenient to adopt. It gives pipes of more uniform thickness and greater density. The inclined method, in which the mould is placed at an angle of about 45° with the horizontal, also gives a good quality of pipe. The horizontal method is used chiefly for the lighter kinds of pipe, and does not give such a good pipe as either of the other methods. With the vertical method the pipe is cast with the socket downwards, to give maximum density at that part, and is cast of greater length than needed, by from 6 inches to a foot, so as to allow the dross and air bubbles to rise to the top, this part being afterwards cut off.

Wrought-iron pipes are generally made in three different ways. The strongest pipes, such as high pressure hydraulic mains, are formed by winding a bar of iron spirally round a core, the abutting edges being then welded together. Pipes of this variety are of very great strength, and have been made to stand a stress of several tons per square inch without injury. The second method is that adopted for pipes of gas strength, and consists of bending a bar round a core and then welding together the abutting edges, thus forming a longitudinal joint. Such a pipe should not be used for other than gas. The third method is similar, but the adjoining edges are lapped and welded instead of being merely butted together. This class of pipe is what is known as water strength.

As has been pointed out in earlier chapters, it is sometimes necessary to protect iron pipes from corrosion. The Angus Smith, galvanizing, and Bower-Barff processes have already been described. Another process is that of glass enamelling the inside of the pipe. This consists of coating them internally with lead glaze as described for stoneware, and then firing them in a kiln. The great trouble with pipes of this kind is the difficulty of cutting them without removing part of the internal lining of glass and so exposing the iron to oxidation.

Lead.—This material is of great importance in sanitary work. Not only is it used for gutters, flashings, flat roofs, cisterns, damp courses, etc., but it is the material of which most of the pipes in a house are often formed.

Lead is produced by smelting ores, the ores from which it is principally obtained being galena and cerusite. It is a very malleable material and can be readily worked to almost any shape without applying heat.

Sheets of lead can be either cast or milled. Cast sheets are not often used, having several drawbacks. They can be obtained up to about 16 feet long by 6 feet wide, but are of uneven surface and thickness, and liable to flaws and sand holes. Milled lead sheets are generally used both for flats and gutters, and also for all other sanitary work. They are obtained by first casting a large, thick block and then rolling and re-rolling it in a mill, having two very heavy steel rollers, until it has been reduced to the desired thickness. Part way through the operation, the sheet which is in process of formation is cut up into parts, these parts being dealt with separately. Milled lead is obtainable in sheets up to about 35 feet long and 9 feet wide, though rather smaller sizes are more usual. As previously stated in another chapter, milled lead is described by its weight per superficial foot.

Lead is also used in sanitary work in quite a different form to the foregoing; that is to say, in the form of red and white lead, as used for jointing in certain cases. Red lead is obtained by oxidizing metallic lead in a furnace, by exposing it to the action of air. A coating of oxide is formed, and this is removed to expose a fresh metallic surface, this process being continually repeated. The oxide is then ground in water between stone rollers, and again exposed to the action of air in another furnace, which permits it to take up more oxygen and gives it its red colour. It is then re-ground in water, and dried. White lead is made by exposing metallic lead to the action of the fumes of acetic acid in the presence of carbonic acid gas. The lead is suspended in jars over the acid and the jars are usually stacked in tiers between permanent and temporary floors covered with tan. A stack formed in this way is left for about three months to ferment, when the heat vaporizes the acid and causes the tan to freely give off carbonic acid gas. This forms a coating of carbonate on the lead, which is then removed and ground. To bring it to its ordinary commercial form, as used by the painter, it is then re-ground in linseed oil.

Lead Pipes.—At one time lead pipes were made by bending the lead round a core and soldering the joint, and pipes of this kind are often found in old houses. Nowadays, however, solid drawn-lead pipes are used, which are seamless. They are made by forcing solid lead through a die by means of a hydraulic press, or by the use of a ram actuated by steam. Over the head of the ram a thick cylinder of lead is enclosed in a very strong casing. At the top of the casing interchangeable dies can be fixed, varying of course with the size of the intended pipe. The ram works around a rigid pillar, to the top of which a short length of core is fixed, having a diameter equal to that of the pipe. Around this is fixed the die, which is larger in diameter by an amount equal to the thickness of the pipe. Through the opening so left, the ram forces the lead in the form of a continuous tube.

In somewhat the same category as lead pipes are tinned-lead pipe and tin-lined pipe. The former is a drawn-lead pipe thinly coated with tin by the simple process of pouring a little molten tin into the lead pipe as it comes from the pipe machine, the pipe being sufficiently hot to keep the tin in a molten state. The tin amalgamates with the lead, to form a surface alloy to some extent, but the coating is far from uniform, and the resulting pipe little better than the ordinary drawn-lead pipe. The tin-lined pipe is an article of quite a different nature, there being a definite tube of tin inside the lead pipe. The construction of the pipe is simple. In the casing of the pipe machine, instead of merely a thick cylinder of lead, is a cylinder in two parts, the inner one of tin and the outer one of lead, the rates of their thicknesses corresponding with the ratio of the thickness of the tin and lead in the finished pipe. The pipe therefore issues from the machine as a compound pipe consisting of a tube of tin inside a tube of lead. The object of tinning or tin lining a pipe is to make it suitable for the conveyance of soft water without injuring its quality, but there is often considerable trouble with the joints, the lining being destroyed and laying the surface of the lead bare.

Bends and traps can be formed from drawn-lead pipe by means of special bending appliances, but the solid drawn-lead bends and traps can be made in a pipe machine very similar to the one described already. The difference lies in the fact that, in place of the vertical ram, two horizontal rams are used. By setting them to work at varying speeds the lead is forced through the die at a faster rate on one side than on the other, thus giving a bend of radius depending on the relative velocities of the rams.

Lead Wool or Leadite.—This substance consists of fine threads or shavings of lead, twisted to form a sort of rope. It is used instead of ordinary molten lead for caulked lead joints, and is particularly suitable for work under water or in positions difficult of access.

Copper.—This material is used for sanitary purposes in many forms, such as sheets for roofing, pipes for hot and cold water work, waste pipes, boilers for hot-water services, etc. It is also of importance as one of the constituents of various alloys, such as brass, gunmetal, and bronze, while it is employed in the composition of the harder solders.

It is obtained by smelting ore, is tough, malleable, and ductile; that is to say, it can be readily drawn into wire. It can be forged, either cold or hot. Copper pipes are unsuitable for the conveyance of drinking water, as the latter is liable to be acted on by salts of copper. Copper pipes can be of seamless or seamed form. The former are solid drawn, formed by repeatedly drawing and rolling a cylinder to reduce its thickness and increase its length. As this process tends to make it brittle, it is repeatedly annealed during the process, annealing consisting of heating it in a special oven having a temperature of about 900° F.

Copper sheets are only obtainable in relatively small sizes, seldom exceeding about 14 square feet in area. To prevent the formation of a film of carbonate, sheet copper, when used for lining sinks and similar items, is often tinned.

Zinc.—Zinc is used in connexion with roof work, for lining cisterns in some cases, as a constituent of various alloys, and also for galvanizing. Most of the zinc used in this country comes from Belgium, and its thickness, when in the form of sheets, is customarily measured by means of the Belgian zinc gauze. It is very brittle when cold, and also when raised to a temperature of about 400° F., but at about 220° F. it is very malleable and can be rolled into sheets, which retain their malleability. Zinc sheets are soon destroyed by the acid air of large towns and also by sea air; they should also not be used where cats can get access to them. Another objection to zinc for roofing is that it blazes furiously at a red heat. Zinc sheets are obtainable up to a size of 8 feet by 3 feet.

Brass.—Brass is an alloy composed of copper and zinc, the proportions varying according to the purpose for which the alloy is required. The best proportion for water fittings is 2 of copper to 1 of zinc.

Gunmetal.—This material is suitable for high quality water fittings, and particularly so where the water is acid, such water injuriously affecting fittings of brass.

Gunmetal is an alloy of copper and tin, the best proportion for water fittings being 9 of copper to 1 of tin.

Solder.—Ordinary plumbers' solder is known as soft solder, and is an alloy of tin and lead in the proportion of 1 of the former to 2 of the latter. For special purposes, bismuth is also added, as for jointing tin pipes. Hard solder, for use on copper, brass, or gunmetal, is of different composition, consisting of copper, zinc, and silver. For good ordinary work, it consists of from equal parts of copper and zinc to 2 of the former to 1 of the latter.

Fluxes.—To assist solder to form a surface alloy with the metals with which it is in contact, and prevent the formation of an oxide on the surfaces of the materials which are being soldered, fluxes of various kinds are used. When using plumbers' solder for joining lead to lead, brass, or copper, tallow is used, and when using fine solder (more fusible), resin and tallow. For use on brass, zinc, or copper, chloride of zinc, also known as killed spirits, is used. Other fluxes are Gallipoli oil, for tin and pewter, and borax or sal ammoniac, for cast iron, malleable iron, and steel.

Rust Cement.—This cement, as stated when dealing with the jointing of iron pipes, is particularly suitable for iron pipes subjected to considerable changes of temperature. It is a mixture of fine cast-iron borings, water, and sal ammoniac if required to be slow setting, or borings, water, and flowers of sulphur if required to be more rapid in setting.

Limewash or Whitewash.—Where it is desirable to give walls a cheap sanitary coating, lime whiting is often used. It is made from pure lime mixed with water, and the addition of 1 lb. of pure tallow to every bushel of lime improves its quality. It will not adhere well to smooth non-porous surfaces, but is an excellent preservative for both stonework and brickwork, preventing them from attack by the acids in the air. For external work, a good whitewash can be made by adding 4 lb. of sulphate of zinc and 2 lb. of common salt to every bushel of lime.

Distemper.—Ordinary distemper is a mixture of whiting and size, the whiting being chalk reduced to powder, and the size a sort of thin glue made from the waste parts of animals, such as horns, hoofs, and skins. The distemper can be coloured by the addition of various earthy pigments.

Many patent distempers, or water paints, are now obtainable, the makers in most cases claiming that their productions are free from size and whiting, the former of which is always liable to decompose and smell. The smell from ordinary distemper can, however, always be obviated by the addition of carbolic acid.

Stoneware Pipes.—Since the foregoing notes on materials were written, the British Standard Specification for Salt Glazed Ware Pipes has been issued. This is a very comprehensive specification, obtainable from the British Engineering Standards Association, 28 Victoria St., S.W., at a charge of 1s. Stoneware pipes for important drainage work should be required to conform with this specification.

CHAPTER XIII

SANITARY SURVEYS AND REPORTS.

AMONGST the general public there is usually too much of the feeling "out of sight, out of mind," in regard to sanitary matters. Householders make the great mistake of not looking on the drains as a part of the dwelling, and a delicate part at that. The drains stand in the same relation to the dwelling as the bowels to the human body. They carry off waste matters which it would be injurious to health to retain in the structure. A leakage of the bowels causes instant injury, whereas the injury due to a leakage of the drains is more gradually felt, but that is only because the proportions between the bowels and the body, and those between the drains and the house are different. In time, the ground adjacent or subjacent to the house becomes sewage sodden, giving off noxious emanations, to say nothing of its possibly injurious effect on any water supply pipes there may be in the vicinity of the drain.

The conditions which should be fulfilled by a really sanitary building have already been given under various headings, and there would be no useful purpose served by repeating them here. They will have shown, however, that in making a sanitary survey of a house, there are many points which require consideration; such as the general arrangement of the building in regard to the positions of sanitary fittings relative to the positions of living rooms and bedrooms; ventilation, dampness, water supply, sanitary fittings, drainage, etc.

Let us consider in detail the procedure in making the inspection, the method of booking the notes, and that of writing the report on such information as is obtained.

A fundamental principle in sanitary survey work is that of taking nothing for granted. The surveyor may find a plan of the drainage at the house; he should accept it as information, but must satisfy himself as to its accuracy. He often finds a gardener or odd man about the house, who is most anxious to give him information in reference to such matters as the courses of the drains, but again such evidence should be verified. If in inspecting, say, the water supply he finds a casing over some of the pipes, such casing should be removed and the pipes traced from end to end.

One of the most important things incidental to the survey will be the testing of the drainage system. There are four principal methods of testing, namely :—

1. The Olfactory or Odour test.
2. The Smoke test.
3. The Water or Hydraulic test; and
4. The Air or Pneumatic test.

The olfactory test is often spoken of with a certain measure of contempt, but one must not overlook the fact that occasionally the circumstances are such that the other tests cannot be applied, whereas the conditions are favourable for this one. It is then of undoubted value. The test is only suitable for soil and waste pipes and the joints around fittings, and can be applied in either of two ways. One is that of using a chemical drain tester. There are many varieties of these, consisting of packages of phosphorous compounds or other evil-smelling substances. They are put up in many forms, and consist of receptacles from which the smell-producing substance is ejected after passing through the trap. They are furnished with fairly long lengths of string, usually coiled round them, by means of which the receptacle can be withdrawn after use. An example of this kind of appliance is shown in Fig. 363, which illustrates what is known as a Kemp tester. It consists of a thin glass tube containing a chemical compound. The substance is kept in the tube by a cap and rubber washer, a spiral spring, S, around the tube tending to force the cap off. This is prevented, before use, by a strip of paper, P, which passes over the cap and down the two sides, to which it is fastened. The whole appliance is only about 2 inches long. To apply a test, it is flushed through the trap by a bucketful of water, hot if available; the hot water rapidly softens the paper strip and releases the contents. This example is illustrated merely to show the nature of such apparatus; there are many others made for the same purpose.

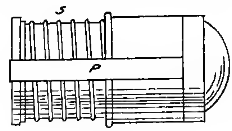


Fig. 363.

The other method of applying the olfactory test is by placing oil of peppermint in a bucketful of boiling water, about one and a half ounces of the oil to a quart of water. The liquid should be mixed and passed through the trap by an assistant, the surveyor himself keeping away during the process, as the smell is very pungent and readily clings to one's clothes. He then goes from room to room searching for traces of the smell which would come from leaky joints in the pipes or fittings or from an insufficiently sealed or unsealed trap.

The smoke test can be used for pipes below as well as those above ground, but it is not a satisfactory test for underground drains. In the case of defects above ground the smoke is readily visible, apart from the question of smell, and in the case of a defective drain having only a shallow covering of porous soil the smoke will readily issue at ground level. With a considerable depth of earth over the pipes, or earth of a dense, damp nature, such as clay, however, the smoke will not find its way through. To facilitate its doing so, a probing iron is sometimes used, consisting of a pointed iron rod a few feet long, with a handle. It is used by walking over the course of the drain and forcing the rod down into the soil at frequent intervals so as to leave holes for the smoke to rise. The probing iron is also used for another purpose, that of probing the ground to locate the course of drains whose position is unknown or uncertain.

The smoke can be produced in two ways; (1) by a smoke rocket or smoke case, and (2) by a smoke machine.

The former is shown in Fig. 364, and consists of a cardboard tube about 8 inches long and $1\frac{1}{2}$ to 2 inches in diameter, the end being closed with paper. It has two wooden strips or fillets fixed to it as shown at S, with a small nail through the middle.

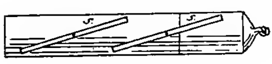


Fig. 364.

These should be turned round so that they are at right angles to the case, in order to keep the rocket off the invert of the drain, clear of the sewage. On lighting the paper and fuse at the end, a dense volume of smoke issues. The case should be removed from the drain after use.

The drawback to the use of smoke rockets is that the smoke cannot be produced under pressure, and to overcome this difficulty many forms of smoke machine have been introduced, differing largely in detail. The broad principle underlying them all is, however, the same; that of producing smoke under pressure by burning oily cotton waste, thick brown paper steeped in creosote oil, and other substances. Fig. 365 shows, diagrammatically, the essential parts of such a machine. S.C. is the smoke chamber, having a water jacket round it, a dome, D, fitting well down into the water space to provide a seal against the escape of smoke. Near the bottom of this chamber is a grating on which the smoke-producing substance is placed. The pipe for the conveyance of the smoke (S.P.) passes down the centre of the chamber, the inlet being near the top as shown. Alongside the smoke chamber is a double bellows, B, actuated by a lever, L. By this means air can be pumped through the air pipe, A.P., to the under side of the grating. The lever must not be worked too rapidly or it may cause the material to blaze instead of smoulder, with a consequently diminished amount of smoke. A pressure gauge is sometimes added at G in order to register the pressure applied.

In testing a soil or waste pipe, the drain should be plugged

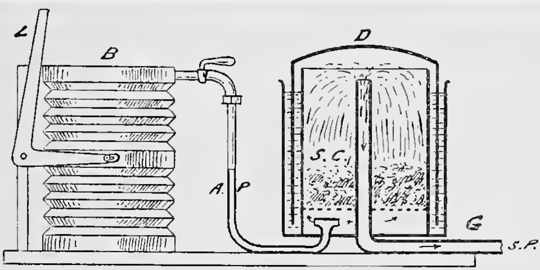


Fig. 365.

at the nearest manhole. This is sometimes only roughly done by means of wet cloths placed around the flexible pipe which is attached to the outlet of the machine, but it is far better to use a proper drain plug. There are two principal types of plug, (1) that consisting of a rubber ring capable of being expanded, and (2) that consisting of a rubber bladder which can be inflated by means of a small hand pump, and encased in coarse canvas to strengthen it and give it a greater gripping power.

There are many varieties of each type, and it is not proposed to deal with them all; in fact it would serve no useful purpose to do so. Fig. 366 shows a section through one variety of rubber ring plug, consisting of two circular discs of iron which can be forced together by means of a wing nut, W.N., thus causing the expansion of the rubber ring, R.R. A screw cap, C, is provided at the outer end, which can be readily removed by means of the projecting lugs shown, either for the purpose of attaching a smoke pipe or for releasing the water when used for the water test.

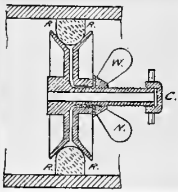


Fig. 366.

The original form of rubber ring was of circular section, but this did not give a good grip to the pipe, and later developments of this type have all tended towards giving greater gripping surface. The best examples of this type, however, do not give such an effective closure to the drain as a good type of bag plug.

The earlier forms of bag plug were of spherical shape, but these are not now so extensively used as those of cylindrical shape. Fig. 367 shows a simple form of bag plug in position. It is inflated by means of a hand pump similar to a bicycle pump, but of stronger make, and after inflation the small tap shown can be turned off. It will be obvious that such a plug will not only accommodate itself to any irregularities in the pipe better than a rubber ring, but will also give a much larger gripping surface and therefore a firmer hold.

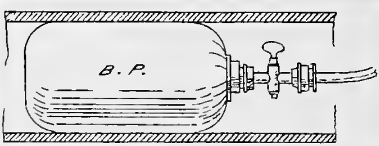


Fig. 367.

A better form of bag plug is shown in Fig. 368. It has two brass ends, with means of attaching a string or wire, W, in order to permit of its being pulled either way, up or down the drain, before inflating it. A brass tube passes right through the bag, with a connexion at C which can be used for attaching either the nozzle of the smoke machine, or a small tap to let the water out in the case of the water test. The bag is inflated through a small pipe, A.P., and is closed after inflation by leaving on the tap of the pump.

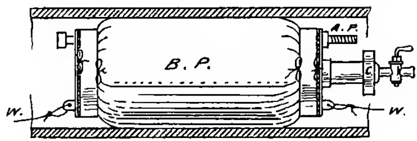


Fig. 368.

In applying the smoke test to a drain, the latter should be plugged at either end so as to form a closed chamber into which the smoke may be pumped. In the case of a soil, ventilating, or waste pipe it is a good plan to test first with the top of the pipe open, and then, if possible, with it closed by means of wet cloths. The first test makes it possible to see if there is any blockage in the pipe, and the second puts a certain amount of pressure on the joints. It will be seen that the smoke test may be regarded as satisfactory in the case of an uncovered drain, but it is not sufficiently severe for a covered one, whether new or old.

Care is necessary in connexion with the use of smoke rockets as fumes of a suffocating nature are liable to accumulate at the bottom of the manhole.

We come next to the water or hydraulic test. It has often been argued that this test is an unfair one, as it puts a greater strain on the lowermost end of the drain than it does on the uppermost. This argument is unsound, as that is the real advantage of the water test. Almost any drain may become blocked, and if it does so at or near the lowest point, the water test will be at once applied naturally, the only difference being that the water in this case will be foul, with consequent danger in case of leakage.

It has also been argued that the water test is not a fair one for other than new drains. The by-laws of local authorities almost universally require new drains to be watertight, the inference being that unless they are so there is injury or danger to health. If it is necessary for a new drain to be watertight in the interests of health, it is equally so for a drain which is no longer new. The argument that the water test is not a fair one for old drains raises the proposition that while it is necessary for a drain, when new, to be watertight, there comes a time in the existence of that drain when that state of things is no longer necessary, but exactly how long after construction that time occurs is a point which I believe no one has yet had the courage to state.

One is well aware that perfect drains become imperfect, and that there are many substantial reasons why this is so, such as, in the case of our large towns, the vibration due to heavy traffic, but that does not alter the fact that a surveyor who allows a client, on the strength of his report, to enter into occupation of a house, the drains of which are not watertight, incurs a grave responsibility.

Broadly speaking, the water test is applied by plugging the lowest point on the drainage system and filling the drains with water until it stands at a depth of say not less than two feet in the upper manhole, a subsidence of the water indicating a leakage. If there is considerable fall on the drainage system it is wise to test it in sections, and wherever the system has several manholes it is advisable to test the length from one manhole to another, working downwards from the upper end, the object of this being to utilize the water from the upper lengths for the testing of the lower. In any case in which there are gulleys at a lower level than the water in the manhole, they should be plugged in order to prevent the water issuing from them. The water should be allowed to remain in the drains for about an hour and a half to two hours in order to give a reasonable test.

Great care is necessary in observing the water level and noting whether it subsides. If the sides of the manhole are of absorbent material, there is bound to be a drop in the water level owing to the absorption. In such a case the production of exact results is a matter of difficulty, considerable experience being needed in reference to the allowance for absorption. If the manhole sides are of non-absorbent material, the depth of the water surface below the side of the manhole can be accurately measured and noted. Anything like a chalk mark, or piece of stamp paper, as an indication of the original level of the water, is of little value, as it can be easily tampered with. The depth should be accurately measured down from the top and the figure booked. A neat contrivance to overcome this difficulty is that known as the Beattie water test gauge. It is shown in Fig. 369, and consists of a horizontal bar carrying an upright support for a small spindle, which passes through horizontally and has a milled headed wheel, S, at one end, and a small drum, on which is wound a tape measure, at the other. At the end of the tape, T, is a plumb bob, P.B., with a long point. It is allowed to fall slowly till the point touches the water surface and the spindle can then be clamped by a small set-screw, S.S. The apparatus can be lifted up from the side of the manhole and put in its case, no one but the observer knowing the water level.

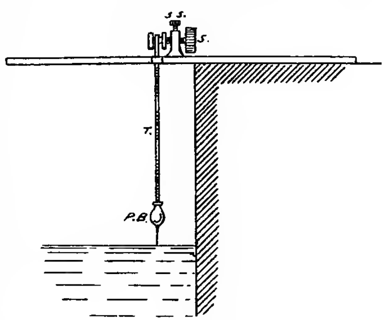


Fig. 369.

Another way of safeguarding this question of water level is to use a Jones Indicator, which consists of a glass graduated tube marked in inches and parts of inches. This can, by means of a flexible tube, be connected to the drain plug at the lower end, and once the water is at rest in the drain, its level can be recorded and noted, a lower reading later betraying any leakage. This appliance is also useful for readily determining the fall of the drain. If the latter is filled so that the water is just half-way up in the mouth of the pipe in the upper manhole, the total fall on that length of drain will be the depth from the water level in the gauge to the centre of the drain plug below it.

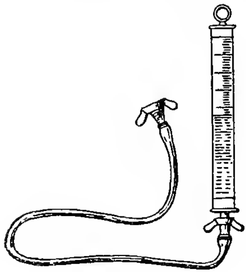


Fig. 370.

During testing, the plugs should be from time to time inspected to see that they are not allowing water to pass them. Another method of applying the water test is to attach a short length of 1½-inch pipe to the plug by means of an elbow or bend, having inside it a small bore pipe to permit of the escape of air as the water enters the drain. The water can be allowed to rise in the pipe to nearly the top, and the depth of the surface below the top can be measured and noted. If there are no manholes, the ground must be opened up at both ends, for the purpose of inserting a plug at the lower end, and of connecting a vertical bend at the upper, in which the water level can be noted.

It is by no means a common practice to test the length of drain from the interceptor to the sewer, but this can be readily done by floating a bag plug through the interceptor, attached to a wire or cord, and then inflating it. This length of drain should be as watertight as the remainder of the system. This possibility of floating the bag plug along the drain and then inflating it is a matter of very great value, for, by it, one is able to localize a leak in the system. Knowing that any length is leaking, float the plug down for a length of, say, 10 feet and then test that short length. If that is satisfactory, deflate the plug and float it on for, say, another 10 feet, and again test. This advantage is not, of course, attached to the use of rubber ring plugs, which can only be used near at hand.

It is a common practice to test soil and vent pipes by means of the water test, though it is considered too severe a test by many sanitary engineers. In passing new work it should certainly be done, but a smoke test under pressure is generally regarded as sufficient for pipes which have been standing some years. The arguments in reference to the fairness of the water test for old drains also apply to this case.

The application of the water test is essentially a matter for a fine day, as in wet weather there is great danger of rainwater finding its way into the drain. During the testing of any drain care should be taken that the sanitary fittings are not used, for the same reason.

The air or pneumatic test is one of which the merits have been much urged in recent years by the opponents of the water test. It applies a uniform pressure to all parts of the drainage system, but that, as already pointed out, does not simulate what happens if a drain becomes blocked at its lowest point, when the pressure to which the drain is subjected by nature is one which increases with the depth of any point below the free surface of the accumulated sewage.

The test is applied by closing all openings on the system, and pumping in air by means of a small pump to which a pressure gauge is attached. If the traps on the system are not also plugged, no appreciable pressure can be applied, since a pressure of about ·036 lb. per square inch on 1 inch of water will be liable to upset the equilibrium of the water seal. If the traps are plugged, any desired pressure can be applied. It is generally accepted that stoneware pipe drains should safely stand a pressure of 3 lb. per square inch (about 7 feet head of water), while properly constructed iron drains should safely stand 10 lb. per square inch (about 23 feet head). The air having been pumped in to a pressure of, say, 3 lb. per square inch as indicated on the pressure gauge, the tap of the pump is closed. Any decrease in pressure recorded by the gauge will indicate the fact of leakage, but it will be seen that the method does not give good facilities for localizing any leakage. The chief argument in favour of the air test, is that air can get through defects which water cannot penetrate.

Other appliances used in the testing of drainage are drain mirrors and electric lanterns. In inspecting a straight length between two manholes, a mirror may be placed in one of the manholes, and the small electric lantern in the other. The mirror is on a stand like an easel, and, if set up at a convenient angle, the observer can, by the aid of the light, note the internal condition of the drain by looking down into the mirror. The effect should be like looking through a tube. If the lantern is a powerful one, its light will be strong enough to illuminate the drain round a slight bend, in which case, although the reflection of the globe containing the light cannot be seen, there is sufficient illumination of the interior of the drain to permit of its interior condition being noted for an appreciable distance from either end.

A drainage system requires maintenance in just the same way as any other part of the habitation, although this is a fact which is largely ignored. Any system of drainage should be regularly inspected and tested, say about every two years.

We now come to the question of procedure in making a complete sanitary survey. Arrangements should be made for the surveyor to be met on the site by a plumber, or preferably a plumber and a labourer, to act as assistants. In London some of the large firms of sanitary engineers keep men who are experienced in this particular work, and send them out with all the necessary apparatus to assist surveyors. The expense is in-considerable, and the value of an assistant accustomed to the work is great.

Having arrived at the site, the surveyor should first make a preliminary and cursory examination of the exterior of the house, and its surroundings. Having done so, he is in the position to instruct his assistant as to the removal of manhole covers, opening up the ground where necessary, plugging the drains, applying the tests, and so on. While this is being done, he is free to turn his attention to the inside of the house until called out by his assistant in reference to points incidental to the tests.

Nothing is more important than that he should be systematic in his inspection. It matters not whether he starts at the top floor and works down to the basement, or vice versa.

Let us assume that the inspection to be made is that of a fairly large house with a basement, and that he intends starting at the lowest floor and working upwards. His notes should be made in a systematic way in proper notebooks kept for this particular purpose. Special books are obtainable, with the various headings printed in, and with sheets of squared paper at intervals for the purpose of making sketch plans, but plain notebooks are better, as no printed notebook can give all the headings likely to be required for every possible case.

Having entered the description of the property and the date, the surveyor should proceed to the basement, and take notes of all matters coming under the heading of sanitation at this level before proceeding upwards; as to items which are satisfactory his notes need only be of the briefest description, but unsatisfactory items should be noted in detail. As he deals with each room he should have regard to its lighting, ventilation, and signs of dampness, if any, and locate the cause. He should look for gulleys in the floor, making a careful search, and having any lumber removed in order that he may do so. If the room contains sanitary fittings they should be thoroughly inspected; if quite satisfactory the only note necessary is, say, "W.C. quite satisfactory," but before making such a note regard should be had to all the following points: floor, walls, type of apparatus, its condition and cleansing properties, trap, its form and condition, means of flushing, capacity of cistern, condition, ball-valve, overflow, flushing pipe, etc., together with all the joints around the apparatus and cistern.

In the case of a sink, the surveyor should have regard to its material, condition, trap, waste pipe, point of discharge, and its situation as regards light; also the nature and condition of the water fittings supplying it.

Having gone through the basement in this way, he should then go to the ground floor and follow a similar procedure; then on to the upper floors, each floor being completed before another is commenced. At the top of the building cisterns will usually be found; the surveyor should have regard to their situation, accessibility, lighting, ventilation, material, capacity, condition, connexions, overflows, and all other details.

The hot-water service should not be overlooked, and unless satisfied that the service is efficient and sufficient, the matter should be settled by lighting the fire and noting the time taken to get hot water and the approximate temperature obtained.

Enough has been written, no doubt, to indicate the general manner of proceeding, but special features will frequently occur. Thus, if there is any reason to doubt the quality of the water, samples should be subsequently taken in the manner previously described. If filters are found, they should comply with the requirements laid down herein for a satisfactory filter.

If gas is used in the house, some sanitary surveyors make a practice of testing the soundness of the gas piping. This is done by a small machine consisting of a pump, pressure-gauge and safety-valve. The pipes should stand a pressure of about 2 lb. per square inch, the method of applying the test being as follows: Shut off the gas at the meter, and connect the pump to a gas bracket by means of a flexible tube attached to the machine. Pump until the gauge registers the desired pressure; the finger of the gauge should then remain stationary. Should it not do so, the leakage can be traced by putting a small quantity of liquid ammonia in the machine and proceeding in the following way: Open the tap of a gas-fitting, preferably that farthest from the meter, to allow the air to escape, and then pump the fumes of the ammonia into the pipes. If a chemically prepared paper is then passed along the pipes, the ammonia fumes which are escaping at any leak will change its colour.

On completing the inspection of the interior of the house, attention must be given to the exterior. Should there be an open area, one must have regard to the condition of its paving and to the facilities for draining it. If there be an ordinary timber floor to the room inside, note the provision as to air bricks for the ventilation of the space below it. In the case of non-basement houses one often finds air bricks blocked up by the banking up of flower beds, or formation of rockeries. The condition of the walls as regards evidence of dampness; of the roof as regards cracked or broken slates or tiles, defective gutters or flashings, and of the eaves' gutters as regards the necessity for cleaning out, all should be dealt with.

Next examine the waste pipes on the faces of the walls, giving regard to the following points: size, material, jointing, fixing, and treatment of upper and lower ends, particularly as regards disconnexion in cases in which it is desirable. Note particularly whether the open ends of soil and vent pipes are in too close proximity to windows or skylights.

One may next inspect gulleys, grease traps, etc., seeing whether they are of satisfactory type, properly set, in clean condition, with sound covers, and so on. Having done this the manholes may receive attention, particularly in regard to their construction, arrangement, condition, and covers. Incidental to this item will be the sufficiency or otherwise of the diameters of the drains discharging into them. One must see, also, whether the drains are disconnected from the sewer or cesspool, and if so, whether the interceptor is in a satisfactory state, of a good type, and whether the stopper of its cleaning arm is secure. The sufficiency or otherwise of the system of ventilating the drains is another point which requires careful consideration.

While the surveyor is giving the bulk of his time to the foregoing items, he will be from time to time interrupted by the necessity of measuring the water levels in manholes, inspecting plugs, and booking results of tests, but there is, of course, no need for him to stand alongside a manhole while the test is in operation. The methods of testing have already been dealt with. If a leak is found in the drains, its position should be located by floating the bag plug through and inflating it at various points as already described. In the case of the pipes above ground, the defective joint or pipe can be readily seen and its exact position booked.

A rough sketch plan of the outline of the building and the courses of the drains should be made, if none is available, so as to enable any proposed alterations to be shown on a plan attached to the report. If any alterations are to be suggested, the approximate dimensions should be figured on this plan. In many cases the courses of the various drains will be fairly obvious from the inspection of the manholes and a comparison with the positions of the gulleys and other features, but in any case of doubt the course of the drain should be traced by pouring coloured liquid through the gulley or fitting. The water may be coloured by adding whiting, or cork dust of various colours is obtainable for the purpose.

The length of drain from the interceptor to the sewer should be tested, or if there is no sewer, the cesspool should be carefully examined and notes made of any defects or objectionable features.

Sufficient has probably been given under this heading to indicate the general course of procedure as to the external inspection.

An example may be given, showing the notes which might be taken when making a sanitary survey of a good-sized house, using an ordinary notebook, and assuming, for convenience, that plans of the building and its drainage are available. The plan of the basement and its drainage is shown in Fig. 371, later in this chapter, in conjunction with the report on the matter.

SANITARY SURVEY OF 116 AIREDALE GARDENS, S.W., FOR C. JONES, ESQ. 12 MARCH, 1919.

INTERNALLY—*Basement.*—Well lighted and ventilated. No internal gulleys. Internal r.w. pipe at back of central staircase. Iron shoe at foot with screw-down cover in good order.

Servants' Hall.—White glazed sink, cracked; grating outlet. One and a quarter inch lead waste discharging into trap of B.P. Sink near by. Waste blocked. H. and C. supply. C.W. tap wants new washer.

Butler's Pantry.—White glazed sink, sound; plug outlet and overflow. Lead covered draining board. One and a half inch lead trap and waste through wall and over gulley. H. and C. supply. Taps in good order.

Scullery.—Two white glazed sinks side by side, badly chipped and worn. One with plug outlet and overflow, other with grating. One and a half inch lead wastes, one discharging into trap of other. Waste through wall and over gulley. H.W. taps want new washers.

Knife House.—Draw-off tap in good order, no drip sink but cement floor with good fall to doorway.

Servants' W.C.'s.—One adjoining area steps. Hopper pan and trap, latter broken. Seat badly broken. Two gal. W.W.P. in good order but handle missing. Other, near by, pedestal wash-down, broken. Seat has balance weights, which have been cause of breaking pan. Two gal. W.W.P. in good order but handle missing.

Cement floors to both, good windows, and ventilated by space below door also.

GROUND FLOOR—*Cloakroom.*—White glazed tip-up lav. basin. One and a quarter inch lead trap and waste through wall and over gulley. H. and C. supply. Taps in good order.

W.C. adjoining. Wash-out apparatus, dirty condition. Dished marble safe, no waste pipe. Two gal. W.W.P. in good order. Well lighted and ventilated.

FIRST FLOOR—*W.C.*—Exactly as last, otherwise in good order.

Bathroom.—White porcelain bath. Fixed enclosure, pol. mahog. top. Lead safe under with WP. through wall. Two-inch lead trap and waste through wall and over hopper head. H. and C. supply—taps in good order.

Draw-off tap beside bath, with lead-lined drip sink under, waste through wall, all in good order.

White glazed lav. basin, weir overflow. One and a quarter inch lead trap and waste through wall and over hopper head. H. and C. supply—taps in good order.

SECOND FLOOR—*W.C.*—Exactly as for first floor and ground floor.

Bathroom.—Exactly as first floor, but no lav. basin.

THIRD FLOOR—*Slop Sink.*—Brown's patent, properly trapped and discharging into soil pipe. Two gal. W.W.P. over, also H. and C. supply. All in good order. Well lighted and ventilated.

Cistern.—Large gal. iron cistern, with overflow through wall. Ball-valve in good order. Supplies all taps except the one in Knife House, which is off main.

HOT-WATER SERVICE.—Large galvanized-iron cylinder beside range in kitchen. Service very efficient, but no safety-valve to boiler.

EXTERNALLY—*Area Pavings.*—Cement, with good falls to gulleys.

Dampness.—Slight dampness on wall adjoining M.H. No. 2 in central area, due to split length of r.w. pipe.

Roof.—Slate, about half-dozen cracked. Lead flashings sound. Parapet gutters require cleaning out.

Waste Pipes.—R.W. pipes all in good order except one just referred to.

Hopper heads taking wastes from baths and lavs. rather fouled.

Soil Pipes.—Centre area, near M.H. No. 2, 4-inch light lead, with wiped joints. Badly bent and bruised. Takes W.C.'s on first and second floors. No anti-siphonage pipes. Carried well up above roof. Grating perished. Joint at foot sound.

Front area, facing street, 4-inch light lead, square section, somewhat dented. From about 12 feet from paving it goes on up to near eaves in 4-inch iron, circular, and then on in 4-inch light lead, circular, to well above ridge.

Gulleys.—All ordinary stoneware yard gulleys, in fair condition. One grating broken in yard at back and one in front area.

Manholes.—Three in all. No. 1 (front area) brown glazed stoneware channels. Bottom not benched and very defective. Walls cement rendered and in good order. Hinged iron cover, broken. Intercepting trap, stopper to arm missing.

No. 2 (central area) similar construction and benching defective as before. Cover badly rusted. No. 3 (at back) ditto, and cover broken.

Diameters of Drains.—Main from M.H. 3 to M.H. 1 of 6-inch pipes, also 6 inches from angle of kitchen to M.H. 1. All others 4-inch. All under floors and pavings, ground not opened up, but appear to be stoneware socketed pipes and cement joints throughout, judging from manhole connexions.

Ventilation of Drains.—Outlet ventilation provided by S.P. in front and centre areas only. No V.P. at back. F.A.I. to M.H. 1 in a chase of wall of W.C. Mica flap valve, grating broken and flap missing.

RESULTS OF TESTS—*Smoke Test on Soil Pipes.*—One in centre area quite sound. Other, front area, weak at joint near eaves, between lead and iron.

Water Test on Drains.—R.W. drain under kitchen discharging into back of gulley, quite sound. Drains under yard slightly leaky. All other drains very leaky, particularly that from M.H. 2 to M.H. 1.

The surveyor should not leave the site until he has considered the recommendations he intends making. It is most important that he should bear this in mind so that he may make sure of the feasibility of such suggestions. There are often obstacles which are not obvious from a sketch plan, and it would not be to his credit to suggest amendments which cannot be carried out.

Having made the survey, the next step is the writing of the report. This is a matter calling for the exercise of considerable care and sound judgment. When making recommendations, all the circumstances of the case must be taken into consideration. It is, perhaps, easy to say, if the system of drainage is, generally speaking, unsatisfactory, remove the whole system and begin again, but if the client is a lessee with a fairly short unexpired term, this would probably lead to nothing being done at all, whereas moderate recommendations would probably be carried out. Counsels of perfection, if injudiciously given, tend to set back the clock of sanitary progress. The surveyor should take his client entirely into his confidence, and tell him frankly, if such is the case, that while a suggested alteration would be a great improvement, there would be no danger to health, under ordinary circumstances, in leaving that particular item as it is.

When reporting to a lay client, care should be taken to keep the report as free as possible from technical expressions which a layman would not be likely to understand. To such a man, a report written in plain language must necessarily gain in intelligibility, and will certainly lose none of its professional value if properly done.

There are many ways of writing a report, each man having his own particular method as a rule, but the following are three good forms :—

1. A formal report, headed as such, free from any personal element, a margin being left in which the various items are given as they are dealt with. The report on each item can be immediately followed by any recommendations which it is desired to make, or all the recommendations can be left until the end of the report. The former is usually the more convenient way, and the recommendations can then be briefly summarized at the end.

2. An informal report, written in a personal manner, in the form of a long letter. The marginal subheadings should be used in this case also, as they help a client to readily find any particular item. The recommendations can be dealt with in the same ways as given for form No. 1. The reports should of course be dated, and headed with the name of the property, after the opening words "Dear Sir".

3. A formal report, headed as such, arranged in, say, three

columns, the first being headed Item, the second Report, and the third Recommendations, the report being signed and dated as before.

We will assume that the surveyor prefers form No. 1. In that case his report, based on the notes already given, might read as follows:—

REPORT ON THE SANITARY CONDITION OF 116 AIREDALE GARDENS, LONDON, S.W., FOR C. JONES, ESQ. 14 MARCH, 1919.

GENERAL NOTE.—The sanitation of this house, although of fairly recent date, is, generally speaking, in an unsound condition, and considerable remodelling and overhauling is necessary.

THE WATER SUPPLY.—The water supply is derived from the mains of the Metropolitan Water Board, but there are no taps off the main except one in the Knife House. All the sanitary fittings are supplied from a large galvanized-iron cistern on the third floor. This cistern is in good order, and has an overflow pipe carried through the external wall.

It is very desirable that the taps over all sinks where water will be drawn for drinking or cooking purposes should be supplied direct from the main. The hot-water service is in an efficient state. There is a large storage cylinder in the kitchen, near the range, but there is no safety-valve on the boiler. It would be well to provide one and to overhaul and clean out the boiler and cylinder.

Hot and cold-water supplies are laid on to all the baths, lavatories, and sinks. The water fittings are of good quality, but several taps require new washers.

THE SANITARY FITTINGS—*Water-closets.*—There are internal closets on the ground, first, and second floors. They are well lighted and ventilated, but each is equipped with a pedestal wash-out apparatus. This is a bad form of apparatus, the force of the flush from the cistern being expended in clearing out the basin, leaving no scouring effect for the trap. They should be replaced by a good type of wash-down apparatus. The closet is flushed by a two gallon water-waste preventing cistern in each case, and these are in good order. Each of the pans stands on a dished marble slab, intended to act as a safe, but these slabs should be provided with waste pipes passing through the external wall.

There are two servants' closets under the pavement, both being in a very insanitary state as regards the apparatus. In both, either the pan or the trap is broken, and in one the seat is badly broken. The flushing cisterns are quite efficient except that the handle of each is missing. Both these closets should be overhauled, and a good type of pedestal wash-down apparatus installed.

The paving, lighting, and ventilation are satisfactory.

Sinks.—There are five sinks. That in the *Servants' Hall* is white glazed, with a grating outlet, the waste pipe discharging into the trap of the *Butler's Pantry* sink near by. This sink is cracked and should be renewed. At the same time a trap should be provided and a new waste pipe taken direct through the wall to discharge over a gulley.

The present method of dealing with the waste is unsatisfactory and the waste pipe is now blocked.

The *Butler's Pantry* sink is white glazed, but with plug outlet and overflow. It is in good order and is fitted with a lead-covered draining board. The sink is trapped and the waste pipe discharges through the wall over a gulley.

The *Scullery* has two sinks, side by side, both white glazed, one with grating outlet and the other with plug and overflow. Both are badly chipped and worn and should be replaced by new. The waste pipe from one passes into the trap of the other. When putting in the new sinks this should be altered, and each sink separately trapped and provided with its own waste pipe, passing through the wall and discharging over a gulley.

A *Slop Sink* is provided on the third floor, properly trapped and discharging into a soil pipe. This fitting is of good quality and in sound order. The small apartment in which it is placed is well lighted and ventilated.

The tap in the *Knife House* has no drip sink under it, but the floor is of cement and has a good fall towards the doorway. There is, therefore, no harm in not providing one.

Baths.—There are two baths, on the first and second floors respectively. Both are of good white porcelain, have fixed enclosures and polished mahogany tops. Fixed enclosures are not desirable, but otherwise the baths are all in good order. Each has a lead safe under, with proper waste pipes. The baths are trapped and provided with good-sized waste pipes discharging through the walls, over hopper heads.

In each bathroom there is a draw-off tap beside the bath, with lead-lined drip sinks and proper waste pipes.

Lavatory Basins.—There are two of these. That in the cloakroom, on ground floor, is an old-fashioned tip-up basin of white glazed ware, with properly trapped waste pipe carried through the wall and discharging over a gulley. This fitting is not very sanitary, and should be replaced by a good modern type of basin, such as is provided in the first floor bathroom.

The lavatory there is in excellent order. Its waste pipe is trapped and discharges over a hopper head.

THE DRAINS.—The courses of the existing drains are shown on the accompanying plan by firm lines, their diameters being figured. They were not uncovered during the inspection, being all under floors and pavings, but from the connexions with the manholes they appear to be of ordinary stoneware socketed pipes, jointed in cement. The water test was applied to the whole of the drains. The rain-water drain under the kitchen is quite sound, but all the other drains are defective. The length under the yard at the back is slightly leaking and is very badly planned. The other drains all leaked badly, but particularly the length between manholes Nos. 1 and 2.

It is strongly urged that the whole of the drains, except the length under the kitchen, be taken up, the trenches properly disinfected, and the drainage relaid with heavy cast-iron pipes, protected against corrosion by the Angus Smith process, and with caulked lead joints, the pipes being laid on concrete. The plan shows the suggested modifications by means of dotted lines. These modifications occur under the yard at the back, and under the front area, the courses of the remaining drains being kept as at present. The complicated junctions under the front area should be done away with, the two W.C.'s and the soil taken separately into the manhole, and the various other wastes collected into a large gulley between the scullery window and manhole No. 1. It should be flushed by means of a ·30-gallon automatic flushing tank, fixed in the Knife House, and discharging at least once a day.

Manholes.—There are three manholes for inspection. They are all of defective construction at the bottom, which is formed of glazed stoneware channels set in concrete, the remainder of the floor being practically flat and badly broken up, instead of being well benched up in cement. These should be remodelled on up-to-date lines, with white glazed channels and proper benching. The walls are rendered in cement and are in fairly good condition. The iron covers to Nos. 1 and 3 are broken, and that to No. 2 is very badly rusted. All three manholes should have new heavy galvanized-iron airtight covers. An intercepting trap is provided to manhole No. 1. It is of satisfactory type, but the stopper to the cleaning arm is missing and there is nothing to shut off the air of the sewer to which the drains are connected. It is important that a proper airtight stopper be provided forthwith. It is suggested that another manhole be added in the yard at the back, which will greatly improve the arrangement of the drainage at this point.

Gulleys.—The gulleys are all ordinary stoneware yard gulleys. In remodelling the system, channel gulleys should be put under the outlets of waste pipes from baths, lavatories, and sinks, the ordinary form being retained for the rain-water pipes. If the system is carried out in iron, the new gulleys should be of iron. Two of the present gulleys have broken gratings.

VENTILATION OF THE DRAINS.—Outlet ventilation is provided by means of the soil pipes in the front and centre areas respectively. There is no outlet ventilating pipe at the head of the system and one should be provided as shown on the plan attached hereto. The inlet for fresh air is placed in a chase in the wall of the W.C. adjoining manhole No. 1 and is fitted with a mica flap valve which is badly broken. If the new vent pipe is added at the back, this fresh-air inlet can be removed entirely, sufficient inlet being provided in such case by the soil pipe in the front area.

RAIN-WATER PIPES.—The rain-water pipes are all in good order, except for a split length on the wall adjoining manhole No. 2, which has caused slight dampness on the exterior of the wall. This length should be removed and a new one provided.

WASTE PIPES.—The wastes from the baths and lavatories above the ground floor level are discharged into hopper heads of rain-water pipes. These heads are all rather fouled and the practice of using them for this purpose is not to be commended. To make a good job, main waste pipes of lead should be provided, carried well above the roof and finished with open ends for the purpose of ventilating them. Where two fittings discharge into the same waste pipe, the traps should be properly ventilated to protect them against siphonage.

SOIL PIPES.—The soil pipe near manhole No. 2 is of light lead, 4 inches in diameter, with wiped soldered joints, but is badly bent and bruised. The joint at the foot is sound, and the pipe is carried well above the roof, but its otherwise defective condition makes it desirable to remove it and provide a new heavy lead pipe of 3½ inches in diameter, together with 2-inch lead anti-siphonage pipes to the traps of the W.C.'s discharging into it. The soil pipe in the front area is partly of lead and partly of iron, partly square and partly circular in section. It is somewhat dented and the tests disclosed the fact that it has a leaky joint. The square section is particularly insanitary. This pipe should also be replaced by a proper one as just described, and both should have domical wire gratings at the top to prevent obstruction by birds.

ROOF AND GUTTERS.—There are about half a dozen cracked slates, which should be removed and replaced by new ones.

The lead flashings are in good order, but the parapet gutters are badly in need of cleaning out.

SUMMARY OF RECOMMENDATIONS.—The foregoing recommendations may be briefly summarized, as follows:—

Additional draw-off taps to be provided from the main water supply pipe.

Hot-water service to be overhauled and safety valve added to boiler.

New washers to be provided to taps where needed.

Present closet apparatus to be removed throughout and new pedestal wash-down closets provided.

Waste pipes to be put to the marble safes.

Handles to be provided to cisterns where missing.

New sinks to be put in Servants' Hall and Scullery, and waste pipes remodelled in both cases.

Lavatory basin in Cloakroom to be replaced by one of modern type.

The drainage to be remodelled, involving relaying nearly the whole in iron pipes, including remodelling manholes and building one new one, overhauling and renewing gulleys, etc.

New soil pipes to be provided in place of existing ones, with anti-siphonage pipes.

New outlet vent pipe to be provided at the upper end of the system, and old fresh-air inlet removed.

Rain-water pipes to be overhauled, and new waste pipes provided, ventilating any traps where necessary.

Roofs and gutters to be overhauled.

(Signed) A. SURVEYOR, F.S.I.

20 Blank Street,
London, S.W.

The plan to be attached to the foregoing report is shown in Fig. 371. It will be seen from the foregoing that technicalities can be largely avoided in writing a report. Another point to be avoided is that of writing a report too much like a specification of the suggested work. The specification is a separate matter entirely, and, being intended for a builder or sanitary engineer, can be in technical language. It would also give much more detailed information as to sizes and materials.

A formal report such as the foregoing would be accompanied by a letter acknowledging receipt of instructions, and stating that the survey has now been made, etc.

If the foregoing report had been written in accordance with the second method given, it might be somewhat as follows:—

20 Blank Street, London, S.W.,
14 March, 1919.

DEAR SIR,

116 AIREDALE GARDENS, LONDON, S.W.

In accordance with the instructions contained in your letter of the 10th inst., I inspected this property on the

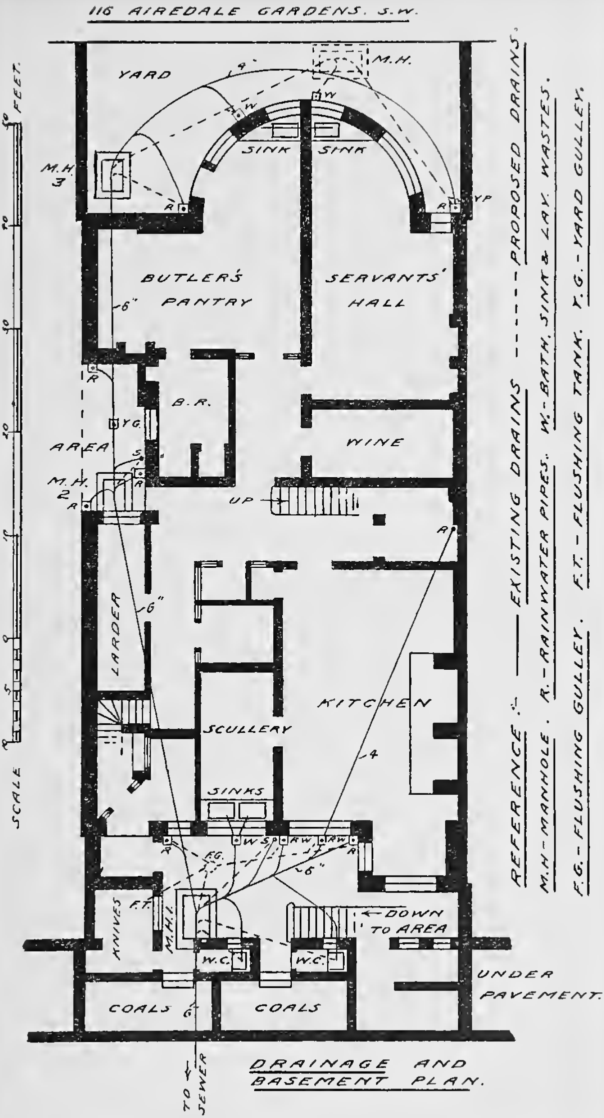

116 AIREDALE GARDENS. S.W.
YARD
M.H.
M.H. 3
SINK
SINK
BUTLER'S PANTRY
SERVANTS' HALL
B.R.
WINE
AREA
M.H. 2
UP
LARDER
KITCHEN
SCULLERY
SINKS
KNIVES
F.T.
M.H. 1
W.C.
W.C.
DOWN TO AREA
UNDER PAVEMENT.
COALS
COALS
TO SEWER
DRAINAGE AND BASEMENT PLAN.
SCALE
FEET.
REFERENCE :- —— EXISTING DRAINS - - - - - PROPOSED DRAINS.
M.H.-MANHOLE. R.-RAINWATER PIPES. W.-BATH, SINK & LAV. WASTES.
F.G.-FLUSHING GULLEY. F.T.-FLUSHING TANK. Y.G.-YARD GULLEY.
S.-SOIL PIPE V.P.-VENTILATING PIPE.

Fig. 371.

13th inst., and now have pleasure in reporting to you thereon as follows :—

GENERALLY.—The sanitation of the house, although of fairly recent date, is, generally speaking, in an unsound condition, and considerable remodelling and overhauling is necessary.

THE WATER SUPPLY.—The water supply is derived from the mains of the Metropolitan Water Board, but there are no taps off the main except one in the Knife House. All the sanitary fittings are supplied from a large galvanized-iron cistern on the third floor. This cistern is in good order, etc., etc., etc.

I am, Dear Sir,
Yours very truly,
A. SURVEYOR, F.S.I.

To C. Jones, Esq.

If, on the other hand, the third method be adopted for the report, a covering letter would be needed, and the report might read as follows :—

REPORT ON THE SANITARY CONDITION OF 116 AIREDALE GARDENS, LONDON, S.W., FOR C. JONES, ESQ. 14 MARCH, 1919.

Item.	Report.	Recommendations.
Water supply.	From mains of Metropolitan Water Board. Large galvanized-iron cistern on third floor, in good order. It supplies all sanitary fittings. No draw-off taps on main supply pipe except one in the Knife House.	The taps over all sinks at which water will be drawn for drinking and cooking purposes should be supplied direct from the main.
Hot-water service.	etc. etc.	etc. etc.

(Signed) A. SURVEYOR, F.S.I.

20 Blank Street,
London, S.W.

The importance of drawing up the report after the fullest consideration of all the circumstances, economic and otherwise, must always be borne in mind, the conditions under which sanitary surveys are made being so very diverse. As already pointed out, one is often justified in making very moderate recommendations, which will lead to the improvements being made, whereas counsels of perfection might lead to nothing being done at all.

CHAPTER XIV

THE COLLECTION AND DISPOSAL OF REFUSE, THE CLEANSING OF STREETS, DISINFECTION, AND SMOKE ABATEMENT.

THE collection and disposal of house refuse is a most difficult but important part of the work of local authorities. The nature of the refuse varies with the locality to some extent, but varies considerably from season to season, if only on account of the fact that fires are in general use in the winter and not in the summer. To a large extent, house refuse consists of vegetable matters containing a high percentage of moisture, usually about 70 per cent.

The only sanitary method of dealing with it is to cremate it. This is done, in a well-administered locality, in special furnaces, known as refuse destructors. Much could be done to reduce the difficulty of destroying it if householders realized that they had some personal liability in the matter, and burned, in the kitchen range, as much refuse as possible, particularly waste vegetable matters.

The nature of house refuse would, at first sight, seem to be a fairly constant quantity, but it is interesting to note that owing to the greater use of gas stoves, electric cookers, and such items, the refuse is altering in character, containing much less cinders and ashes than hitherto, causing the calorific or fuel value to be lower. A natural corollary of this is that the cost of destruction is increasing. In some places refuse destructors which used to be worked entirely by refuse have now to be assisted by means of coal.

When it is pointed out that the average amount of refuse collected per annum is about a quarter of a ton per head of population, it will be seen that the dealing with the waste matters of a large population is a big matter.

Fixed ashpits are rapidly becoming a thing of the past, and it is good, from a sanitary point of view, that this is so. The use of portable galvanized-iron bins, of a capacity not exceeding 2 cubic feet, should be insisted on. The bin should be covered and should be placed on an impervious floor, such as a block of concrete finished with cement. It should be distinctly impressed on the householder that it should not be used for liquids, and in some places perforated bins are used to prevent such use. The lid should not be tightly fitting, as unless the bin is of very thick metal, it is apt to get battered out of shape by banging it on the edge of the dust cart, after which the lid will not fit at all. A lid with a deep rim, fitting loosely over the bin, is better.

The bottom of the bin, in any ordinary case, is generally found to be very wet and muddy, making it difficult to entirely empty its contents. A bin has recently been introduced with a removable bottom in order to overcome this difficulty. Fish offal is the worst kind of refuse to deal with, and fish shops and restaurants should have separate receptacles for this, with airtight covers, the refuse being kept quite separate as it is valuable for manure.

The usual practice for collection, in the case of large towns, is a weekly house to house call, with a daily call in the case of hotels and restaurants. The weekly call is none too satisfactory, causing the accumulation of a larger quantity than it is desirable should exist in the immediate neighbourhood of small houses. The exact hour of call is often uncertain, and the dustman often finds no one at home, which intensifies the nuisance from a sanitary point of view.

The adoption of small receptacles and a daily call has been made in the case of some large towns, with conspicuous success and no increase in the annual cost.

The carts formerly used were of wood, but they are not economical as regards repairs, and difficult to cleanse and disinfect. The best form of van for the purpose is one having an iron body on a wooden frame, and fitted with an iron cover. These are far more easily cleansed and disinfected and are altogether better than the old form.

While the best method of disposal is by burning, it must be noted that many other methods are in use. In the case of some towns near the sea, such as Liverpool and New York, refuse is barged out to sea in special barges, and dropped into deep water. This method has its drawbacks; in winter the weather is often such that the barges dare not go out for sometimes a week at a time, which necessitates storage and consequent nuisance. Again, the tide will often bring a quantity of the lighter particles of refuse back again.

In agricultural districts it is sometimes possible to sell it, or give it away, to farmers for manure, especially when mixed with lime or sewage sludge. This method, however, necessitates the sorting out of old iron, tin cans, and such things, and the work is very unhealthy and objectionable. Refuse should receive a minimum of handling, no matter what method is adopted.

At one time refuse was often sold, or given, to brickmakers, but the large amount of valueless material found in the refuse nowadays has made this method of disposal practically obsolete. At one time, also, some authorities adopted the method of sorting and utilizing the refuse, barging the residue away or tipping it on vacant land, but this method is fast dying out.

At Southwark a system of pulverizing the refuse is adopted the plant consisting of a steel cylinder in which revolves a shaft carrying powerful hammers. The resulting powder can be disposed of as manure. The cost of labour and carriage in this installation is 3s. 1d. per ton and the material realizes 2s. 3d. per ton, making the net cost of disposal 10d. per ton, not considering interest on the money spent in installing the system.

Many towns formerly adopted the method of carting the refuse to outlying districts and using it for filling up hollows. This practice cannot too strongly be condemned on sanitary grounds.

The idea that there is anything to be made out of towns' refuse is generally fallacious, but it is possible to do a little in this way. Thus, if a refuse destroying furnace is used, the tin cans are often picked out as the furnace is being stoked; so also are bottles. The tin cans, in the case of some large installations, are treated by elaborate processes for the recovery of both the tin and the solder, leaving only the scrap iron which formed the body of the so-called tin can. The scrap iron is formed into bales by subjecting it to great compression, and the process can be made to pay if the quantity is sufficient.

In the early days of destructors objection was made that they were nuisances to a neighbourhood, producing offensive smells, and that fine ash or dust was carried up the chimney shaft and scattered for a considerable distance around. Before the scientific principles underlying their construction were understood, there is little doubt that such complaints were well founded, but such great advances have been made that sanitarians are now agreed that the plan of disposing of towns' refuse by burning is the only really satisfactory one.

The essentials of a satisfactory destructor installation are that its position should be fairly central, to economize cost of cartage; it should convert the organic matters into harmless and useful inorganic matters; and there should be no nuisance from smell, smoke, dust, or other cause.

There are two kinds of destructor, (1) that with a relatively low temperature furnace, fed by a natural draught of air, and (2) that with a very high temperature and forced draught.

The design of refuse destroying furnaces has been built up on a foundation laid by the first destructors installed in England and erected at Manchester in 1876, the inventor's name being Fryer. This installation is still in use, with modifications, and a brief description of the original Fryer de-

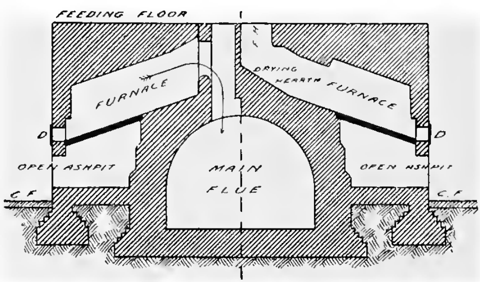


Fig. 372.

structor will serve the purpose of showing the lines on which development has taken place.

It consists of a group of cells, each of which constitutes a separate furnace, consisting of a wide but shallow arch with inclined fire bars below it. The disposition of the cells is largely a matter of convenience, depending on the exigencies of the site, but they are often placed in two rows, back to back, as shown in Fig. 372. Each cell is about 9 feet front to back, and about 5 feet wide. The front of the furnace is formed by the fire bars with the arch over them, the former being of very heavy section and set to an inclination of about 1 in 3. The back of the furnace is divided into two parts, one in the form of an opening through which the gases, given off by the burning refuse, pass to the main flue, as shown in the left hand half of Fig. 372, and the other in the form of a charging opening or feed hole, F.H., with an inclined drying hearth below, as shown in the right half of Fig. 372. In other words, Fig. 372 shows a section through two cells, placed back to back, the section at the left being through one part of the cell and that at the right through another part. The top of the destructor forms a platform on to which the vans bring the refuse by means of an inclined road. The opening for the entry of refuse is divided from the opening for the exit of gases by a wall, and the refuse is prevented from getting into the main flue by the round-topped low wall shown in the section. In this original form the main flue was made very large, so as to act as a dust catcher, and the ashpit below the fire bars was open at the front, adjacent to the clinkering floor, C.F. The clinker was removed through doors formed at D.

The cells are provided with special openings for the introduction of infectious bedding, diseased meat, dead animals, etc., which fall direct upon the burning refuse and are consumed without nuisance.

It will be seen from the section, that the gases given off by the burning refuse passed straight into the main flue and did not get that cremation which is so desirable. The first great advance was made by the Horsfall destructor, in which the gases pass over the hottest part of the fire to an outlet flue in front, leading down to the main flue as shown in dotted lines in Fig. 373. The ashpit was enclosed, and a forced draught provided for. This was done by providing a blast flue for each row of cells, placed alongside the main flue to get a fairly high temperature. The air is driven through the blast flue by means of a powerful steam jet at the end and enters the ashpit through air boxes, A.B., at the sides of the cell. The sides of the cells are particularly liable to damage and the clinker is very liable to adhere to them. The air boxes are arranged with plates which are readily renewable in order to simplify matters as to this point. It will be seen that the

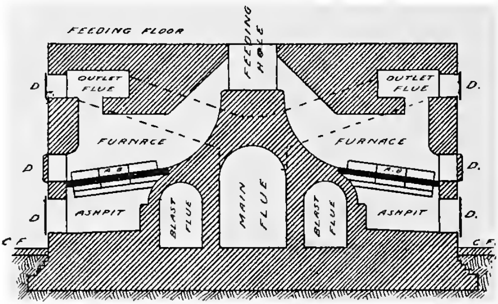


Fig. 373.

drying hearth has no place in this form. The fire bars are shown by a thick black line as in the previous example. There are three doors to each cell, the top one for cleaning the outlet flue, the next for clinkering, and the lowest for access to the ashpit.

Some destructors are fed at the top, some at the back, and some from the front. An example of a back-fed destructor cell is shown in Fig. 374. It will be seen that this is a modification of the Horsfall type shown in Fig. 373. The furnace is fed from a feeding floor below the top of the destructor. This method is quite sound, as there is no great loss of heat by opening the charging door, owing to the

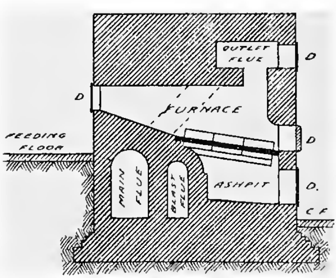


Fig. 374.

front situation of the outlet flue. Front feeding, on the other hand, is open to the objection that there is more loss of heat.

As already stated, the refuse should have as little handling as possible, and in large installations systems of mechanical feeding are now largely adopted.

The addition of the forced draught and the alteration of the position of the outlet flue led to the cells being able to consume about twice as much refuse per day as was possible before, and at a lower cost.

Further improvements have, however, been made in destructor practice. Thus, the air is heated to a high temperature before admission to the blast flue, the heated air raising the temperature of the furnace by an amount equal to nearly twice as much as its own temperature. It is usual to utilize the heat from the furnaces to generate steam, which is used for various purposes, such as the generation of electricity, pumping water or sewage, and so on. The boilers should not be too near the furnaces or they will tend to lower the temperature in them. The air heater is arranged in the form of tubes, through which the waste gases pass after serving the boilers, thus raising to a high figure the temperature of the air around the tubes. Such air is then driven to the ashpit by means of either steam blowers or fans. Both fans and blowers have their advocates, but a blower would seem to be better where a pressure has to be overcome. Not only does the hot air raise the temperature of the furnace, it also helps to absorb the moisture in the burning refuse.

Another item in the installation is a large combustion chamber, generally arranged at the end of a row of cells, the object being to bring down the velocity of the gases, on their way to the chimney shaft, to a low figure, so as to ensure the deposit of dust in a position at which it is easily accessible.

While the cellular plan is the original, and generally followed, some types of destructor are not split up into separate cells, but have a continuous fire grate from end to end, with undulating arches over them to deflect the gases over the fire on their way to the flue. Here, again, both methods have their advocates, and good examples can be pointed to on either system.

Under the old natural draught system a temperature of about 900° F. was seldom exceeded, but in the case of a good modern high temperature furnace the figure ranges from about 1500° to 2000°.

One advantage of placing the cells back to back is that the main flue can be placed between them, and its high temperature thereby be preserved. The fire grates generally vary from about 25 to 42 square feet in area.

It will be seen that in order to maintain the high temperature necessary for perfect cremation of the refuse, the doors must not be opened more than necessary. One of the best recent improvements is the Horsfall Tub Feeding system. A large container or tub is lowered, by an overhead travelling crane, into a charging pit so that the carts can tip their contents directly into it at ground level. Each tub holds about two tons of refuse, and enough tubs are provided to receive the storage for the hours when collection is not going on. The tubs are lifted to the high level by the crane, and placed on a platform to await charging. When a furnace has to be charged, a tub is lifted by the crane, and lowered into a cradle over the furnace. The descent of the cradle opens the charging door, and the ascent of it, when the tub is lifted again after charging, again closes the door. The operation of charging the two tons into the furnace takes less than a minute, the system effecting a great saving of labour and increasing the working capacity of the cell. Further, it ensures the maintenance of a high temperature.

The temperature of the waste gases of a good destructor is far higher than that of the gases from an ordinary boiler furnace, and after serving a boiler, and being utilized for heating the air for the forced draught, they can be further used to warm the water which is on its way to the boiler. This is done in what is termed an economizer, an apparatus somewhat like a hot-water coil, the waste gases playing round the pipes.

The building in which the destructor installation is housed requires careful ventilation, and care must be taken that the ventilation is inward and not outward, as in the latter case there might easily be nuisance from smell. One of the best ways is to provide an air duct high up in the building, communicating with the air supply for the forced draught. The forced draught, by this arrangement, pulls the air out of the building, and passes it on to the ashpits.

It is difficult to give figures of any value in reference to destructor installations, but the following give a rough idea. The approximate cost of the installation can be put at about £500 per cell, excluding the cost of the building, boilers, and chimney shaft. The percentage of clinker left, after burning the refuse, averages from 25 to 33 per cent. The quantity consumed per cell per twenty-four hours varies very much, both according to the make of furnace, method of stoking, nature of draught, etc., and can be anything from about 8 to 20 tons. The cost of destruction averages about 1s. 8d. per ton in London, and nearer 1s. per ton in the provinces.

The composition of the clinker also varies somewhat, but it is stated by Mr. H. P. Boulnois, M.I.C.E., to be, generally speaking :—

Silica	69·4 per cent
Iron and alumina oxides	21·4 ,,
Carbonate of lime . .	9·2 ,,

the composition of the fine ash being much the same, but containing more silica.

Many destructor installations have, in the past, been failures by reason of the fact that efforts were being made to get too much out of them. The complete destruction of the refuse must always come first and foremost in any satisfactory installation, and the raising of steam, etc., be an after consideration. There are, however, certain residuals incidental to any such process. As has been seen, the waste gases can be utilized for raising steam; bottles and tin cans can be rescued, and lastly, but by no means least, there is the clinker. When finely crushed it can be used instead of sand in mortar and plaster, for sanding slippery roads, and for bedding paving slabs. It is also largely used for fine concrete, such as paving slabs or paving laid in situ. The slabs are generally of three parts fine clinker and one part Portland cement, moulded under a pressure of about 60 tons per square foot. In some places bricks have been made from the clinker. Thus, at Fulham, pressed bricks are made of one part of Portland cement to nine parts of finely crushed clinker. The resulting brick is only very slightly absorbent, very strong, equal to about blue Staffordshire bricks, but grey in colour.

Other uses for clinker are, filter beds for sewage, filling up low-lying land, and foundations of roads for light traffic.

The cleansing of streets is a matter which, generally speaking, is quite distinct from the destruction of house refuse, though part of the street refuse is often mixed with that from the houses and taken to the destructor. Street refuse consists of dust, mud, rubbish, road-scrapings, ice, snow, and filth.

Streets must be kept clean primarily for sanitary reasons, but also for appearance, comfort, and convenience. Dust carries organic impurities and is a means of spreading the germs of disease. That from wood pavements is especially injurious to the lungs and eyes. From the point of view of cleanliness, the materials used for road surfaces may be placed in the following order: (1) Asphalt. (2) Wood paving (new).

(3) Tar macadam. (4) Wood paving (old). (5) Granite setts, and (6) Macadam.

The secret of success in cleansing streets is method. A definite system should be mapped out, and departed from under no circumstances whatever. Not only should the local authority cleansė the main and side streets, they should be made liable also for cleansing courts and alleys.

In a well-regulated town, the main streets are cleansed at least once a day, and the work should in such case be finished by between 6 and 7 o'clock in the morning. For all streets with considerable traffic, a street orderly service should be established, boys removing continuously horse droppings, etc., and depositing them in iron bins at the side of the road or pushing them into heaps with long-handled scrapers. Hand barrows are preferred by some municipalities, owing to shop-keepers using the bins as dust boxes.

Suburban streets do not need such frequent cleansing as the busy streets of the town, and it is usually sufficient to cleanse them about twice a week.

A moment's consideration will disclose the fact that some roads must be easier to cleanse than others. Thus, asphalt is non-absorbent and jointless, therefore such garbage as collects on it can be readily removed. Granite setts, however, though practically non-absorbent, give a very rough surface with a multiplicity of joints in which garbage can collect.

Asphalt and wood block roads should be frequently washed, but in many cases one hears of the difficulty of obtaining the necessary supply of water. In most places there is only one supply for all purposes, public and private, and it is a matter for consideration whether an unfiltered supply for washing streets, fire extinction, and such purposes, could not advantageously be provided. The frequent washing of wood block paving is found to remove the complaints as to smell. The hygienic value of the washing can be increased by the addition of some simple disinfectant to the water. A gallon of liquid carbolic acid to 2000 gallons of water would be a valuable disinfectant.

In rainy weather the street orderly boys should be armed with squeegees, with which to push the slop which forms on the surface into the side channels. This tends to keep the road surface clean and safe for traffic.

Macadam and granite sett roads are best cleansed by sweeping, either by hand or machine. Mechanical sweepers were first introduced by Sir Joseph Whitworth. One type consists of a series of brooms, about 30 inches wide, attached to a pair of endless chains, which turn round two sets of pulleys, an upper and lower set. The pulleys are geared to the cart wheels and revolve with them, the mud or dust cart being in front of the brooms. The sweepings are carried up an inclined plate, and drop into the receptacle. The machine is horse drawn and requires only a driver; it does not work very well when the mud is in a stiff, semi-solid condition, but if water carts are sent out before the machine there is little trouble. Some forms of mechanical sweeper have no dust receptacle and merely sweep the dust and mud to the side of the machine. A good mechanical sweeper will do the work of from ten to twelve men.

The disposal of street sweepings is generally a troublesome matter. The scrapings from macadamized roads can generally, if washed, be used with lime or cement for mortar. Mud is often tipped on waste land, but it should not be placed on possible building sites. It can also be mixed with house refuse and burned in a destructor.

Apart from the question of cleansing is the question of watering streets in order to keep down the dust in dry, windy weather. In the case of wood-paved roads the watering is also beneficial to the wood itself, making it less subject to injury by abrasion. In crowded districts, or in times of epidemics, disinfectants should be added to the water. An example would be 1 lb. of permanganate of potash and half a pint of sulphuric acid to 100 gallons of water. Blocks of a disinfectant termed pynezone are also largely used for this purpose.

The road may be watered by a hose or by means of a water cart. In England the latter method is the more usual, both horse and motor driven carts being used. The water either issues through a perforated pipe or is distributed by falling on two rotating discs or spreaders. A good cart or wagon will spread the water over a width of 20 feet, the quantity used being about one-fifth of a gallon per square yard of surface.

In the case of snow, it is difficult to do anything until the fall has ceased, when all available men should be set to work, dealing with the streets in the order of their importance. The snow should be banked up at the sides of the road, clear of the channels and gulleys, with gangways through where desirable. Snow ploughs, both horse and motor driven, are also used. The question of disposing of the snow is one which often gives trouble. Sometimes it is tipped down manholes into the sewer, but this is only possible with very large sewers. The best plan is to cart it away to the parks and open spaces and tip it on the land. If the town is on the banks of a river, the snow can be thrown into the river.

The expense of completely clearing streets of snow is a very great matter. For example, it has been pointed out that to clear a 6-inch fall of snow from the streets of London would require more horses and vehicles than exist in that area. Any idea of doing more than to clear the principal streets of any large town in case of a heavy fall of snow is one for the squandering of a large sum of money.

A few brief notes on the subject of disinfection will not be out of place in the present volume.

The principal infectious diseases are: cholera, chickenpox, diphtheria, erysipelas, influenza, measles, mumps, scarlet fever, smallpox, enteric fever, typhus fever, tuberculosis, and whooping-cough. Under the germ theory of disease, which is now almost universally accepted, it is held that certain diseases are produced by germs or micro-organisms.

The spread of disease can be prevented by means of what are termed disinfectants. There is much popular error in reference to this term, and it is necessary to point out that a disinfectant proper is a germicide, that is to say, it kills the germs of the disease, as opposed to an antiseptic, which, while preventing putrefaction, does not destroy germ life; it is in fact a preservative. It is necessary, also, to refer to deodorants, which are often confused with disinfectants and antiseptics. A deodorant simply masks disagreeable odours, by fixing the ammonia compounds and sulphuretted hydrogen. Deodorants are of no direct value in preventing the spread of infection.

Examples of disinfectants are: Hot air, steam, izal, formaldehyde, sulphur dioxide, chinosol, chlorine, chloride of lime, perchloride of mercury, carbolic acid, etc.

Examples of antiseptics are: Condy's fluid, Sanitas, eucalyptus, camphor, iodoform, etc.

Examples of deodorants are: eau-de-Cologne, camphor, Sanitas, eucalyptus, tobacco smoke, etc.

Fresh air and sunlight have some germicidal properties. The complete destruction of germs, or true disinfection, can only be brought about by either chemical means or heat. In most districts there is a public disinfecting station, where articles can be sent for disinfection. Such a station will be described later.

Where articles of clothing and bedding cannot be sent to a disinfecting station they should be burned if possible; otherwise they should be boiled or soaked for twenty-four hours in some disinfecting liquid, such as a solution of izal, 5 parts to 100 parts of water; chloride of lime, 2 ounces to a gallon of water; carbolic acid, 5 parts to 100 parts of water; or perchloride of mercury, ½ ounce, hydrochloric acid, 1 ounce, and aniline blue, 5 grains, to 3 gallons of water.

Perchloride of mercury, or corrosive sublimate as it is often called, is a very powerful disinfectant and dangerous to use on account of its being colourless.

Coal-tar is the original source of most of the patented disinfecting liquids which are on the market. One of the most powerful disinfectants is that known as formaldehyde, which is largely manufactured in Germany. It is generally supplied to the public in the form of solution containing 40 per cent of formaldehyde, the solution being known as formalin. In the same way that the destructive distillation of coal produces coal-tar, so a similar treatment of wood produces wood-tar. In both cases other materials are produced, including, in the latter case, what is known as wood naphtha or methyl-alcohol, from which, by an oxidizing process, the formaldehyde is produced. The use of formaldehyde is apt to produce a painful irritation of the skin and nails, and it is very desirable, therefore, to prevent the hands being wetted by it.

In the case of articles of small value, the safest way is to burn them, but disinfection may also be secured by exposing them to either dry or moist heat. Exposure to hot air at a temperature of 284° F. for four hours is about equal to the effect of exposure for five minutes to steam at a temperature of 212° F. Steam is therefore much more largely used.

There are many forms of steam disinfecting apparatus. One of the oldest and best known is the "Washington-Lyons". The disinfecting chamber is of oval section, encased by a steam jacket, the outer casing being covered with asbestos to assist in retaining the heat. The apparatus is built into a wall which divides a large room into two, and which has no door or other means of communication except a fixed window, through which signals can be given. The infected articles are brought into the room on one side, hence distinguished as the "infected" side, and are put in a cradle or hung on hooks in a light frame on wheels, which is then run into the disinfecting chamber and the door closed and strongly screwed up, a rubber joint making it airtight. Steam, at a pressure of 30 lb. to the square inch, and a temperature of 273° F., is then turned into the outer jacket so as to raise the temperature of the inner chamber high enough to prevent condensation of the moisture, from the clothes, etc. Next, the air is exhausted from the chamber as far as possible, to give space for the steam. This is done by the suction caused by a jet of steam passing over a pipe, with a high velocity, a two-thirds vacuum being obtained in about ten minutes. Steam is then admitted for ten minutes, till a pressure of 30 lb. per square inch is registered, corresponding to a temperature of about 250° F. It is then shut off to see if the pressure gauge shows any fall, due to particles of steam condensing; if so, steam is turned on again till the pressure remains constant. In bad cases, the steam is turned on a second time for a further ten minutes.

After the steam is cut off, dry air is passed in through tubes on which steam is playing, in order to thoroughly dry the articles, the cradle being then drawn out through the opposite door of the apparatus, or the "clean" as opposed to the "infected" side of the disinfecting station. The whole process takes from thirty-five to forty minutes.

Great care has to be exercised in regulating the temperature, as the sanitary authority disinfecting is held liable for any damage done to the articles.

It is essential that saturated steam should be used, superheated steam having little greater power of penetration than hot air. Saturated steam is water vapour at a temperature not much above that at which the steam is generated, while superheated is that which has been further heated, converting it to something like a gas.

There are a large number of patterns of steam disinfector and it is difficult to say that one is better than another. One of rather a different type to that just described, however, is the "Thresh" disinfector. In this, the lower part of the enclosing jacket of the cylinder acts as the boiler, and has a small furnace under it. The steam passes continuously through the disinfecting chamber, escaping up a chimney, and so is not under pressure, as in the case of the Washington-Lyons apparatus. Heated air is then admitted, and the articles thus rapidly dried.

Infected articles should be brought to the disinfecting station in proper vans, lined with iron, and airtight, kept solely for the carriage of infected articles, separate vans being used for carrying away the clean articles, and kept for that purpose only.

A public disinfecting station consists principally of two rooms, the infected and disinfected side, separated by a wall with no possibility of the passage of air from one to the other, such as a door or opening window. The apparatus is built into this wall. The van used for the carriage of infected goods should be housed at the infected end of the building, and the clean van at the other end. An incinerator, or small refuse destructor, should be installed at the infected end for the destruction of things which are too filthy to clean. Bedclothing and similar things require to be soaked in water and washed before passing through the disinfector, as the steam would fix the stains permanently. It is therefore usual to instal a certain amount of laundry apparatus, such as a washer, hydro-extractor (or centrifugal wringer), drying chamber, and mangle, etc.

Some things cannot be subjected to steam at all. It is therefore a good plan to provide a formalin chamber, that is to say, a room kept exclusively for submitting articles to the action of formaldehyde gas, generated by special types of lamp.

Bathrooms should be provided, one for men and one for women, for the cleansing of verminous persons. The bathrooms should adjoin the infected room, and have special hoppers, locking each side, in which the person can place his clothes, which are then put through the disinfector and made fit for use again.

In some cases, a bottle-washing room is added with special washing machines, sinks, etc.

It perhaps need hardly be said that any such building should be exceptionally well lighted and ventilated, and that the walls and floors should be non-absorbent, the walls being preferably of glazed tiles to facilitate cleansing. All angles should be rounded, with the same object.

We come next to the disinfection of rooms. This can be done in many ways. Assume sulphur dioxide is to be used: Open all cupboards, drawers, boxes, etc., saturate the walls, floor, and woodwork with water, and seal up all openings, such as fireplace, windows, doors, and ventilators, with brown paper. Place the sulphur on a tin plate, say 2 lb. to every 1000 cubic feet of space, and support it in a larger vessel containing water, to guard against fire. Put this in the middle of the room, ignite the sulphur, and make a speedy exit. Shut the door and seal it up by pasting strips of paper round. Leave the room thus for twenty-four hours. Then open the doors and windows, strip the paper off the walls and burn it, wash off the ceiling with limewash, and scrub the floor and all woodwork, furniture, etc., with a solution of perchloride of mercury.

The sulphur dioxide can also be obtained in tins under pressure, which is a convenient form, as all that is necessary is to cut off the top of the tin and allow the gas to escape.

Gilt picture frames, or steel goods should not be allowed to remain in the room, as the sulphur spoils them.

Formaldehyde is largely used for the fumigation of rooms, being either vaporized by means of special lamps, or sprayed over the surfaces of walls, ceilings, floors, etc.

Many forms of lamp and spray have been introduced, but it is deemed beyond the province of this volume to deal with them. Some important experiments in reference to the spraying of disinfectants were carried out by Drs. Thresh and Lowden, who arrived at the following conclusions:—

1. That for spraying to be efficient, every portion of the surface to be disinfected must be thoroughly moistened with the disinfecting solution ; merely passing the spray into a room and trusting to its settling upon the surfaces, is utterly unreliable.

2. That whitewashed surfaces require particular attention, being far more difficult to disinfect than surfaces of wood and paper.

3. That solutions containing under 1 per cent of chinosol, or 2 per cent of formaldehyde, are not absolutely reliable. Solutions, therefore, of not less than these strengths should be used.

4. That a proper spray, properly used, effects room disinfection in the minimum of time and with the minimum of expense, and is more reliable than disinfection by sulphur, or formalin vapour.

Some of the forms of disinfecting lamp are arranged so that they can, if desired, work from the outside of the room by spraying through the keyhole.

Another point which may be just referred to under the heading of drainage and sanitation is that of smoke abatement.

In the case of boiler furnaces on a large scale, the chief cause of smoke is improper stoking and an insufficient air supply. If the furnace is regularly stoked with small quantities of fuel at short intervals, and is provided with proper draught, either natural or forced, there should be no nuisance. The chimney should not, in fact, be looked upon as intended to let the smoke out, its purpose being to produce a draught through the furnace and assist combustion.

As the hot gases rise up the chimney, air must enter the furnace to take their place. If a forced draught is used injudiciously, it is apt to be productive of considerable smoke, but forced draught systems should be capable of regulation, and be put in the hands of competent stokers.

In the case of domestic fireplaces, the details given as to their construction in Chapter IV should be carefully followed; that is to say, briefly, the fireplace should be almost entirely of firebrick, with a minimum of iron. The stoking should be regular; one should not let the fire go almost out and then heap it up with coal; such a procedure is bound to lead to smoke, not necessarily in the house, it is true, but every such addition helps to pollute the air of our towns.

Further improvement might be made by the provision of better linings to chimney flues. They are often of very rough construction and not properly parged and cored in order to leave a free passage through them. The use of unglazed tubes of clay ware for lining flues is no new idea and has much to recommend it. Glazed tubes are unsuitable, as they give no grip to the soot and are apt to let it fall down and cause considerable trouble and inconvenience.

CHAPTER XV

LEGAL NOTES.

THE bulk of the law as to sanitary matters is embodied in Acts of Parliament, and the matter is complicated by the fact that procedure under the various sanitary enactments is not entirely uniform. The Acts affecting the Metropolis as a whole, do not, generally speaking, extend to the City of London, while the provinces are also not subject to them. On the other hand, the Acts affecting England as a whole do not, generally speaking, include the Metropolis.

Briefly, the country generally is subject to a large number of Acts, most of which are, by Statute, included in the general term "The Public Health Acts". The principal of these is the Public Health Act, 1875, a general Act, in force everywhere without being formally adopted, subject to certain reservations in regard to rural districts. Other important ones are the Public Health Act (Amendment) Acts, 1890 and 1907. The former is essentially adoptive and only in force where expressly adopted by the local authority. It consists of several distinct parts, any or all of which can be adopted. The 1907 Act also consists of many distinct parts. Part 1, referring to minor matters, applies, without express adoption, to England and Ireland, but the remainder of the Act is adoptive, it being open to local authorities to adopt either the whole or any part, or even a section of such part.

The Metropolis is subject, principally, to the Metropolis Local Management Act, 1855, and its numerous amending Acts (the chief of which is that of 1862), the Public Health

(London) Act, 1891, and the London Building Acts. The City of London has its own Sewers Acts.

By the principal Sanitary Acts, sanitary authorities were constituted with very full powers of administration, including the making of by-laws, the appointment of medical officers of health, surveyors, inspectors, etc.

The authorities under the Public Health Acts, as amended by the Local Government Act, 1894, are the Urban and Rural District Councils. The authorities under the Metropolis Management Acts, as amended by the London Government Act, 1899, are the Metropolitan Borough Councils, with the London County Council as controlling authority.

Sanitary procedure in the City of London used to be regulated by the Commissioners of Sewers, but, by the City of London Sewers Act, 1897, the Commission ceased to exist, and its powers and duties were vested in the Public Health Department of the Court of Common Council.

To deal completely with the subject of sanitary law would mean a separate book on the subject, and it is therefore proposed to deal only with the principal matters, such as sewerage, drainage, sanitary accommodation, and nuisances.

Both in town and country the sewers, generally, are vested in the local sanitary authority, which must keep them in repair and free from nuisance, and must cause all necessary sewers to be made. In default, a complaint to the Local Government Board will bring about an inquiry, and if the complaint is well founded, pressure will be brought to bear on the defaulting authority, the powers of the Board extending to the appointment of some one to carry out the necessary work at the expense of such authority.

The owner or occupier of premises within the district of any sanitary authority is entitled to drain into the public sewers after giving notice and complying with the regulations of the authority. Any person surreptitiously connecting his drains to public sewers is liable to penalties, disconnexion of his drains, and payment of all the expenses of the authority in the matter.

The Public Health Act, 1875, provides that an owner or occupier of premises outside the district of a local authority has a right to connect his drains to the sewers of such authority on terms to be mutually arranged, or in case of dispute, settled by a court of summary jurisdiction or by arbitration.

All buildings must have efficient drainage. The 1875 Act provides that the local authority shall, by written notice, require every house without a drain, sufficient for its effectual drainage, to be drained, within a specified time, into any sewer not more than 100 feet from the site of the building. Should no sewer be so near, the drainage must be to a covered cess-pool or such other place as the authority may direct. If the notice is ignored, the authority can do the work and recover the cost. Where the cost of such drainage would, for two or more houses, be in excess of the cost of constructing a new sewer, the authority may construct one, requiring the owners or occupiers to drain into it, and apportioning the cost of such sewer on the properties benefited.

The corresponding provision for the Metropolis, under the Metropolis Management Act, 1855, is more comprehensive, in that it gives more detail as to the requirements, but its effect is not much greater. The section gives specific powers of inspection during the progress of the work, with power to order alterations or additions, or modifications, on the fuller knowledge afforded by the opening up of the ground as the work proceeds. Most of these points, however, are covered by the drainage by-laws, both in London and the provinces. One point worth noting is that the 1855 Act says, "If a sewer of sufficient size be within 100 feet of any part of the building and *at a lower level*," whereas the 1875 Act omits the reference to level. While the London Act thus provides for drainage by gravitation only, the provincial Act could presumably be made to extend to any other means of drainage. As this provision of the 1855 Act would not fit all cases, a section was incorporated in the 1862 Act, extending the distance to 200 feet, and providing, as a temporary measure only, for drainage to cesspools, if no proper sewer exists within that distance.

In deciding what is necessary for the effectual drainage of a house under the Public Health Act, 1875, it has been held in Matthews *v.* Strachan (1901) that the local authority must consider only what is necessary for the house in question. It cannot take into consideration what is desirable, having regard to the disposal of the sewage of the district, and so require separate drains for sewage and for surface water, except under a special local statutory power.

Under the Public Health Act, 1875, if the drains of a building are sufficient and effectual, but not adapted to the general sewerage system of the district, the local authority may close such drains on the condition of providing, at its own expense, other drains as sufficient and effectual for the premises in question. Under the same Act it is unlawful, in any Urban District, newly to erect a building, or rebuild one which has been pulled down to ground floor or lower, without such drainage as, on the report of the council's surveyor, appears necessary, discharging into a sewer if one exists within 100 feet, otherwise into a cesspool, etc. This proviso is also applicable to the Metropolis by the Act of 1855, with the additional proviso that the drain shall be available for the drainage of the lowest floors, and that wherever such building is rebuilt as aforesaid, the level of the lowest floor shall be raised sufficiently to allow of the construction of such a drain; and for that purpose the levels shall be taken and determined under the direction of the sanitary authority.

The regulations of sanitary authorities usually stipulate that the work involving disturbance of public roads and footpaths shall be done by them at the owner's or occupier's expense, but in London this power is given them by Statute. Both in London and the provinces the sanitary authority may, on payment of the costs thereof, undertake the connexion of drains to sewers, or do any works of drainage on behalf of owners of buildings.

The foregoing are the principal statutory provisions in reference to new drainage; those affecting existing drainage will be dealt with under the heading of nuisances.

As to sanitary accommodation, the 1875 Act provides (under penalties) that houses newly erected, or being rebuilt, must have a sufficient water-closet, earth-closet, or privy, and ashpit with proper coverings. While this section refers only to new buildings, there is a retrospective provision also, to the effect that if a house, on the report of the surveyor or inspector to the authority, appears not to conform with the requirements just stated, the authority shall, by written notice, require such accommodation to be provided within a specified time, failing which the authority can do the work and recover the cost.

Section 39 of the 1907 Act gives the local authority additional powers as to the *amount* of closet accommodation in both old and new buildings, and also empowers the local authority to enforce the conversion of privies and earth-closets to water-closets or slop-closets. In the case of such compulsory conversion, if the authority does the work in default of the owner, the expenses are to be borne as follows: On the conversion of pail-closets, the authority is to bear all the expense, but in the case of closets other than those with a movable receptacle, the authority is to bear only half the cost. The Act further provides that there are to be no conversions to slop-closets except under an order of the Local Government Board after an inquiry. A right of appeal is given under this section to a court of summary jurisdiction. If the appeal is against a demand for work to be done, the owner can question the reasonableness of the proposal; but if it is against the cost of work done by the authority in default of the owner, the latter can only question the reasonableness of the cost.

The provision applying to London in respect of this matter of sanitary accommodation is Section 37 of the Public Health (London) Act, 1891, which is substantially the same in effect as the provision in the 1875 Act, but definitely places water-closets first, providing that earth-closets or privies shall be allowed if sewerage or sufficient water supply be not available.

All factories and workshops must have sufficient sanitary accommodation, with proper separation of the sexes. In connexion with this, the Board of Trade has issued an order under the Factory Act of 1901, defining adequate accommodation as meaning one closet for every twenty-five women employed; for men, one for every twenty-five men employed up to 100, and beyond that figure one for every forty, provision being made for the reduction of this number in large works where more than 500 of either sex are employed. In such cases the number is reduced to one for each sixty hands if a proper system of control is adopted.

The foregoing are the provisions as to new accommodation; those with reference to existing defective accommodation will be given under the heading of nuisances, but there are a few provisions of a miscellaneous nature which may with advantage be here referred to.

The following are items from the Public Health Act (Amendment), 1890: No room over a cesspool, privy, or ashpit to be occupied as a dwelling or sleeping room, or workplace, heavy penalties being enforceable on both owner and occupier in default.

No new building to be erected on land covered with, or impregnated with fæcal, animal, or vegetable matters, unless and until such matter be removed or rendered innocuous. Buildings described in deposited plans as other than a dwelling-house must not be used as a dwelling-house unless the structure thereof is approved by the authority for that purpose, and has the amount of open space at the rear thereof that is required by the by-laws in force in the district.

The 1907 Amendment Act empowers the local authority to enforce the drainage or paving of yards of dwelling-houses when unsatisfactory. The authority must give written notice to the owner to do the work within twenty-one days, or may, in default, do what is necessary and recover the cost.

The Public Health Act, 1875, made it unlawful to let or occupy separately as a dwelling, any cellar not so occupied at the time of passing the Act, and specifies very fully the requirements which must be fulfilled by cellars already so used.

The Public Health (London) Act, 1891, provides that underground rooms *may* be let separately as dwellings, whether so let before the passing of this Act or not, on certain requirements being fulfilled.

This matter is further dealt with by the Housing, Town Planning, etc., Act, 1909, which gives large powers to local authorities as to dwellings unfit for habitation, but the number of basements separately let as dwellings is not sufficient to warrant the point being more fully dealt with in these brief notes.

Reference may be made to the more important by-laws which may be made by local authorities.

The Public Health Act, 1875, empowered Urban District Councils to make, among others, by-laws with respect to the structure of new buildings for securing the interests of health; with respect to the sufficiency of air space about buildings, and the ventilation of them; with respect to the drainage of buildings, water-closets, earth-closets, cesspools, etc., and to the closing of buildings unfit for habitation.

This power is extended, where the Amendment Act of 1890 is in force, to include also by-laws with regard to the flushing of water-closets, the height of rooms intended for habitation, the paving of yards and open spaces about dwelling-houses, and the provision of back ways (in connexion with the laying out of new streets), to facilitate the removal of refuse, etc. Such of the above as refer to the drainage of buildings, water-closets, earth-closets, etc., and the flushing of water-closets, may be made retrospective. A Rural District Council is also empowered, under the 1890 Act, to make by-laws as to sanitary matters.

The Model By-laws issued by the Local Government Board apply only to the drainage of new buildings, but the Board will sanction by-laws as to re-drainage, though a relatively small number of local authorities have taken advantage of the fact, and in many places old buildings can be re-drained practically without any official control or supervision.

By-laws made by an authority are of no effect unless and until they have been confirmed by the Local Government Board. A good model code of by-laws was prepared by the Board for the guidance of local authorities and it has been largely adopted. These by-laws were, however, drafted as a guide only, and do not call for criticism, since they have been considerably varied in many localities, resulting in a lack of uniformity.

In the Metropolis, the question of by-laws was long on a less satisfactory footing. The structure of buildings, surrounding air space, erection of buildings on low-lying land, etc., are dealt with by the provisions of the London Building Act, 1894. By-laws as to nuisances are made by the sanitary authorities under powers given by the Public Health (London) Act, 1891.

The regulations as to drainage and sanitary fittings are framed partly under the Public Health (London) Act, 1891, and partly under the Metropolis Management Act, 1855. Section 39 of the former Act provides that the County Council shall make by-laws as to water-closets, earth-closets, privies, ashpits, cesspools, and receptacles for dung and the proper accessories thereof, whether constructed before or after the passing of this Act. The sanitary authority shall make by-laws as to keeping water-closets supplied with sufficient water for their effective action. The authority has to enforce and observe the by-laws and can only give directions in accordance therewith, other directions being void.

A very complete set of by-laws has been prepared by the London County Council and is in force under this section, and, properly enforced, will be bound to maintain a high standard of efficiency. Some of the chief points of this code are the following :—

All water-closets must be against an outside wall, must be properly lighted and ventilated, and must not be approached directly from any room.

All earth-closets must have two outside walls, must be entered from the outside only, and must abut on an open area of not less than 100 square feet, extending below the floor level.

Any person who shall newly fit or fix any apparatus in connexion with any existing water-closet, shall, as regards such apparatus and its connexion with any soil pipe or drain, comply with such of these by-laws as would be applicable to the apparatus so fitted or fixed if the closet were being newly constructed.

The construction of privies is not vetoed, but it is fortunately so hedged with conditions as to render their construction almost impossible.

Every person intending to construct a water-closet, earth-closet, or privy, or to fit or fix in connexion with one any apparatus, trap, or soil pipe, shall, before doing such work, give notice in writing to the clerk to the sanitary authority.

No fixed ashpits may now be built, and those in existence prior to the passing of these by-laws must be covered.

The owner of any premises shall maintain, in proper condition of repair, every water-closet, earth-closet, privy, ashpit, cesspool, receptacle for dung, and the proper accessories thereof.

The sanitary authority is also empowered, under this Act, to make by-laws for securing the cleanliness and freedom from pollution of tanks, cisterns, etc., for storing water for drinking or domestic purposes.

Section 202 of the Metropolis Management Act, 1855, empowers the making of by-laws as to the dimensions, forms, and mode of construction, and the keeping, cleansing, and repairing of the pipes and other means of communicating with sewers, and the traps and apparatus connected therewith, etc., and a very complete code of by-laws was issued by the London County Council under this section in 1901.

The chief points in the London Drainage By-laws are the following :—

In the case of newly erected buildings, waste pipes from urinals, sinks, and lavatories must not discharge, either directly or indirectly, into pipes conveying rain-water from roofs. Drains are to be laid on concrete 6 inches thick, carried up at each side for a width not less than the outside diameter of the pipe, and embedding the drain all round for at least one-half its diameter. No drains to pass under buildings if avoidable, and all stoneware drains under buildings to be in straight lines and embedded in at least 6 inches of concrete. New drains to be watertight and to stand a pressure equal to not less than 2 feet head of water. When a drain passes under a wall, provision must be made for its protection from the settlement of the wall by putting arches over the pipes. Soil pipes of 3½ inches in diameter, if satisfactory as to height and other matters, will suffice for the ventilation of a 4-inch drain. Lead soil pipes to be connected to drains by the aid of flanged thimbles of copper, brass, or other suitable alloy, secured to the lead by wiped joints. A stoneware or other glazed trap must be connected to a lead soil pipe by a brass socket secured to the latter by a wiped joint and to the former by means of Portland cement. The vent pipe to a water-closet trap must be connected so that the joint is in the direction of the flow, to prevent its becoming stopped up at the point of junction.

The owner of any building shall at all times maintain in a proper state of repair all pipes, drains, and other means of communicating with sewers, and the traps and apparatus connected therewith.

These by-laws shall, so far as practicable, apply to anyone constructing or reconstructing any pipe or drain, or other means of communicating with sewers, or any trap or apparatus in connexion therewith, in any building erected before the confirmation of these by-laws, as if the same were being constructed in a newly erected building. That is to say, so long as existing sanitary arrangements remain unaltered, these by-laws will not apply to them, but if altered at any time, the by-laws will apply so far as applicable to such work. In connexion with this point, however, it is interesting to note that it was decided in the case of The Metropolitan Industrial Dwellings Co. *v.* Long (1903), that substituting new water-closet pans and traps for defective ones, without altering the existing soil pipe, did not make it necessary to put anti-siphonage pipes to the traps.

The question of the deposit of plans and particulars in respect of drainage work was long on an unsatisfactory footing in London, but the difficulty was overcome by the passing of the Metropolis Management Amendment (By-laws) Act, 1899, authorizing the London County Council to make by-laws dealing fully with this branch of the subject.

Briefly, the purport of these by-laws is as follows:—

Anyone about to construct a drainage system as a whole must deposit plans and sections (in duplicate) with the sanitary authority, together with duplicate copies of a detailed description of the proposed work. The plans and sections must show all floors affected by the proposed work, and the general arrangement of the parts of the building, including the roof; the size and position of every waste, ventilating, and drain pipe, manhole, etc., and the position of every sanitary fitting. Such plans shall show the positions of all windows and other openings, and all chimneys within 20 feet from the open end of any soil or vent pipe. These plans are to be to a scale of not less than 16 feet to 1 inch. At the same time, a block plan must be deposited, to a scale of not less than 22 feet to 1 inch, showing the building in question and any other buildings on the site, together with any adjacent buildings affected by the work. Names of streets, and description of premises in question, difference in level between lowest floor and the pavement adjoining, must be indicated, as well as the level of adjoining yard or open space; lines, depth, size, and inclination of the proposed drains, and, so far as can be ascertained without opening the ground, the lines, sizes, depths, and inclinations of any existing drains; means of ventilation, position, and form of every existing or proposed manhole, gulley, junction, etc., and the points of the compass.

Such a block plan will not be required if the information just referred to is shown on the larger scale plans. These drawings and particulars are to be deposited at least fifteen days before it is proposed to commence work, and, in the case of a new building, before beginning to erect such building.

While the foregoing apply to a scheme as a whole, other by-laws deal with additions to, partial or entire reconstruction of, and alterations to, drainage. They provide that, in such cases, it shall be sufficient if duplicate plans, etc., are submitted, showing such particulars as shall enable the sanitary authority to ascertain whether the proposed work is in conformity with the statutory provisions and by-laws formed thereunder.

If, in any case, plans and sections have been previously deposited for the construction of the drainage as a whole, it will be sufficient to specify the date of the previous deposit, and to show the new work on the plans about to be deposited, and only so much of the existing work as will enable the authority to see the relative positions of the old and the new. There is no necessity to deposit plans and particulars unless the proposed work involves the alteration or entire reconstruction of any pipe, drain, or other means of communicating with sewers, or the traps and apparatus connected therewith.

In cases of urgency, it is provided that if an alteration must be made to the drains at once, a notice must be forthwith sent to the authority to that effect, and the necessary plans, etc., deposited within two weeks.

Penalties are provided for the breach of these by-laws, which, however, have unfortunately not that element of completeness which is desirable to ensure uniformity of procedure, and conflicting regulations for their administration have been prepared by various Metropolitan Borough Councils. One incidental difficulty lies in the fact that, in some boroughs, alterations to drainage work are in the hands of the Surveyor's Department, and in others in the Sanitary Inspector's or Public Health Department. It would be well if the duties of the Public Health Department were restricted to the discovery and investigation of nuisances, and the serving of notices, followed by legal proceedings if necessary, the execution and supervision of drainage work (the term drainage being here used in its widest sense) being left to the Surveyor's Department.

It will be well, before dealing with the question of nuisances, to refer to two or three of the definitions under the various sanitary Acts.

The term "Owner" is one which has led to litigation. The Public Health Act, 1875, and the Metropolis Management Act, 1855, give definitions which, though slightly differing, bear practically the same interpretation. Both define the owner as "the person for the time being in receipt of the rack rents of premises in connexion with which the word is used, whether on his own account, or as agent or trustee for any other person, or who would so receive the same if such premises were let at a rack rent".

There is a difference in the interpretation of the words "rack rent". Under the 1875 Act, it is a rent which is not less than two-thirds of the full *net* annual value of the property out of which the rent arises, while in the Public Health (London) Act, 1891, the word net is omitted, the other words being the same.

The "full net annual value" is the rent which might be reasonably expected from a tenant from year to year, free of all usual tenants' rates and taxes, and tithe commutation rent charge (if any), and deducting an allowance for repairs and insurance. The "full annual value," however, is given, in the 1891 Act, as the foregoing without a reduction for repairs and insurance.

Two cases may be cited bearing on the definition of owner. The first raises a point affecting lessees—the case of Truman, Hanbury, Buxton & Co. *v.* Kerslake (1894). Messrs. T., H., B. & Co. were lessees of premises. They subleased them at the same rent, and subject to the same covenants and conditions as they themselves were subject to, for a premium of £790, the sublessee becoming the occupier. On a nuisance arising, it was sought to make Messrs. T., H., B. & Co. liable. The High Court held, on appeal, that the sublessee was the owner, he being the only person with power to let the premises at a rack rent.

The other case, Broadbent *v.* Shepherd (1901), is one which shows that an agent cannot shirk liability by throwing up his agency for the property. A sanitary authority took proceedings, under the 1875 Act, against the agent or owner in respect of the abatement of a nuisance. The magistrates held that the agent was not the owner within the meaning of the Act, and dismissed the summons. The Divisional Court reversed this ruling and remitted the case to the magistrates, who, at the second hearing, again dismissed the summons, this time on the ground that the defendant was no longer the agent for the property. On a further appeal to the High Court, it was held that the magistrates could make an order requiring him to abate the nuisance, although no longer agent for the property. A possibly important point in this case was the fact that a notice failed to find the actual proprietor of the property at an address furnished by the agent.

The expressions "Drain" and "Sewer" have, perhaps, given rise to more litigation than anything else in the sanitary Acts. Both are underground pipes for the conveyance of waste liquids, and there ought to be no great difficulty in making a statutory distinction between the two. Unfortunately, however, there has been much confusion, which legislative efforts towards enlightenment have intensified rather than otherwise.

There was a time when sewers, apparently, did not even mean lines of pipes, for one finds in "Les Termes de la Ley" the following interesting definition: "Sewers seems to be a word compounded by two French words, Seoir, to sit, and Eau, water, for that the Sewers are Commissioners that sit, by virtue of their Commission, and authority grounded upon divers Statutes, to inquire of all nuisances and offences committed by the stopping of rivers, erecting of mills, not repairing of banks, bridges, etc., and to tax and rate all whom it may concern, for the amending of all faults which tend to the hindrance of the free passage of the water through her old and ancient courses ". This meaning of the word has obviously now become obsolete.

It must be remembered, at the outset, that the interpretation put by law on the terms drain and sewer in London is different from that in the provinces.

In the Metropolis, the drainage of buildings in combination with one another, is recognized and provided for. In the provinces this is not so, although before the passing of the 1875 Act buildings were often drained together. The local authority may, under that Act, require a separate drain for each house, and its reason for wishing to do so will be seen from the definitions.

Under the 1875 Act, a drain is any drain of and used for the drainage of one building only, or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises, occupied by different persons, is conveyed, and sewer is defined as including sewers and drains of every description except drains to which the word drain, interpreted as aforesaid, applies.

Under this definition a drain is used for one building only, or premises within its curtilage, and therefore, if it is connected to pipes passing from an adjoining building to a public sewer in a street or road, the length of pipes from the point of junction to such sewer becomes a sewer, and as such, it is vested in the sanitary authority. This provision tended to impose on the authorities the duty of repairing miles of piping which should have been repairable by the persons for whose exclusive benefit they existed, and Section 19 of the Amendment Act of 1890 was no doubt intended to remedy this. It has only partially done so.

The section provides that where two or more houses belonging to different owners are connected with a sewer by a single private drain, an application may be made under Section 41 of the 1875 Act (relating to complaints as to nuisances from drains), and the authority may recover expenses incurred by them in executing works, etc., in such shares as shall be settled by their surveyor, or, in case of dispute, by a Court of Summary Jurisdiction. For the purpose of this section, and for this purpose only, the expression drain includes a drain used for the drainage of more than one building, which, for all other purposes, is a sewer.

There has been a great deal of litigation over these two words, the principal cases being those of Travis *v.* Uttley (1893), Self *v.* Hove Commissioners (1895), Hill *v.* Hair (1895), Bradford *v.* Mayor, etc., of Eastbourne (1896), Seal *v.* Merthyr Tydvil U.D.C. (1897), Thompson *v.* Eccles Corporation (1904), Haedicke *v.* Friern Barnet U.D.C. (1904), Wood Green U.D.C. *v.* Joseph (1908), and Jackson *v.* Wimbledon U.D.C. (1905).

In Travis *v.* Uttley it was held that pipes passing through private ground and taking the drainage of three houses constituted a sewer, the Act of 1890 not having been adopted. In Self *v.* Hove Commissioners it was held that the notice given by the authority to the owners of a private drain did not amount to a request to them to do the work on behalf of such authority, since it had adopted the Act of 1890. The case of Hill *v.* Hare has been much criticized, and the judgment to the effect that the Act of 1890 does not apply to lines of pipes which were sewers within the meaning of the 1875 Act when the 1890 Act was passed, has been again and again repudiated by the Courts, notably in the case of Bradford *v.* Mayor, etc., of Eastbourne. In this case (Fig. 375), which is the leading one on this point, many houses, the property of different owners, drained into a long drain lying under private land and constructed before 1890, the property of the defendant being marked B. The whole of the drains shown were held to be a single private drain within the meaning of Section 19. The case of Seal *v.* Merthyr Tydvil U.D.C. is one which it would have been very desirable to have carried to the Court of Appeal. It was held by Mr. Justice Cave that the words "different owners" were only used in Section 19

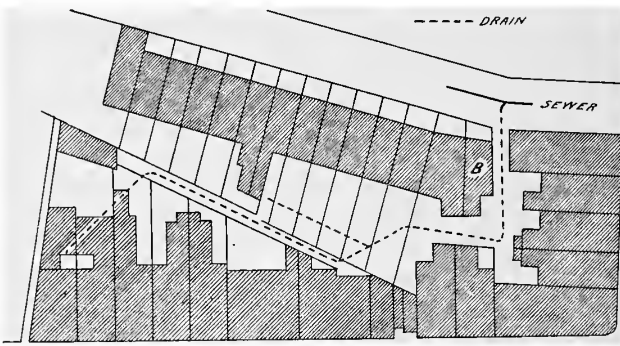


Fig. 375.

of the 1890 Act because several houses, the property of the same owner, and drained by a single drain on such private property, were within the same curtilage, and that such drain was therefore merely a private drain; but this judgment has not been followed in the later cases, and any line of pipes, outside London, draining two or more houses in the same ownership, is a sewer, unless constructed by any express agreement to the contrary, or unless a special local Act provides otherwise.

In the case of Thompson *v.* Eccles Corporation, it was definitely laid down that the words "belonging to different owners" in Section 19 mean "not all belonging to the same owner," and that it was not necessary that each house should have a different owner. Fig. 376 shows this case, the line of pipes under Thompson's property, marked T, being held by the Court of Appeal to be a single private drain. In this case also, as well as in that of Haedecke *v.* Friern Barnet U.D.C., it was decided that, if a nuisance occurs by reason of defects on one property only, the whole cost of remedying such nuisance can be charged on that property, and notices

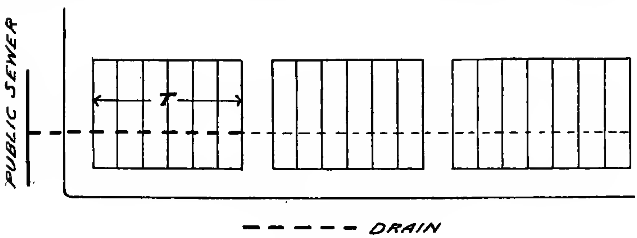


Fig. 376.

need not be served on the other properties under Section 19 of the 1890 Act. In the last-mentioned case it was also decided that there is no single private drain liability unless and until the Act of 1890 is adopted. Fig. 377 shows this case. The four houses belonging to plaintiff and marked H, were held by the Divisional Court to drain into a sewer, but this decision was reversed by the Court of Appeal on the interpretation of the words "belonging to different owners".

The case of Wood Green U.D.C. *v.* Joseph (Fig. 378) is a peculiar one. A row of sixteen houses drained in pairs into a line of pipes lying in private ground at the back. Six houses side by side, marked J, belonged to the defendant. The common drain to each pair of houses was admitted by both sides to be

connected to it, and the Court held that it had not lost its character as a sewer by the subsequent addition of the drainage of the houses higher up and belonging to different owners—a decision confirmed by the Court of Appeal and the House of Lords.

The decision of the Court of Appeal in the case of Jackson *v.* Wimbledon U.D.C. appears at first sight to be in conflict with that in the case just mentioned, but the facts were really very different (Fig. 379). Running from behind some houses, to a sewer in the road in front of them, was a line of pipes admitted to be a single private drain. Into the head of this

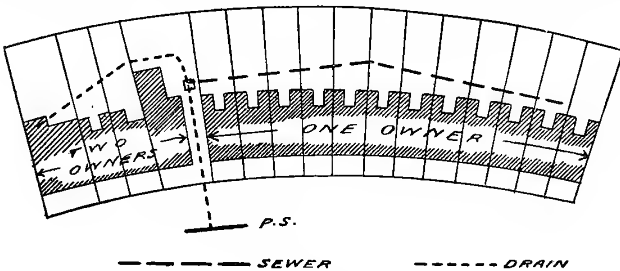


Fig. 379.

drain sixteen houses drained, twelve on one side and four on the other side of the single private drain. The twelve on one side belonged to the plaintiff Jackson, who maintained that the line of pipes receiving the drainage of all his houses was a sewer, a contention upheld by the Court, which thereby established the fact that a sewer can discharge into a single private drain.

The law on this matter is sadly in need of amendment, but Parliament seems unfortunately too busy with legislation which many deem of a less pressing nature. One cannot help feeling that many of these cases can only be regarded as a temporary exposition of sanitary law. Thus Lord Chief

Justice Alverstone has said: "It is almost essential, in the interests of stopping legislation, and putting local authorities in a position of knowing what their position is, that there should be an amending Act with regard to this section—Section 19 of the Public Health (Amendment) Act, 1890". Mr. Justice Darling has also said: "I do not profess to be able to give any kind of reason for the decision at which I have arrived," and Mr. Justice Channel, "The problem is really an insoluble one".

Again, there has been much questioning as to the meaning of the word curtilage. The interpretation given by Mr. Justice Cave in Seal *v.* Merthyr Tydvil U.D.C. does not appear to be confirmed by the cases under the London Acts, which will be referred to later. The curtilage of premises is generally referred to as if it were the fence or boundary enclosing such premises, but the definition adopted by Lord Justice Lopes in Pilbrow *v.* St. Leonards, Shoreditch (1895), was, "a little garden, yard, field, or piece of void ground adjacent to and belonging to the messuage," a definition from which Lord Justice Rigby, in the same case, dissented. Mr. Macmorran, K.C., in defining this term in his well-known work on the "Law of Sewers and Drains," summarizes it as the land adjoining a building and which would pass with it, on a conveyance, so far as necessary and convenient for its use.

The term drain in the Metropolis Acts is defined in the same way as in the Public Health Act, 1875, with the addition that it "includes any drain for draining any group or block of houses by a combined operation under the order of any Vestry or District Board". The Act of 1862 extends this to cover combined drainage "to the order or direction of, or with the sanction or approval of, the Metropolitan Commissioners of Sewers before 1 January, 1856". As the Commission of Sewers was created in 1848, there is no such thing as a combined drain constructed before that date (Appleyard *v.* Lambeth Vestry, 1897). It should be noted that it would appear that the combined drainage must be by *order* so far as drains laid after 1 January, 1856, are concerned, and that approval or sanction is to be deemed equivalent to order so far as earlier work goes; but this is not exactly the case, the terms of the 1855 Act having been held to authorize the sanction of combined drainage without an express order in the case of drains laid since 1856.

There have been numerous cases involving the definition of combined drainage in London. The surreptitious connexion of drains to others converts them, from the point of connexion, to sewers. A case of this kind is that of Geen *v.* Newington Vestry (1898), where a drain from a stable was connected to one from an adjoining house, and, on a nuisance occurring, the surreptitious connexion was disclosed. The line of pipes was held to be a sewer. In the case of Bateman *v.* Poplar Board of Works (1888), the approval of the defendant Board was held to be of the same value as an order, though no formal order was drawn up. Another leading case is that of Kershaw *v.* Taylor (1895). A builder was directed to drain some houses in pairs. He drained them in fours, and the main lines of pipe were held by the Court of Appeal to be sewers. A similar case is that of Bullock *v.* Reeve (1900). In Holland *v.* Lazarus (1897), an order was made for the drainage of four houses by a combined operation. Without the sanction or approval of the Vestry, a drain receiving the discharge of a rain-water pipe from a fifth house was connected to the head of the combined drain, and turned it into a sewer.

In the case of Shoreditch Vestry *v.* Phelan (1896), two houses were drained together without an order. One house was subsequently disconnected. The pipe had previously become a sewer, and it was held that this disconnexion could not be held to convert it from a sewer to a drain. "Once a sewer, always a sewer," is a dictum the Courts have always adhered to. At first sight it might appear that a recent case (Kershaw *v.* Smith, King's Bench, April, 1913), has upset this dictum, but this is not so.

The facts of this case were as follows: A case of grouping was sanctioned in 1884, but a deviation was made from the plans approved. This deviation was not detected by the Local Authority until 1912, when the owner was ordered to alter the drainage of the houses to comply with the original order on sanction. On his failure to comply, the authority did the work and sought to recover the cost. The High Court held, on appeal from a magistrate's decision, that the line of pipes in question was a sewer until April, 1912, when it ceased to exist, being replaced by a drain on compliance with the order of the authority. The case was heard before Justices Ridley, Pickford and Avory, Justice Pickford dissenting from the foregoing judgment, which remains established, however, unless upset by a higher Court. A careful reading of the foregoing brief note will show that the dictum of "once a sewer always a sewer" has not been departed from in this case.

In Pilbrow *v.* St. Leonards, Shoreditch (1895), two blocks of buildings were separated by a causeway. One block had no access to the causeway, and the other block opened only on to it. Both blocks were drained by a combined operation without an order of the Vestry. It was held by the Court of Appeal that the blocks were premises within the same curtilage, and that the main drain in the causeway was therefore a drain only. It is difficult to reconcile this decision with that in a case affecting the Lowther Arcade, which formerly existed in the Strand, on the site now occupied by Coutts' Bank. In this case, St. Martin's Vestry *v.* Bird (1894), there was a double row of shops forming an arcade, there being gates at the end which were closed every night, and the whole being in one ownership. All the shops were drained to a central line of pipes, which was held to be a sewer.

In the case of Stevens *v.* Hampstead Borough Council (1910), plans were approved, in 1878, for draining six houses by a combined operation into a public sewer lying in a particular road. Actually, two houses were drained to the sewer in that road, and the other four to a sewer in another road. The plaintiff claimed that it was not therefore a case of combined drainage. The Court instanced the case of the first two houses having been built, and the others never having been erected owing to altered intentions, and asked if it could be suggested that the rule of combined drainage would not then apply, and decided that the pipes in question were combined drains and not sewers. It should be noted, however, that this was a Court of London Sessions case, and not a decision of the High Court. In the case of Harvey *v.* Busby (1906), the Court of Appeal, in a question of deviation from the ordered grouping of houses for drainage purposes, expressed regret that it was bound by previous decisions which were, at all events, most unfortunate—thus showing a tendency to the opinion that unfair burdens were being put on the authorities in this matter.

Another interesting case is that of Wilson's Printing Company *v.* The Finsbury Borough Council (1909). Plans were approved in 1883 for draining three buildings by a combined operation. Subsequently the surface drainage from a court was added to the head of the drain. The High Court held that this turned what was a drain into a sewer which the defendant Council was liable to repair, and the plaintiffs were given damages from the date of their notice to the Council of the blocking up of this sewer, and for the amount they had incurred in doing the necessary repairs.

In the case of Florence *v.* Paddington Vestry (1895), an owner received notice to repair a defective drain. He spent £47 on it and then found it was a sewer. The Court awarded that he be refunded the money spent, and given a declaration that it was a sewer.

Under the decision of the Court of Appeal in Silles *v.* Fulham Borough Council (1903), a rain-water pipe conveying water from two houses into the drain of one house brings such drain into the category of a sewer and so repairable by the public.

In the matter of surreptitious connexions, a wrongdoer cannot apparently gain advantage by his own wrongdoing, but it is possible that a man might not, in all cases, he held liable for the wrongdoing of his predecessors in title.

The burden put upon the ratepayers by this matter is considerable, the sanitary authority having the onus of producing evidence of ordering or sanctioning combined drainage. The London County Council introduced a Bill into Parliament during several successive sessions, with a view to placing the combined drainage question on a better footing, but without success. This failure is rather curious in the face of the fact that the West Ham Corporation secured the passing of an Act in 1898, relieving them from all liability in such cases. A sewer must not be built over, and "once a sewer, always a sewer". This consideration has induced many private owners to maintain lines of pipes as drains which they might have successfully alleged to be sewers.

Sufficient has, no doubt, been given to show the position with regard to the drain and sewer question, and the next point to consider is that of nuisances.

It is the duty of all sanitary authorities to cause the systematic inspection of their districts for the detection of nuisances, and to enforce the provisions of the Public Health Acts. Both the 1875 and the 1891 Acts provide for the appointment of sanitary inspectors, although in the provincial Act the term inspector of nuisances is used.

Both the 1875 and the 1891 Acts define fully the term nuisance, the two definitions being very similar. So far as we are concerned at the moment, the chief nuisances are:—

(*a*) Any premises in such a state as to be a nuisance or injurious to health (1875 Act). The London Act adds "or dangerous" after the word injurious. The practical effect of this is that, in the provinces, magistrates almost invariably require proof of injury to health, while, in the Metropolis, proof of danger to health is sufficient, a much more reasonable requirement.

(*b*) Any pool, ditch, gutter, water-course, privy, urinal, cesspool, drain, or ashpit, so foul, or in such a state as to be a nuisance, or injurious to health (1875 Act). Here again, in the London Act, the words "or dangerous" are added, with the effect already stated, while there are also added, after water-course, the words "cistern, water-closet, earth-closet". The effect of this addition is but slight.

It could readily be maintained that, by reason of an insanitary cistern, water-closet, or earth-closet, the premises were in such a state as to constitute a nuisance, but the water-closet and earth-closet are dealt with by another section.

The definition in the London Act also includes "the absence of water fittings," etc. This is not given in the definition of nuisances in the 1875 Act, but it is really covered by a separate section of that Act.

The Public Health Act (Amendment) Act, 1907, where adopted, extends the definition of nuisance to include also "cisterns which are defective, or so placed or constructed as likely to become so; defective gutters and rain-water pipes; and deposits of material causing dampness in adjoining buildings".

Two very important sections in the 1875 Act are Nos. 40 and 41. The former provides that every local authority shall see that all drains, water-closets, earth-closets, privies, ashpits, and cesspools in its district are constructed and kept so as not to be a nuisance or injurious to health. Section 41 provides that a local authority, on written application of any person stating that a drain, water-closet, earth-closet, privy, ashpit, or cesspool is a nuisance or injurious to health (but not otherwise) may send a surveyor or inspector after, in ordinary cases, twenty-four hours' notice, or in cases of emergency without notice, and have the ground opened and an inspection made.

The written application referred to may be made by a sanitary inspector, and the 1907 Amendment Act, if adopted, extends this section to cover cases in which the existence of a nuisance is *suspected.*

If the inspector is refused admission, an order of the Justices may be obtained authorizing entry.

If no defects are found, all must be made good, without delay, at the expense of the authority, but if alteration or amendment is required, written notice must be sent to the owner or occupier, requiring the necessary work to be done within a specified time. If the notice is not complied with, penalties are provided, and the authority may do the work and recover the cost.

In the case of the Mayor, etc., of Bromley *v.* Cheshire (1907), it was held that the fact of the twenty-four hours' notice being given is not a condition precedent to the right to sue for the cost of work done by the authority in default of the owner or occupier.

An interesting point was decided in the case of Lancaster *v.* Barnes U.D.C. (1898), in which it was held that, under a nuisance notice involving the relaying of part of a drain, extra work in order to get a better fall to such drains was an improvement for which the owner could not be held liable.

Sections 40 and 41 of the Public Health (London) Act, 1891, are also very important, their provisions being more stringent than those of the 1875 Act. Without the necessity for any complaint to have been made as to a nuisance, the sanitary authority may, after twenty-four hours' notice, or, in case of emergency, without notice, enter any premises and examine any of the following works—that is to say, any water-closet, earth-closet, privy, ashpit, or cesspool, and any water supply, sink, trap, siphon, pipe or other works or apparatus connected therewith, or for the purpose of ascertaining the course of any drain. This would at first appear to limit the inspection to ascertaining merely the *course* of any drain, but it is generally held that the words "pipe or other works and apparatus connected therewith" are sufficiently comprehensive to cover drains also. If all is found in proper order and condition, and in accordance with the Act, the by-laws of the County Council and the sanitary authority, and with any directions given by the sanitary authority in any notice, the authority must make all good, and compensate for any damage done.

If found not to be in proper order and condition, or not made or provided in accordance with by-laws and directions, or contrary to the Act, the reasonable expenses of examination are to be repaid to the authority, and are recoverable, while Section 41 provides that (1) in any of the following cases: (*a*) If examination shows the work not to be constructed or provided according to by-laws and directions, or to be contrary to the Act, or (*b*) if a person, without consent of the authority, constructs or rebuilds a water-closet, earth-closet, privy, ashpit, or cesspool, which has been ordered by them not to be made, or to be demolished, or (*c*) if a person discontinues a water supply without lawful authority, or (*d*) if a person destroys any sink, trap, siphon, pipe, or any connected works or apparatus either without lawful authority or so that the destruction creates a nuisance or is injurious or dangerous to health, then a person so offending is liable to a penalty not exceeding £10, and if he does not rectify matters within fourteen days after, to a further daily penalty; or the authority may, in lieu of proceeding for the penalties, enter and do the work and recover the expenses from the offender.

(2) If on examination any one of the matters referred to appears in bad order and condition, or requires cleaning, alteration, or amendment; or to be filled up, the sanitary authority may serve a notice on the owner or occupier, requiring the necessary work to be done forthwith, penalties being recoverable in default, or the authority may enter and do the work at the offender's expense.

(3) Any person aggrieved by any notice or any act of a sanitary authority under the section, in relation to any water-closet, earth-closet, privy, ashpit, or cesspool, may appeal to the London County Council, whose decision shall be final.

It should be noted that there is an appeal allowable only in the case of the items just enumerated.

Although it would perhaps appear from the foregoing that old drains not in accordance with the by-laws must be made to accord with them, this is not so. The by-laws as to water-closets and similar matters are retrospective in action, but, if the drains are found, on inspection, to be in good order and condition, but not in accord with the Act and the by-laws, the sanitary authority appears to have no power to compel remedy, but can have refunded the reasonable expenses of the examination.

Cases have sometimes arisen under Section 42 of the 1891 Act, which makes the admirable provision that "if a water-closet or drain is so constructed or repaired as to be a nuisance or injurious or dangerous to health, the person who undertook or executed such work shall, unless he shows such defective work was not due to any wilful act, neglect, or default, be liable to a fine not exceeding £20, but in such a case he shall be entitled to have any other person, i.e. his agent, servant, or workman, whom he charges as the actual offender, brought before the Court, and if he proves to the satisfaction of the Court that he used due diligence to prevent the commission of the offence, and that the said other person committed the offence without his knowledge, consent, or connivance, he shall be exempt, and such other person convicted ".

An interesting case as to this is that of Young *v.* Fosten (1893), in which the High Court held that the builder may be proceeded against in the first instance as the person who undertook or executed the repairs within the meaning of the section.

Both in London and in the provinces, on being satisfied of the existence of any nuisance, the sanitary authority shall serve a notice on the person by whose act, default, or sufferance the nuisance arises or continues, or if such person cannot be found, on the owner or occupier of the premises, requiring him to abate the nuisance within a specified time, and to execute such works and do such things as may be necessary.

A nuisance notice may, in the case of a nuisance caused jointly by several persons, be served on any one or all of them. If the nuisance is due to structural defects, the notice must be served on the owner. If the notice is not complied with, the authority may summon the offender before a Court of summary jurisdiction, which may order compliance and impose penalties, or the authority may enter and do the work, and recover the cost.

The appeal against a nuisance order lies to Quarter Sessions. In the provinces, the order may take the form of an abatement or closing order. In London, the order may take the form of an abatement, prohibition, or closing order, respectively. No appeal is allowed unless the order is a prohibition or closing order, or structural works are required. In cases of urgency, if the order is appealed against, and the Court is satisfied that there is immediate danger, it may authorize the sanitary authority to enter on the premises and abate the nuisance.

Houses without proper and sufficient water supply are, under Section 48 of the Public Health (London) Act, 1891, to be dealt with as nuisances, and to be deemed uninhabitable. Newly erected houses must not be inhabited unless and until they are certified by the sanitary authority as provided with proper and sufficient water supply. An owner permitting occupation contrary to this is liable to heavy penalties.

Under the Public Health (London) Act, 1891, the sanitary authority has power to make by-laws as to nuisances arising from, among other things not affecting the surveyor, the paving of yards and open spaces in connexion with dwelling-houses.

In London it is customary to send two notices as to nuisances, one an "intimation" under Section 3, and the other a statutory notice under Section 4, of the 1891 Act. If, under threat of legal proceedings, work be done by the occupier or owner which should be rightly done by the local authority, the cost might possibly be recovered from such authority, provided the notice be the statutory one under Section 4, but this is doubtful, and the best course would be to resist the summons by appearing and establishing the liability of the authority. It was, however, held in the case of Oliver *v.* Camberwell Borough Council (1904), that work done under an "intimation" only could not be held to be done under compulsion, and that in such case the owner or occupier had no remedy.

In the case of Nathan *v.* Rouse (1905), a case of nuisance from combined drainage, the local authority had served notice on one owner only, who did the work, and the Court held that, in the absence of a covenant binding the other users of the drain to contribute to its repair, there was no statutory liability on them to so contribute. In this case, also, Nathan had failed to prove, as required by the 1891 Act, that the nuisance was caused or increased by any act of the defendant, who was another user of the drain.

The chief provisions of the Acts of 1875 and 1891 in reference to costs and expenses are these :—

Costs and expenses in reference to a nuisance order are recoverable from the person on whom the order is made, but, if the order is made on the sanitary authority, or no order is made, but the nuisance is proved to have existed at the time of serving the notice, the expenses are recoverable from the person whose act, default, or sufferance causes the nuisance. If the nuisance is caused by the act or default of the owner, the expenses are recoverable from the person who is, for the time being, the owner within the meaning of the Act.

Where recoverable from the owner, the claim may be levied on the occupier, who shall pay, and may deduct the amount from the rent which becomes due from him; but no larger sum is recoverable from the occupier than the amount due from him to the owner, and except in case of fraud, nothing in the sections dealing with this is to affect any contract between the landlord and the tenant.

The Public Health Act, 1875, provides that the amount of costs and expenses recoverable in respect of a nuisance shall not exceed, as a whole, one year's rack rent of the premises, but this provision does not occur in the London Act.

All notices given by a sanitary authority must be in writing, which includes printing. The owner and occupier need not be designated by full name, but as "owner" and "occupier" respectively. Notices may be sent by post, left on the premises, or fixed to the building if no one is in occupation.

It will have been seen that the powers of the local authority, as exercisable on its behalf by its inspectors, are very extensive; and it is in the interests of the health of the public at large that the provisions of the Act should receive the widest interpretation.

The question of the liability of lessees for drainage work under various covenants is a very extensive one, owing to the diversity of covenants, but a few examples may be given for guidance.

In the case of Foulger *v.* Arding (1902), a lease for years had no repairing covenant, but provided that the lessee should " pay and discharge all taxes, rates, including sewers, main drainage assessments, and impositions whatever, which now are or at any time during the continuance of the said term taxed, rated, assessed, charged, or imposed upon or in respect of the said premises, or any part thereof, or on the landlord, tenant, or occupier of the premises by authority of Parliament or otherwise howsoever ". The Court of Appeal held that the lessee was liable, under the words "impositions charged or imposed upon or in respect of the premises," for making a water-closet instead of a privy, in accordance with a notice from the sanitary authority under the Public Health (London) Act, 1891, by-laws of the London County Council. It was also laid down in this case that a covenant must be assumed to relate only to matters which may reasonably be supposed to have been in contemplation by the parties as being within the purview of such contract.

In another London case, Stockdale *v.* Ascherberg (1903), which was not carried to the Court of Appeal, a tenant on a three years' agreement, covenanting to " pay all outgoings of every description, etc.," was held to be liable for the cost of reconstructing defective drains, it being held that the shortness of the term did not limit the interpretation of the word " outgoings ". The term " imposition," in the case of Warrener and Brayshaw *v.* Ninnis (1903), was held to cover the reconstruction of drains, no matter how short the term.

The question of the condition of drains is one which has often to be dealt with by those engaged in the management of property. An agent must not lightly assure an intending tenant that the drains are all right. In the case of De Lassalle *v.* Guildford (1901), the plaintiff had taken property on a lease which contained no reference to drains. He executed the counterpart, but refused to hand it over until he received an assurance that the drains were in order. On the defendant's verbal representation that they were in good order, the counterpart was handed over. The drains proved very defective, and the plaintiff brought an action for breach of warranty. It was held by the Court that the representation of the defendant was a warranty collateral to the lease, and for breach of which an action was maintainable.

It is also necessary to refer to the provision of the Housing, Town Planning, etc., Act, 1909. Section 14 of this Act provides that "in any contract made after the passing of the Act, for letting for habitation a house, or part of a house, at a rent not exceeding:—

"(*a*) In the case of a house in the county of London, £40; (*b*) in the case of a house in a borough or urban district with a population of 50,000 or upwards, £26; and (*c*) in the case of a house situate elsewhere, £16; there shall be implied a condition that the house is, at the commencement of the holding, in all respects reasonably fit for human habitation, but the condition shall not be implied when a house, or part of a house, is let for a term of not less than three years upon the terms that it be put by the lessee into a condition reasonably fit for occupation, and the lease is not determinable at the option of either party before the expiration of that term". A further section provides that the house shall be *kept* in such a condition, and gives the landlord and local authority right of access for inspection at all reasonable times after twenty-four hours' written notice to the tenant or occupier.

If the local authority considers that the implied condition has not been complied with, and it does not make a closing order, it can give written notice to the landlord to do such works as may be necessary to make the house in all respects reasonably fit for human habitation within a reasonable time, not exceeding twenty-one days. Within such twenty-one days, the landlord can give written notice to the local authority that he intends to close the house for human habitation, and this has the effect of a closing order; but if the notice is not complied with, and the landlord does not give a counter notice as described, the local authority can do the work themselves, and recover the cost from the landlord as a civil debt, or they can order it to be paid in annual instalments within a period not exceeding the landlord's interest, or in any case not exceeding five years, with interest at 5 per cent, and such instalments are also recoverable as civil debts.

A landlord can appeal to the Local Government Board against a notice, or against a demand for the recovery of expenses, by giving notice of appeal within twenty-one days after the notice or demand has been received, and no proceedings are to be taken against him while such appeal is pending.

The term "landlord" means, for this purpose, any person who lets to a tenant for habitation, and includes his successors in title, and the term "house" includes part of a house.

These provisions extend to houses or parts of houses let in lodgings or occupied by more than one family, and to the "owner" under the Public Health Act, 1875, and the Public Health (London) Act, 1891, and by-laws may be made and enforced thereunder, the "owner" being given power of entry for inspection.

The Housing, Town Planning, etc., Acts, 1909 and 1919, also deal fully with the subject of closing and demolition orders, but these points are considered beyond the range of these general notes on the chief points of the law in relation to domestic sanitation.

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