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NUMBER 110

THE EXTRUSION OF METALS

CONTENTS

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INTRODUCTION

Although it had been found possible as early as 1850 to extrude such metals as lead and tin and thus form pipes and bars, the extrusion process had not, at that time, been successfully applied to the shaping, by means of extrusion, of such metals as copper, delta-metal, etc. It was when Alexander Dick, the inventor of the delta-metal, made some experiments with this material under high pressure and at high temperature, during the latter part of the eighties, that it was first shown that this material could be extruded in a heated state. There were, however, several difficulties to overcome. The extrusion process, as is well known, consists of hot plastic metal being pressed through a form or die at high pressure, so that a continuous bar or pipe of the cross-section of the die or form is produced. Lead and tin can be extruded at comparatively low temperatures (250 degrees F.), but copper and similar metals require temperatures all the way up to 1750 or 1800 degrees F.

The main difficulties to be overcome are to maintain the high temperature and plasticity of the metals during the extrusion, and to make press cylinders and dies which will be able to withstand the effect of the high temperatures and pressures. The first condition was met by Dick by filling the press cylinder with molten metal and by surrounding it with heat insulating material, such as ground granite. In order to prevent the heated metal from forcing itself between the plunger and the cylinder, when the pressure was applied, a spherical steel piston was employed which spread when the pressure was applied, and in this way effectively closed the cylinder behind the metal.

The advantages of the extrusion process, as compared with the ordinary rolling and drawing process, soon became apparent. The extrusion process permitted parts of unusual cross-section to be produced in great quantities. In fact, sections could be extruded which could not be rolled under any circumstances. In Fig. 26 is shown a number of special sections which have been produced by extrusion. On account of the high pressure under which the metal is extruded it becomes more compact and its strength is increased. The extruded shapes, therefore, possess those qualities which make them especially useful in machine design The surfaces are smooth, and free from flaws and other defects. The dimensions of the extruded shapes can be gaged with great accuracy, so that they may be used either directly or with very little additional finishing. After the advantages of the new method had become known, it was soon adopted and further developed by many different individuals and concerns.

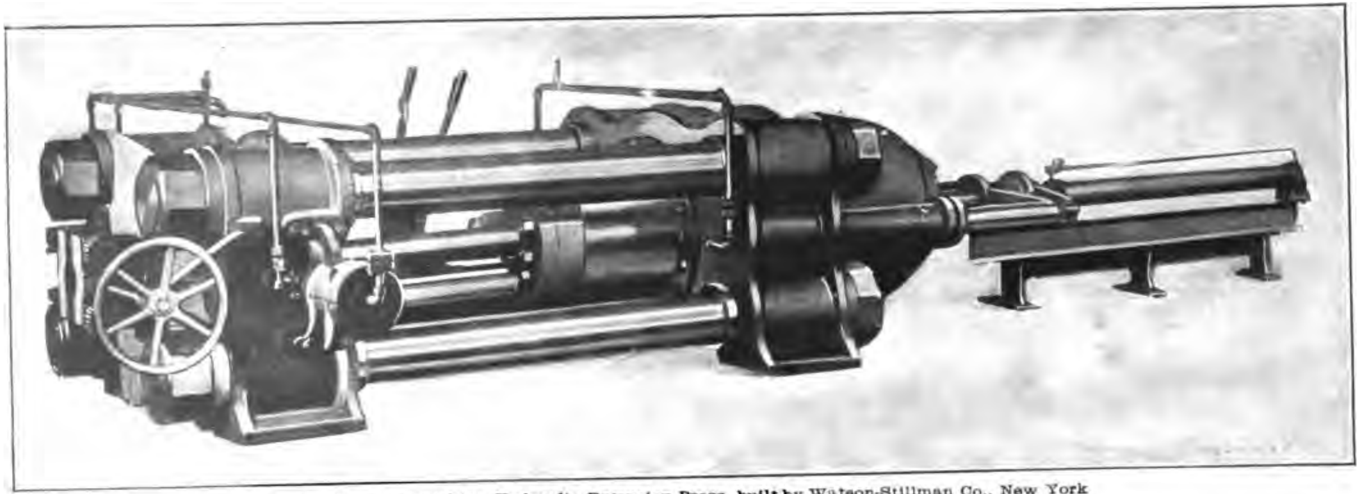


Fig. 1. Two-thousand-ton Hydraulic Extrusion Press, built by Watson-Stillman Co., New York

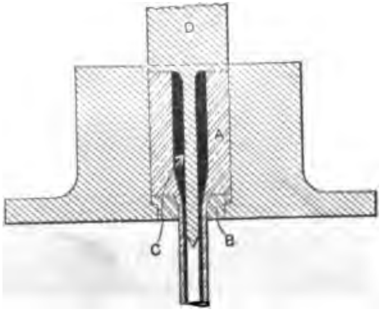


Fig. 2. Making Tin-lined Lead Pipe

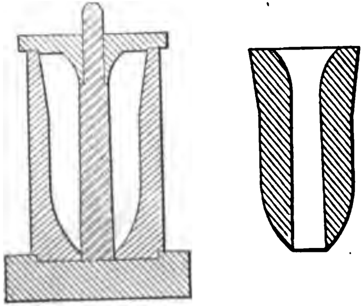


Fig. 3. Improved Ingot Mold and Lead Ingot

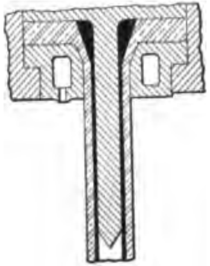


Fig. 4. Jacketed Die

Machinery

CHAPTER I

THE EXTRUSION PROCESS

The extrusion process for manufacturing metal shapes for various purposes is rapidly growing in favor. Intricate shapes can be made by this process that would be impossible to roll and that would be very expensive to machine; and shapes that could be rolled can be produced more accurately to size by the extrusion process than by rolling, and can also be made from various kinds of metals. While the principle on which this process operates is a very old one, it was not a commercial success until the hydraulic press was enough developed to be used for this purpose. During the past two decades many improvements have been made that have enabled shapes to be made quicker and cheaper, and of metals that are stronger, harder and tougher than those formerly used. The great progress in metallurgy also has produced strong alloys that could be more easily extruded.

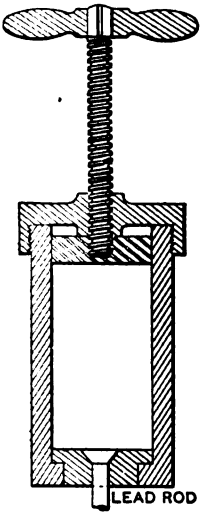


Fig. 5. **Early Press for Making Lead Rods**

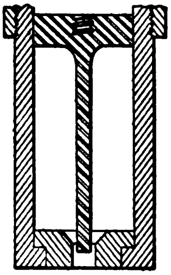


Fig. 6. **Principle of Press for Making Lead Pipe**

Machinery

In Fig. 1 is shown one of the latest types of machines used for extruding or squirting solid metal alloys through metal dies into the required shapes. Like most other machines of the present day, the one shown has evolved, or gradually grown, from a crude, simple device. It has required the services of many engineers and mechanics and over a century of time, to develop it to its present state. The alloys and the methods of extruding them have also passed through the same evolution. Notwithstanding this, some manufacturers very zealously guard the methods employed in producing extruded shapes as secret processes. Like many other methods, however, they are secret in name only, and the details can always be obtained by those who make a study of this subject.

Historical Review

The first patents on record were taken out in England in 1797. Like the die-casting process, the extrusion process started by using lead for the metal to be extruded. Lead-tin alloys were used later, and these developed into the lead-tin-antimony compositions that are used for type and anti-friction metals, and led the way to the copper-zinc alloys that may contain small percentages of aluminum, lead, nickel, iron or other ingredients.

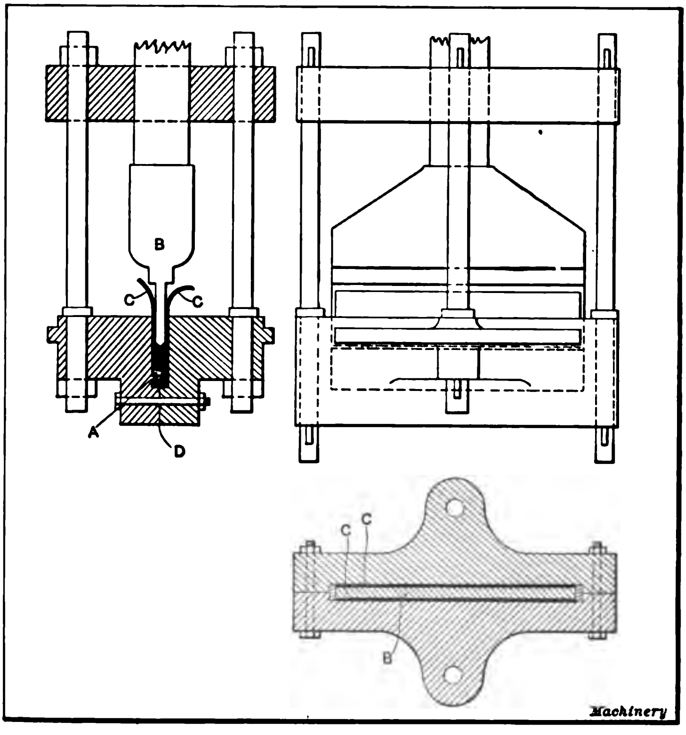
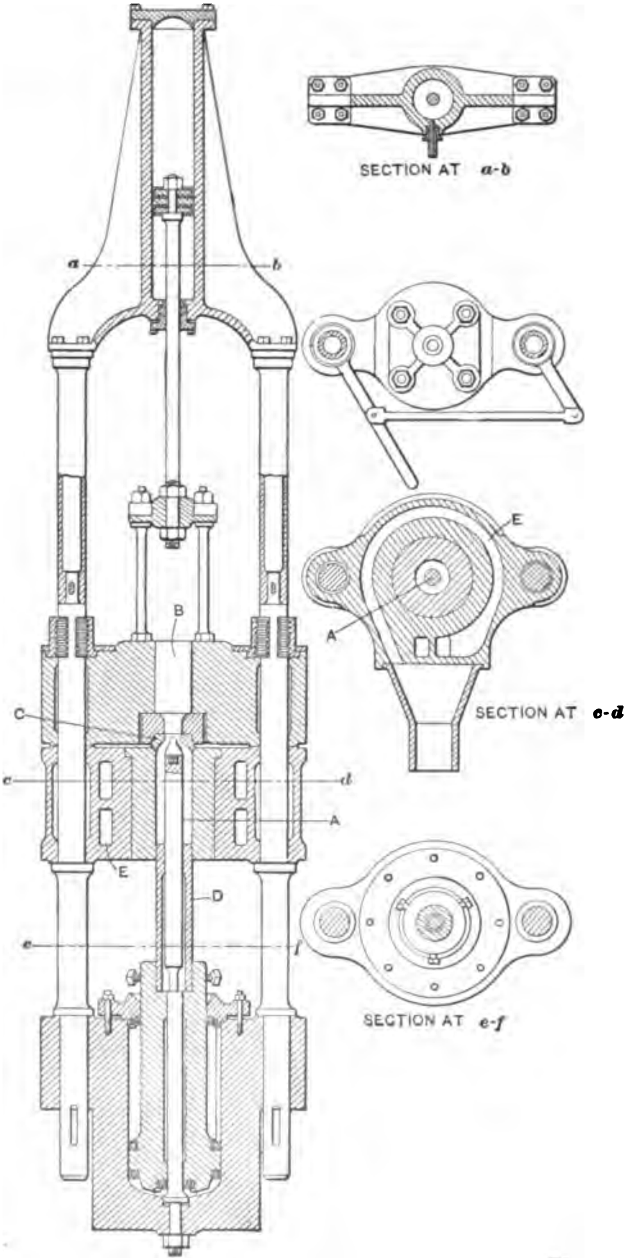


Fig. 7. Machine for Making Lead Sheets

One of the first forms of extrusion machines is shown in Fig. 5. In this the cylinder was packed full of lead and the whole heated so that the hand-screw would squirt the lead out at the end in the form of a lead rod of the shape or size desired. The lead-tin alloys used for soldering were made into rods in a similar manner. The next step was to put a rod in the center of the plunger as shown in Fig. 6. This rod partly filled the opening through which the metal passed, so that the latter was extruded in the shape of a tube. This simple tool was



Machinery

Fig. 8. Hydraulic Press for Making Tin-lined Lead Pipe

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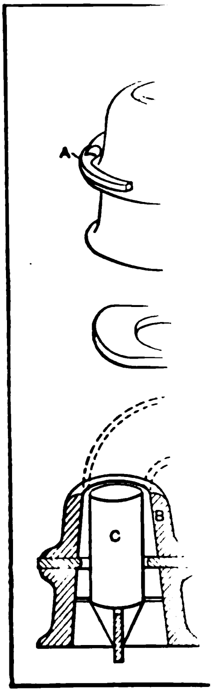

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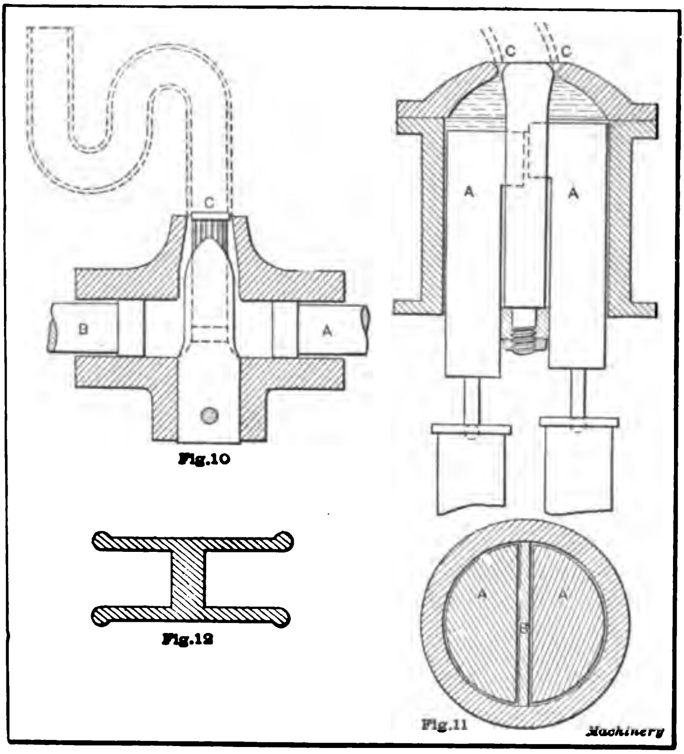
presented other difficulties due to the sharp corners in the cylinder. Therefore, the lead ingots were cast in a mold of the shape shown in Fig. 3, and the tin ingots were cast in another mold that would make them fit the inside of the lead ingot. Another difficulty encountered was due to the uneven heating of the dies, and they were jacketed as shown in Fig. 4, so that steam or water could be circulated through them. In this way the die could be heated up to the required temperature before starting to make pipe, and maintained at this temperature while running.



Figs. 10 and 11. Other Devices for Making Curved Pipe. Fig. 12. Extruded Shape used for Leaded Glass Windows

In 1869, A. H. Hamon of Paris, France, patented the hydraulic press shown in Fig. 8 for manufacturing tin-lined lead pipe. In this the lead ingot that surrounded the hollow tin ingot was placed in the cylinder at *A*, and ram *D* was operated to force the metal through the die at *C* and the opening at *B*, where it was coiled onto a reel. A blast of hot air or steam was sent through the ports *E* to bring the metal to the correct temperature for extrusion. This temperature was below the melting point of the tin, but high enough to make the mass pasty, so that it could easily be extruded through the die. This design is practically the same as that of the extrusion machines of the present day.

Some details have been improved, however, and metals of a higher melting temperature can be extruded. Thus, some of the more plastic brasses are now made into commercial shapes.

In 1873, Robert Cunningham patented a device for making curved pipe for water traps, and a re-issue of this patent was granted in 1881. This device is shown in Fig. 9. It can be attached to any machine that contains hot lead and the required mechanism for squirting the lead through it. The diaphragm *A* moves back and forth through case *B*. Its center hole will thus, at times, be eccentric with the interior opening of the case, and, thereby, control the volume of metal that passes through this opening on different sides. When the hole in the diaphragm is central with the case, the volume of metal that passes through on all sides of core *C* will be equal, and the extruded pipe will be straight, as shown in the upper right-hand corner of the illustration. When the diaphragm is moved to the left, however, the largest volume of metal will pass on the left-hand side of core *C*, and the pipe will curve to the right, as shown in the lower left-hand view. When diaphragm *A* is pushed to the right, the volume of metal will be largest on the right-hand side, and the pipe will curve in the opposite direction. Thus, by pushing this diaphragm to the right and left the required distance, traps can be made as shown in the lower right-hand view, and these can be given any desired form.

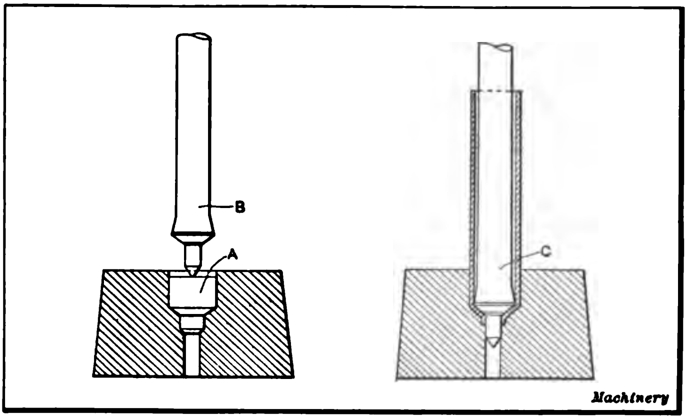


Fig. 13. Method of Tube Making

Another method of accomplishing the same results is shown in Fig. 10. In this case the volume of metal on different sides of the core is controlled by two rams. When rams *A* and *B* are forced in at an equal speed, the metal coming out around core *C* will be equal in volume on all sides and the pipe will be straight. If ram *A* is made to travel faster than ram *B*, the volume of metal to the right of core *C* will be the greater, and the pipe will curve to the left. If ram *B* is made to travel faster than *A*, the volume of metal to the left of core *C* will be the greater, and the pipe will curve in the opposite direction.

In Fig. 11 is shown still another device that performs the same work.

In this case ram *A* is made in two halves, each of which can be driven at a different speed. Hence, the metal on either side of partition *B* can be forced through the opening around core *C* in varying volumes. This causes the lead pipe to curve in either direction as much as desired, or extrudes it in a straight line.

The softer metals were also extruded in other shapes for various purposes, such as printers' leads, shapes for holding glass in leaded glass windows (as shown in Fig. 12), etc. Very thin metals used for metal foil were also produced. These latter were made from lead-tin alloys, and many different compositions were used to get stronger, tougher and better wearing metals than pure lead. Very thin tubes, such as are used for artists' paints and similar materials, were also made by a similar process. At *A* in Fig. 13 is shown a disk of metal with plunger *B* in position to be forced down into it. At *C* the plunger is shown at the bottom of its stroke and the tube is completely formed. The grids or plates for secondary batteries were made by the extrusion process as much as twenty-five years ago. These consist of narrow strips of metal crossing each other, and joined at the intersections so as to form hollow squares. They often have more than one hundred squares in them. They were made by extruding a long cellular mass which was later cut up into thin grids.

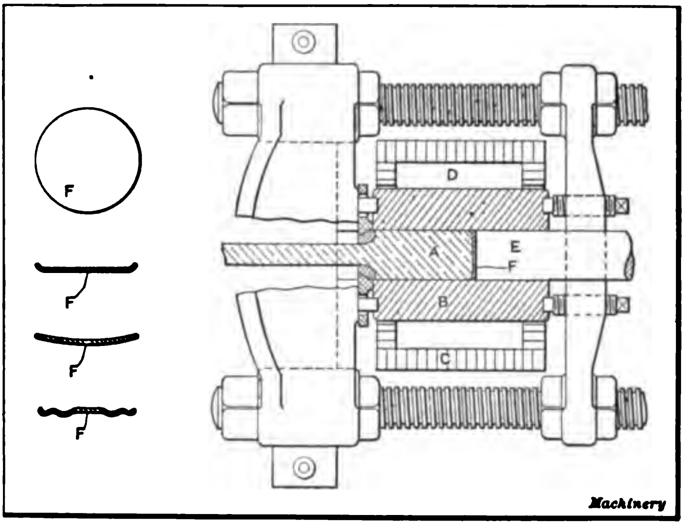


Fig. 14. Coke-fired Ingot Container

When metals or alloys with a higher melting temperature than the lead and tin first used were formed into various shapes by the extrusion process, several problems other than that of a powerful machine presented themselves. One of the greatest of these problems was that of the temperature. It was very desirable to be able to extrude brasses and bronzes, as they were much stronger than alloys with a lead or tin base. It was necessary to keep the temperature below the fusion point, as otherwise it would be difficult to cool the extruded shape to the solid state before it left the die. Also, if the metal was too soft when being extruded, it would not be subjected to the compression required to give it the additional strength that made the process really valuable. On the other hand, if the temperature was not high enough, the metal would not extrude through the die opening, and the billet would spread in the cylinder or container, grip the side walls, and thus become wedged in.

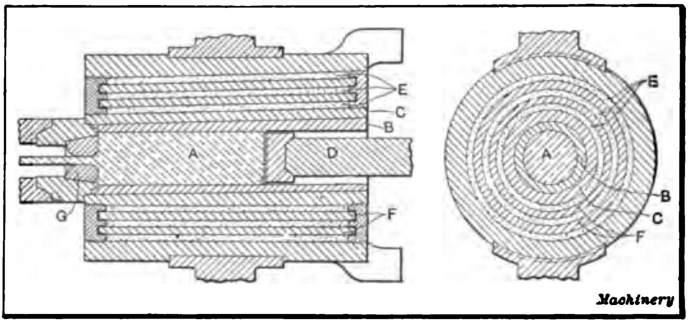


Fig. 15. Steel and Asbestos Container

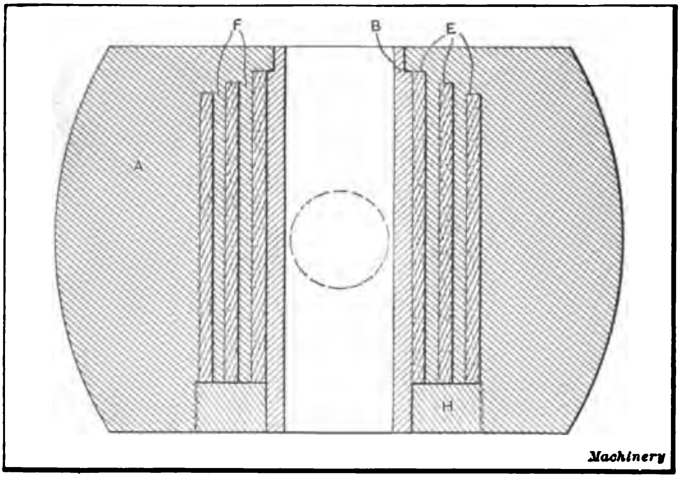


Fig. 16. Cast Container with Layers of Heat-insulating Materials

It was also difficult to find a metal for the dies that would withstand the strains produced by the hydraulic ram, or keep cool enough when the heated metal was being forced through. It was found, however, that tungsten steel would not soften enough to be pressed out of shape when brasses and bronze were extruded at a temperature just below the melting point. To maintain this temperature while the whole billet was being extruded was, however, difficult. This difficulty was finally overcome by designing special billet containers, and these are now a part of all extruding machines.

Billet Containers

One of the first designs of this type was patented by George A. Dick in England in 1893. This device is shown in Fig. 14, in which *A* is the billet of metal that is being extruded; *B*, the cylinder or billet container; *C*, a case built around the container; and *D*, a passage through which the flames from a coke or coal fire were passed. With this apparatus, copper and zinc alloys that were red hot and plastic at from 800 to 900 degrees F., were successfully extruded. When the billet was inserted in the container, a disk similar to those shown at *F* was placed over the end of the ram *E*. This disk will spread, fit the wall of the container tightly, and prevent the metal in the billet from squeezing back past the ram and wedging it. These disks were made from metal with a higher melting temperature and less plasticity than the metal being extruded.

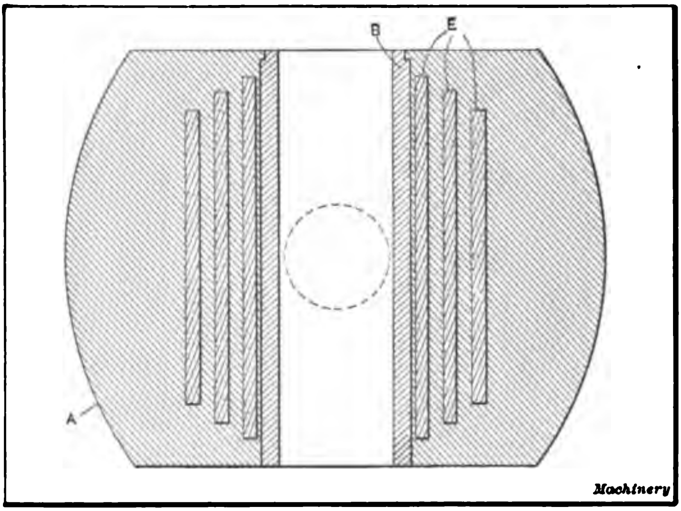


Fig. 17. Another Type of Cast Container

While this device worked better than anything previously used, it was difficult to control the coke fire so as to maintain a uniform temperature. Another difficulty was met with in trying to conduct the heat away from the head, owing to the thickness of the metal that had to be used to withstand the pressure exerted by the hydraulic ram. As considerable heat was given out by the billet, and the penetration through the thick cylinder wall was slow, the exterior would be much cooler than the interior. This caused unequal expansion and contraction, and frequently resulted in cracks and fractures. Hence, a built-up head or billet container was designed, having alternate layers of steel and asbestos.

One of the first built-up containers is illustrated in Fig. 15. This also was designed by Mr. Dick in the same year as the coke-fired container. Most of those in use at the present time are built on this principle; *A* is the billet; *B*, the tapered container that fits into a tapered hole in the built-up cylinder; *D*, the ram; *E*, the openings between the steel rings *F*, which are packed full of asbestos; and *G*, the die through which the billet is extruded.

By surrounding the walls with several layers of refractory material, like asbestos, supported by steel rings, the heat was prevented from penetrating the cylinder walls. By thus keeping the cylinder at a lower temperature, it had greater power to resist the pressure from the ram; and by retaining the heat in the billet, its temperature was kept more uniform, and it could be more easily extruded. This design also greatly reduced the unequal expansion and contraction and the consequent cracking and breaking. These cylinders, or containers, enabled the extrusion process of manufacturing metal shapes to become much more of a commercial success, and to-day many parts are being manufactured more economically in this manner than they formerly were by casting in sand molds.

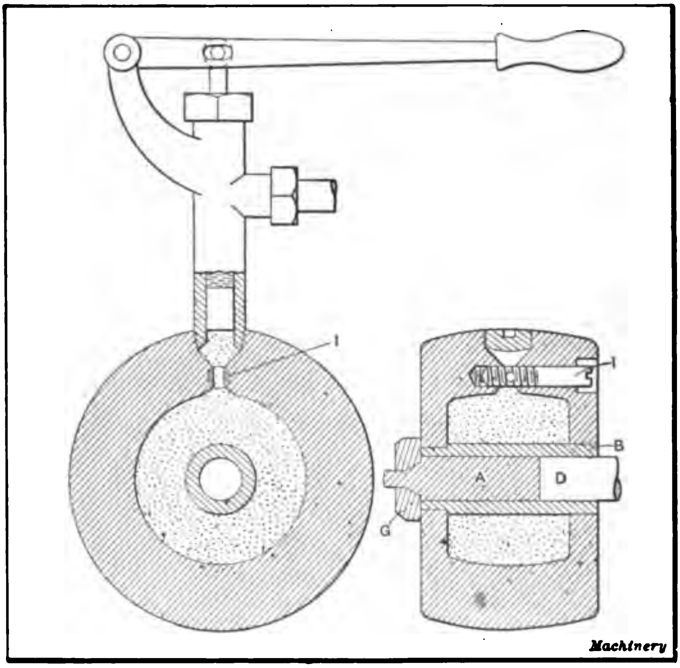
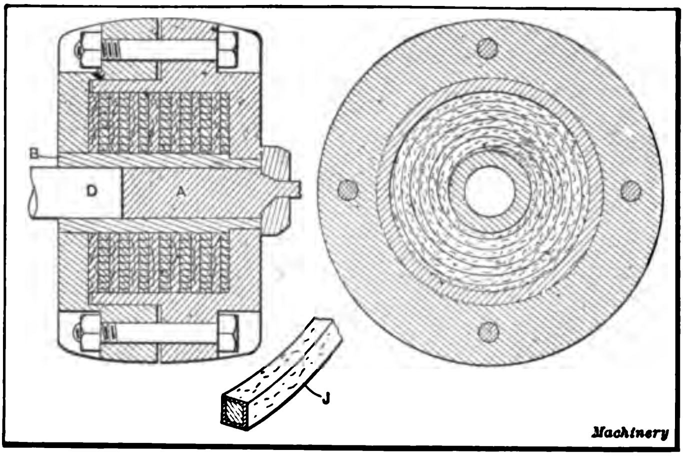


Fig. 18. Heat Insulation forced into Place by Pump

Following the Dick designs, many forms of billet containers have been designed. Fig. 16 shows one in which the outer case *A* and steel rings *F* were cast in one piece. After the billet container *B* had been put into position, the openings were packed with heat-insulating materials, and ring *H* was screwed into the case. In Fig. 17 cores were made from broken granite, scrapstone, trap-rock or other suitable heat-insulating materials, and these were located in the mold and the case cast solidly around them. Billet container *B*, however, was inserted as a separate piece, because this part wears and must be replaced, while the container proper may last indefinitely. It is not always possible to manufacture cylinders in this way, as the metal from which they are cast may shrink much more than the refractory material in the cores. This is almost sure to cause a fracture in the casting when it is solidifying. A style in which the cylinder is cast hollow is shown in Fig. 18. After the billet container *B* has been placed in position, the hollow space is filled with refractory materials like glass, sand, etc., by forcing these materials through valve *I*, with a force pump, as shown.



Machinery

Fig. 19. Container wound with Wire and Asbestos Insulation

In Fig. 19, lining *B* is wound with asbestos-covered flat wire and the cylinder clamped together over this with bolts. The form of wire shown at *J* is used, and the coils are separated by rings of asbestos. This retains the heat and strengthens lining *B* enough to prevent it from bulging or cracking under the pressure transmitted by the ram. The rings of asbestos may be left out, and the covered wire wound in solid, or it may be wound alternately with strips of asbestos of the same size, staggered. A sectional view would then present the appearance of a checker board.

Electrically-heated Container

One of the latest types of cylinders is arranged so that the ingot to be extruded can be electrically heated. Not only the cylinder, but the die-block and the end of the ram also can be similarly heated. This is shown in Fig. 20. Here *A* is the ingot that is being extruded; *B*, the billet container; *C*, the cylinder; *D*, the ram or plunger; and *E*, the winding of metallic tape which has enough resistance to impede the

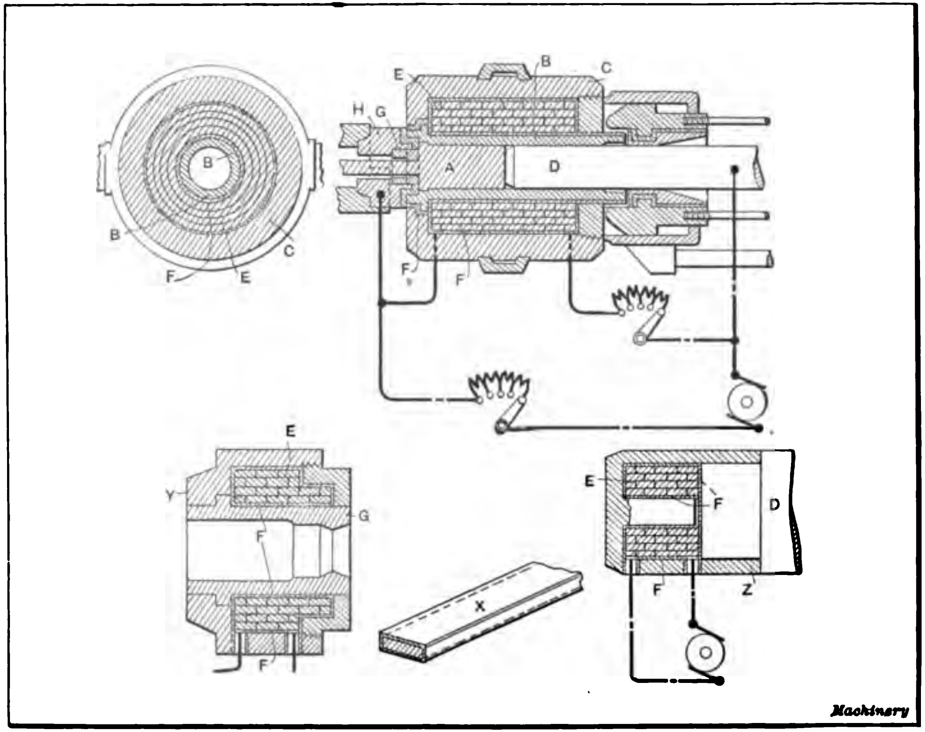


Fig. 20. Electrically-heated Container

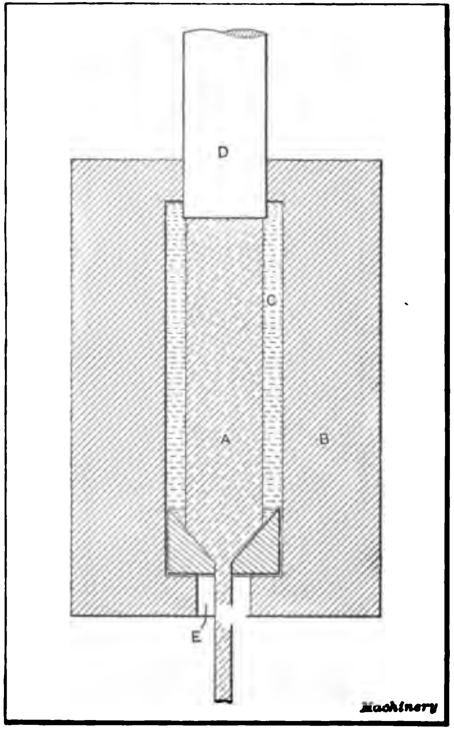


Fig. 21. Liquid-surrounded Ingot

current and generate the heat. A section of this tape is shown at *X*. It is usually made of copper and covered with some insulating material. The insulation that confines the electric current and prevents it from entering other parts of the machine is shown at *F*; *G* is the die, and *H* the die block, which may also be electrically heated by constructing it as shown at *Y*. The end of the ram *D* may be electrically heated by constructing it as shown at *Z*. This would entirely surround the billet with electric heating apparatus.

In extruding-machines or processes, the billet is heated to the proper temperature before it is placed in the cylinder, and hence the only thing required is a maintenance of this temperature until the metal has been extruded. If, therefore, the cylinder were electrically heated, it might be all that would be required. The ram would seldom require heating, and it would weaken it to place a resistance in the end of the ram. For metals with higher melting temperatures, however, it might be desirable to heat the die-block electrically, and this could readily be done as shown. The electric current is by far the best means of heating the metal and maintaining it at a steady temperature. With rheostats, the current can be easily controlled, and, consequently, the amount of heat required to maintain an alloy at a certain temperature is easily regulated to within a few degrees.

Special Forms of Containers

An attempt was made to abolish the troubles caused by billets adhering to the container walls, by using the design in Fig. 21. Here billet *A* is much smaller in diameter than container *B* and is surrounded with some kind of liquid at *C*. Thus, when ram *D* forces the metal through die *E*, liquid *C* is supposed to keep the ingot from gripping the walls of the container and wedging therein. It is claimed for this method that aluminum or metals of similar ductility can be extruded at atmospheric temperature, this being due to the fact that the billets can be made much smaller in diameter than the interior of the containers; that the ram *D* need only be a tight fit at the extreme end of the container; and that the liquid acts as a lubricant, and the adhesive force is thus entirely overcome. Thus a greater power can be applied to the ram, and the extruded metal be made more dense. The heat can also be done away with, except that which is caused by friction when the metal passes through die *E*. The liquid *C* can be oil when metals are extruded cold, and this will lubricate the apparatus and aid in overcoming the friction as it passes through the die. Water also might be used. Metals of a higher melting temperature could be extruded, and consequently greater strengths obtained. When it became necessary to heat metals for extrusion, fused caustic potash or other materials might be used.

In attempting to press cold metals through a contracted hole like the die of an extrusion press, the billet spreads under the compression and grips the side walls. To overcome this adhesive force and make it less than the forward pressure of the ram, billets are softened and made plastic by raising their temperature. This also reduces the strain

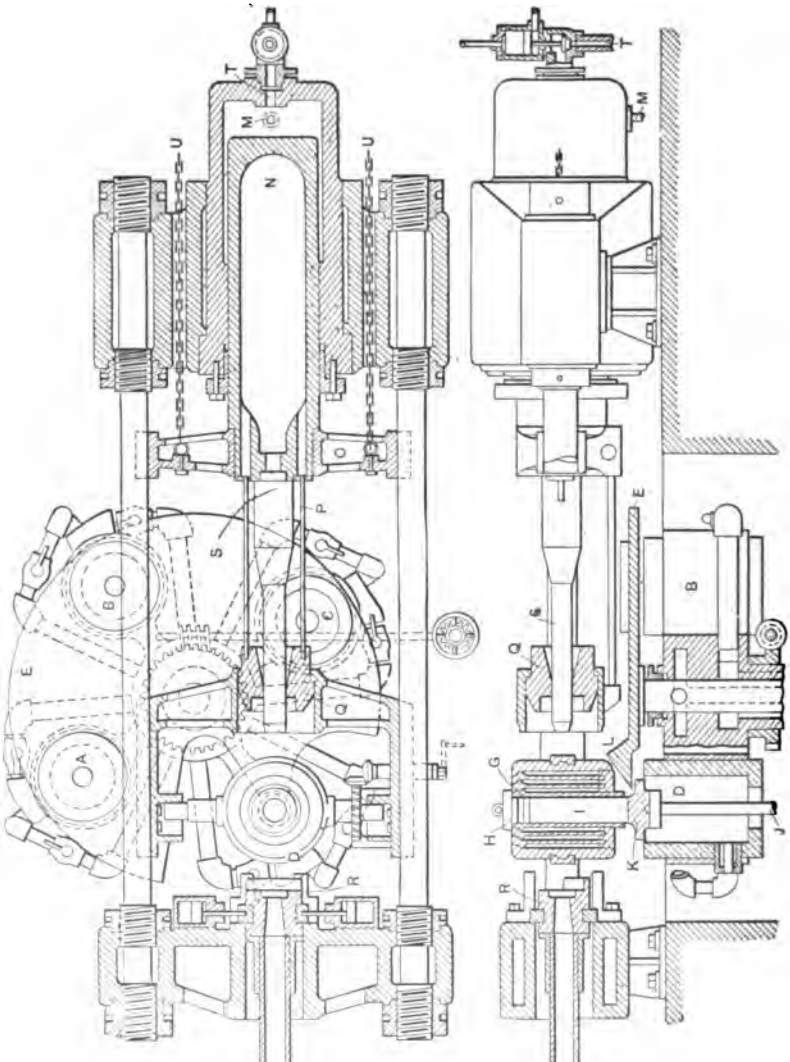


Fig. 22. Main Features of a Modern Extrusion Machine

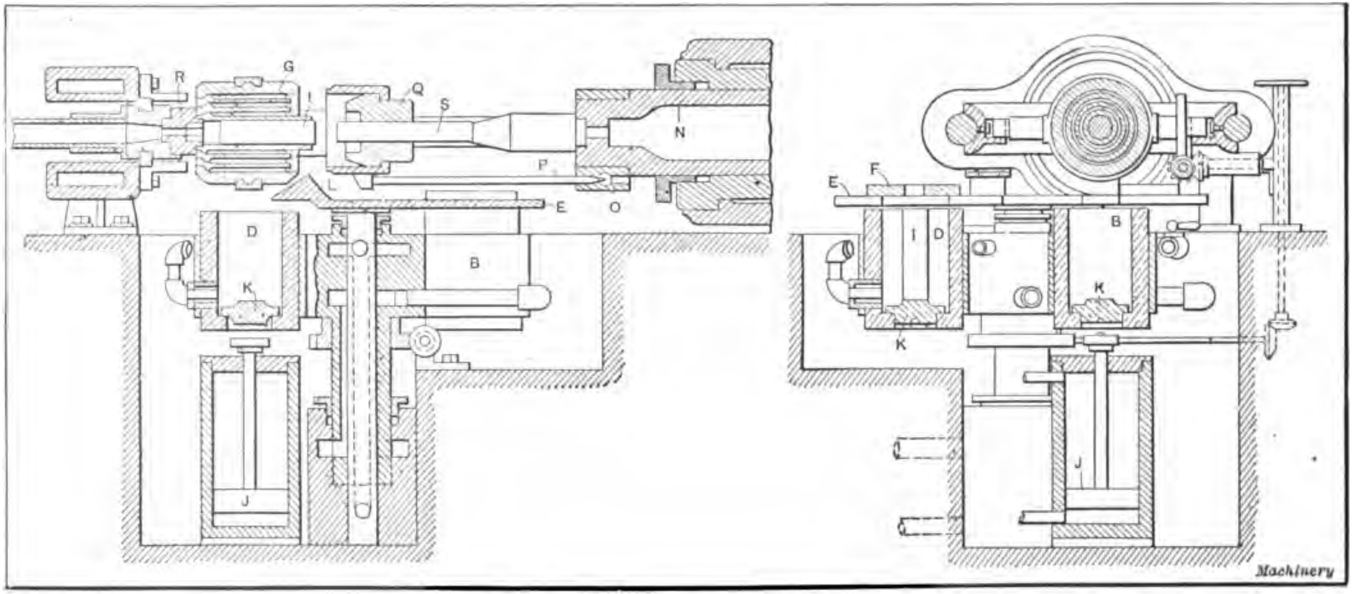


Fig. 23. Main Features of a Modern Extrusion Machine

against the die. If the extruding metal is heated too high it will be too soft, and its grain will be coarsened. The design of cylinders requires that the ram or plunger shall fit the billet container so tight that no metal from the billet can force its way between the ram and the container wall. At the same time it must be loose enough not to score the sides of the container. These requirements also put a limit upon the pressure which can be employed. This limit is not very high, owing to the fact that the die spreads in proportion to the strain put upon it. The higher the temperature to which it is heated, the more it will give way to this strain.

When metals are extruded at atmospheric temperature, a higher pressure must be used. The metal is condensed more and the grain greatly refined. This adds strength, hardness, and toughness to the metals to a degree that it is impossible to attain in other ways. One illustration of the pressures required is shown by the fact that to extrude aluminum at 600 degrees F. only requires one-fifth of the pressure that is required at 70 degrees.

A Modern Extrusion Press

The principal parts of a complete modern extrusion machine are shown in detail in Figs. 22 and 23. Nearly all of the hand labor is done away with in this machine. It heats the billets to the proper temperature, inserts them in the container by hydraulic pressure, and extrudes them by the same pressure. Four gas-heated furnaces are located around a central shaft under the extruding press so that their tops come a little above the floor line. Three of the furnaces, when they are in the positions *A*, *B* and *C*, are covered with a disk screen *E*, that has an opening over each furnace. When starting the operations, the cold billet is inserted in the furnace located at *A;* cover *F*, containing a vent-hole, is placed over it, and the furnace revolved to the position at *B*. It is next revolved to the position at *C*, and while in the positions *B* and *C*, other billets are being extruded. After this, it is turned to the position at *D*.

The cylinder is then revolved on trunnions to the position shown at *G;* cover *H* is placed over it, and billet *I* is pushed up into it by hydraulic piston *J* raising loose block *K* from the bottom of the furnace where billet *I* rests on it. The gas for heating the furnaces enters the hollow shaft on which they revolve, and passes out through ports and piping to each of the four furnaces. The air passes through ports surrounding this hollow central shaft and then through pipes to the different furnaces. After the billet is in the cylinder, this is again revolved on its trunnions to the extruding position; projection *L*, on disk cover *E*, prevents the billet from falling out while the cylinder is being revolved.

With the extrusion cylinder in position, fluid is admitted under pressure to the hydraulic cylinder through port *M*. This moves the hollow piston *N* forward and first transmits power to the device *O* and rod *P* and causes part *Q* to butt against extrusion cylinder *G* and hold it firmly in its seat against the die and die-holder *R*. Container cover *H* has, of course, been removed. Now, ram *S* acts on billet *I* and extrudes it through die *R*. When the ram has reached the end of its stroke, the fluid is allowed to escape through port *T* and with the other mechanism attached, the ram is brought back to the starting position by weights attached to chains *U*.

In this machine, as well as in others, a small end of the billet cannot be extruded. This part often sticks in the cylinder, but it is easily removed by turning the cylinder over the furnace at *D* and turning on the gas, so as to melt it out. With this machine many alloys can be extruded that could not be used with the cruder and simpler machines formerly employed.

Several new extrusion presses have also been brought out abroad. Those best known in Germany are built by the firm of Friedr. Krupp A. G., Grusonwerk in Magdeburg-Buckau. The methods and processes used in connection with one of these machines will be described in the following. The complete installation consists of a foundry for producing the metal blocks, a heating furnace, and a hydraulic press and pumping arrangement.

The Casting of the Metal Blocks

The metal blocks are cast in long sections and are afterwards cut up into pieces of suitable size for the presses. The blocks are cast in permanent molds, and in order that as smooth a surface as possible may be obtained, it is necessary that the inside of the mold be of a close-grained metal, free from flaws. In order to still further insure against blow-holes or porous parts in the cast blocks, the molds are covered on the inside with a preparation, the same as is done in the casting of copper and brass in general.

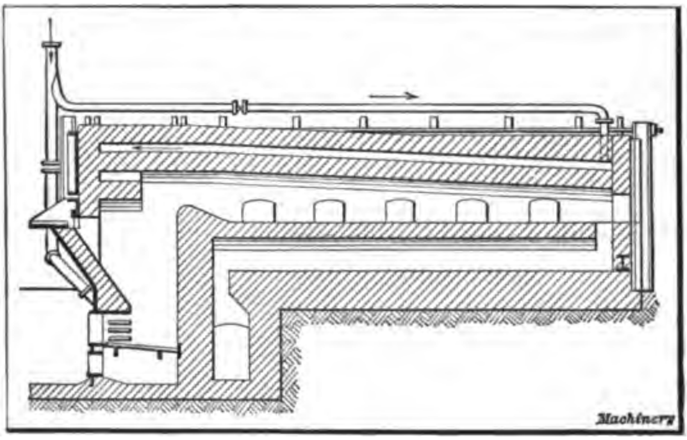


Fig. 24. Section through the Heating Furnace

After the blocks are cast and cut into parts, they are inspected for defects, and any burrs or fins that may be present are removed by chisels or scraping. Special care must be used in producing hollow parts for pipe. In this case, it is especially important that the core be central with the outside, in order that homogeneous walls of uniform thickness may be obtained in the extruded pipe.

Heating the Metal Blocks

The metal blocks are heated in a special furnace which should be placed close to the extrusion press. The important feature about the heating is that the block must be heated clear through to the center, and not be brought to the press when merely the surface has been brought to the required temperature. A furnace used for heating the blocks is illustrated in Fig. 24. The blocks are inserted at the end opposite the grate, and roll by gravity down the somewhat inclined surface toward the fire-box. When the required temperature is obtained, they are pulled out through an opening at the side. In order that good results may be obtained in the extrusion process, it is important that the blocks do not come in contact with the brickwork of the furnace. The surface on which the blocks rest is, therefore, covered with a cast-iron plate. The length of the furnace is made to suit the capacity and speed of the action of the press. The width is usually made about three feet. The heated blocks are most conveniently transferred from the furnace to the press by means of an overhead trolley.

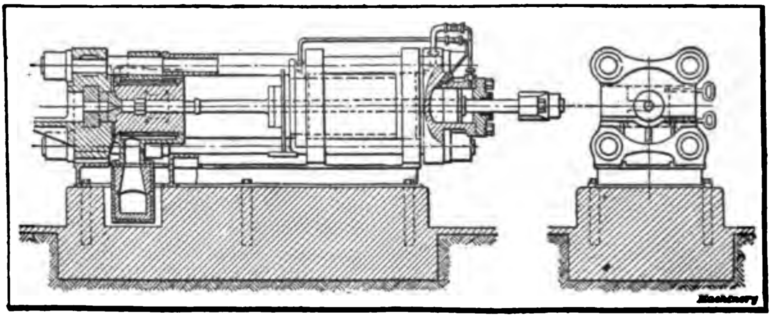


Fig. 25. General Arrangement of Krupp Extrusion Press

The Hydraulic Extrusion Press

The hydraulic extrusion press shown in Fig. 25 is of the horizontal type. The press consists mainly of the hydraulic cylinder, the dies, the pressure chamber or extrusion cylinder, and a head which holds the dies. Four heavy connecting bars tie this head to the hydraulic cylinder. The pressure chamber is located between the head and the hydraulic cylinder and moves on four guide bars.

TABLE I. GENERAL DIMENSIONS OF EXTRUSION PRESSES

Dimensions	Smaller Size	Larger Size
Total pressure, pounds	1,430,000	2,200,000
Maximum pressure, pounds per sq. in.	3770	4125
Diam. of hydraulic cyl., inches	22	26
Stroke, inches	27½	31½
Diam. of extrusion cyl., inches	4⅝	5½
Max. diam. of extruded bars, inches	2	2¾
Required horsepower	100-150	175-225

These presses are built in two sizes, the main dimensions of which are given in Table I. The output of the presses varies according to the size and form of the cross-section of the different extruded shapes. With trained operators and simple cross-sectional shapes, it is possible to extrude about 20,000 pounds of metal in ten hours in the small-size press and 35,000 pounds in the larger press. This output cannot be obtained, however, when tubing of difficult sections is being extruded. The figures given above correspond to two hundred press operations in ten hours. In order to be able to maintain this efficiency the press chamber must be sufficiently heated at the beginning of the work and there must be no interruption in the operation. For the complete installation required for one press, four men are necessary, one of whom works at the furnace.

Details of the Hydraulic Press

The hydraulic cylinder is made of steel casting and lined on the inside with a copper bushing. The pressure chamber is made of so-called "Krupp special" steel which even when heated has a high tensional strength. This chamber or cylinder is forged and is provided with a jacket of steel casting. Between the pressure chamber and jacket an open space is provided through which the heated gases from the fire-place arranged beneath the pressure chamber can pass. By this means the chamber is heated to the required temperature, the gases from the combustion escaping through a pipe above the pressure chamber into the chimney. The required temperature to which the pressure chamber should be heated by external means is about 600 degrees F. This heat is required so that the metal blocks which are heated to some 1650 or 1800 degrees F. may not be suddenly cooled. Should sudden cooling take place, the surface of the metal block may lose its plasticity and the extrusion may either be unduly delayed or be made entirely impossible. The high temperature of the walls of the pressure chamber, while the extrusion takes place, requires an especially high quality of metal, and it has been proved in a number of instances that forged Krupp special steel answers the requirements better than any other known material.

In order to prevent too high a pressure in the hydraulic cylinder, a safety valve is provided on the pump which opens at a pressure of about 4500 pounds per square inch. In order to instantly relieve the pressure in the hydraulic cylinder, a releasing valve is inserted between the pump and the controlling valve on the machine.

The dies containing the shape for the extruded form are held in the head. This latter takes the pressure during the extrusion process. One of the greatest difficulties in the past with machines of this type has been to remove the remainder of the metal block in the pressure chamber when operations are suspended or when practically all the metal has been extruded. Part of the metal would usually be pressed in between the joints, solidify and make the removal of the various parts difficult. In the Krupp press this difficulty is taken care of as follows: As already mentioned the pressure chamber is placed between the head and the hydraulic cylinder, but is movable on four guide rods. A tapered hole is provided in the pressure chamber in the end towards the head, and the dies are formed with a corresponding taper. An auxiliary hydraulic cylinder is provided at the right-hand end of the press in Fig. 25, and the pressure chamber is connected with the piston of the auxiliary cylinder by means of a cross-head and two connecting-rods. By this means the pressure chamber can be operated. Before the beginning of the extrusion, the pressure chamber is forced against the die by means of this auxiliary cylinder, and due to the tapered hole and the tapered end of the die a very close-fitting joint is provided, so that the metal, during the extrusion process, cannot enter between the two surfaces. At the end of the extrusion, the auxiliary cylinder operates the pressure chamber in the opposite direction, thus opening up a space between the die and the pressure chamber and making it possible to easily remove the remaining metal from the top of the die.

The press can be operated with considerable rapidity. For simple shapes, it is possible to go through the complete cycle of operations for one metal block in three minutes, this time being divided as follows: Putting the metal block into the pressure chamber, 1 minute 25 seconds; extrusion, 50 seconds; opening up the space between the pressure chamber and die, 10 seconds; removing the remaining metal, 15 seconds; and returning to the original position, 20 seconds. The effect of the extrusion process on the tensile strength of various metals is indicated by Table II.

TABLE II. INFLUENCE OF THE EXTRUSION PROCESS ON THE PROPERTIES OF METALS

Metal	Cast		Extruded	
	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent
Copper.........	28,500	35	34,000	38–40
Magnalium......	43,000–64,000	5	53,000–71,000	10
Aluminum......	14,000–17,000	3	33,000–38,000	4.3
Delta-metal......	33,000	11	98,000	21.8
Durana-metal...	58,000–74,000	35	60,000–81,000	38

Examples of Work Produced by the Extrusion Process

The half-tone illustration Fig. 26 shows sections manufactured by the extrusion process by the Coe Brass Mfg. Co., Ansonia, Conn., the well-known makers of extruded shapes. Various special forms of angles are made in this way. Gears, ratchet wheels, gear racks, padlock hasps, and other special shapes are turned out in long bars which are afterwards sawed up to give the pieces their required thickness. Moldings have also been made for the Navy Department. An extruded angle that was made for the Navy had a tensile strength of 85,000 pounds per square inch, an elastic limit of 33,800 pounds per square inch, an elongation in 8 inches of 18.1 per cent, and a reduction of area of 20 per cent. Some quite intricate shapes have been made.

Where parts, such as flat lock keys, can be made in the punch press, they can be made cheaper this way than by the extrusion process. Such parts as the hasp on padlocks, however, are made more econom-

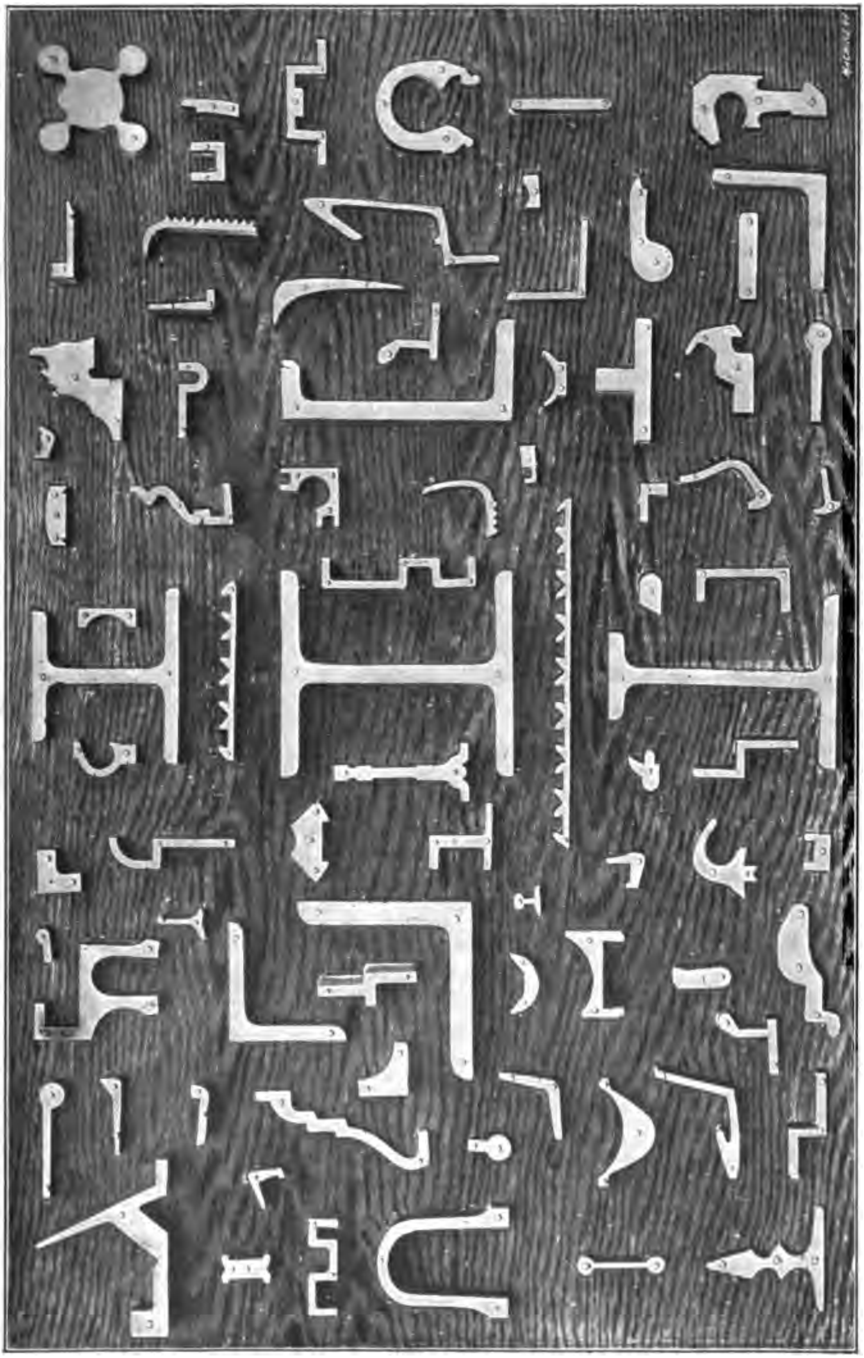


Fig. 26. Examples of Extruded Metal Shapes produced by the Coe Brass Mfg. Co.

ically by the extrusion process, as they would be difficult to punch out owing to their thickness. There are also numerous other lock parts that are cheaply made from extruded metal. The extruded shapes can be made to within 0.0005 inch of the correct size. This makes the process very useful for parts that would otherwise have to be machined.

Metals and Metal Alloys used in the Extrusion Process

In the extrusion of metals it is natural that lead should have been the one first used, as this is the most plastic of metals. Lead in the form of filings can be compressed into solid metal with 13 tons pressure to the square inch. It will flow through all the cracks of the apparatus. like liquid, when a pressure of 32 tons per square inch is applied to it. Its plasticity as compared with that of other metals is shown by the fact that powdered tin can be made into solid metal with a pressure of 19 tons per square inch; copper, with 33 tons; zinc, antimony, aluminum and bismuth with 38 tons, while other metals require considerably greater pressure than this. Tin would flow through the cracks of the apparatus like liquid at a pressure of 47 tons per square inch, and the other metals at a considerably higher pressure. Lead and tin, or any alloys that might be made from them, however, have very little strength and thus their use has been limited.

While copper is very malleable, ductile and tough, and consequently would flow freely through a die under pressure, it has but limited strength, and, consequently, cannot be used for very many purposes. As lead, bismuth or antimony have an injurious action on copper and make it hard, brittle and cold short, these elements cannot be alloyed with it for extrusion purposes, except in very small quantities. When more than 0.5 per cent lead is added to copper it makes it both hot and cold short, and it cannot be worked hot; 0.2 per cent lead, however, may be present without impairing the tenacity of copper. Tin in small quantities does not appear to affect the working properties of copper, except to make it somewhat harder. Larger percentages of tin, however, would render copper too hard for extrusion purposes, and would give it a flaky grain that weakens the metal. When zinc is alloyed with copper, 1 per cent zinc will make the copper hard and red short, but 20 per cent zinc alloyed with 80 per cent copper will produce an exceedingly malleable alloy. Small percentages of zinc do not alter the character of copper in other ways. The zinc also produces a greater tensile strength.

An alloy composed of 55 per cent copper and 45 per cent zinc was the first comparatively strong metal that was used for extrusion purposes. This is also one of the most common alloys used at the present time. The brasses that contain from 50 to 60 per cent copper and 40 to 50 per cent zinc are the most plastic, and hence are the alloys most frequently used for extruded metals. The brasses containing from 75 to 85 per cent copper are malleable while hot, but are rather too hard to extrude easily, while the brasses containing from 62 to 70 per cent copper are not malleable at a red heat and hence are difficult to extrude.

Small quantities of iron add strength to the brasses and do not make them difficult to extrude; hence Delta metal, manganese bronze and similar alloys can be used in the extrusion process. Aluminum, when used in small percentages, makes copper harder than when 8 to 10 per cent is used, and hence the aluminum bronzes with from 8 to 10 per cent of aluminum are the most easily extruded. An alloy containing 90 per cent copper and 10 per cent aluminum, or one with 85 per cent copper, 10 per cent zinc, and 5 per cent aluminum is also used, but ordinarily the copper content is kept lower than this. With these aluminum bronzes, however, a tensile strength of from 65,000 to 85,000 pounds per square inch is obtained, with an elastic limit of from 40,000 to 60,000 pounds, an elongation in 8 inches of about 18 per cent, and a reduction of area of about 20 per cent. Some tests on extruded shapes made for the Government have shown even better results than this.

Pure zinc can be greatly strengthened by an extrusion process conducted in the proper way. If the area of the die opening in relation to the area of the zinc billet to be extruded is in the ratio of 1 to 15, the temperature of the metal is kept between 85 and 180 degrees F., and the extruded metal is submitted to a pressure of not less than 90,000 pounds per square inch, the coarse crystalline structure of the ordinary zinc is transformed into a fine grain, and the zinc assumes the properties of brass. A tensile strength of 29,000 pounds per square inch can be obtained in this way and an elongation of from 26 to 70 per cent. For comparison, ordinary zinc only has a tensile strength of 5000 pounds per square inch and almost no percentage of elongation. Zinc in the extruded condition can also be readily worked with machine tools and it is quite malleable and flexible.

CHAPTER II

THE EXTRUSION OF SHELLS AND TUBES

Just because a diemaker miscalculated a little, leaving the face of a punch too long, there is a growing corporation doing business in a comparatively new field of metal goods manufacturing. This, in a nutshell, explains the existence of the Metallic Shell & Tube Co., of Pawtucket, R. I., although the whole story is somewhat longer.

In 1903, George W. Lee was located in Binghamton, N. Y., engaged in the manufacture of the familiar one-piece collar button shown at *A* Fig. 27. After a short time it became apparent that by means of such machines as the multiple plunger press others were turning out collar buttons by the ton so cheaply that he could not compete with them. Naturally, he began to look around for some other similar product that he could manufacture with his equipment of presses, shears and tools, and he hit upon the idea of a fastener, part of which is shown at *B*, Fig. 27. He immediately patented this "bachelor's button," and commenced to manufacture it on a small scale.

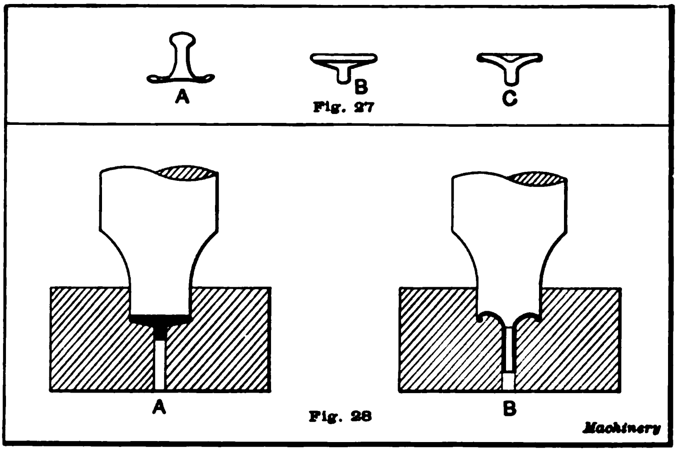


Fig. 27

Fig. 28

Fig. 27. A, Collar Button; B, Fastener; C, Improved Fastener. Fig. 28. A, Die for Fastener, with Work in Place; B, Die intended to produce a Fastener of Improved Design, showing Piece actually produced.

After getting fairly well started, it occurred to him that if he made a slight change in his dies, so as to give the face of the button the appearance indicated at *C*, Fig. 27, the product would have a more finished appearance, without increasing the cost of manufacture. The dies for the button appeared about as shown at *A*, Fig. 28, in which the aluminum blanks, ½ inch in diameter, were placed and formed in the usual manner. To obtain the improved shape of the face of the button, he assumed that it would only be necessary to leave a small projection on the punch. He then made a punch with the projection left a little longer than he had intended, but he concluded to try it out. To his amazement, he found that instead of the slightly changed button that he had expected, he had a tube about ¾ inch long, with the flanged face of the button intact, as shown at *B*, Fig. 28. He pondered over the matter, tried more blanks in this die, with the same results, and decided that the explanation was that the metal, being confined on all sides except for the annular opening formed by the opening in the die and the projection of the punch, *had* to go through this space when pressure was applied.

With this principle in mind, he tried several other experiments along the same lines, and finally applied for patents on the process of extruding tubular metal bodies by means of dies of the type shown in Fig. 29. When the patent examiner at Washington read the specifications and saw the drawings, he was incredulous, and before allowing the patents, Lee was obliged to make several tubes for the examiner; after furnishing affidavits as to his work, the patents were allowed. During the next four years Lee worked incessantly on the process, but with little real success.

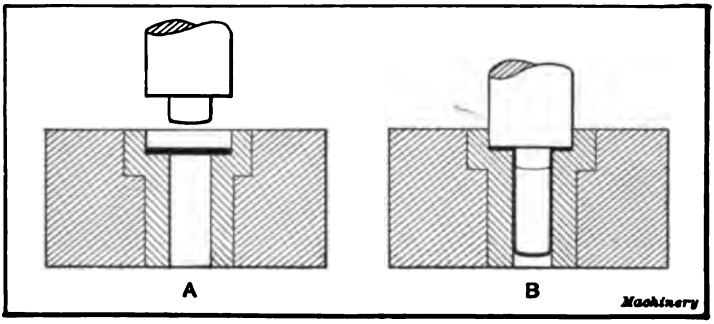


Fig. 29. Lee's Method of Making Tubular Articles, Patented in 1906. A, the Die with Blank in Position; B, the Extruded Shell

At this point Mr. Leslie E. Hooker and three other men bought the patent rights of Lee and organized a company to make a commercial success of the extrusion process. Mr. Hooker had been watching the experimental work for some time. He took out several patents on improvements, and started a factory in Pawtucket, R. I., where at present the extrusion process is being worked successfully. The company is making tubes and shells in large quantities, and as manufacturers and designers are becoming more and more aware of the value of extruded work, the prospects seem unusually bright for the future.

General Outline of the Process

Since George W. Lee stumbled over the extrusion process in 1903, many changes have been made in the details of the methods, but in general the principles are the same. Briefly stated, the extrusion of tubular bodies is accomplished by confining a metal blank within a strong cylindrical chamber whose only outlet is through an annular opening at the bottom, formed by the projection on the punch and the hole in the bottom of the die. The size of this opening may be made of any required dimension, so that tubes and shells of different measurements can be made.

Figs. 30 and 31 illustrate the features of dies for extruding tubular shapes. The containing ring is shown at *A*, the lower die at *B*, and the punch at *C*; part *D* is the former. In Figs. 29 to 32 inclusive, the die rings, dies and punches only are shown, for they are the vital parts of the apparatus. In Figs. 30 and 31 the blanks are shown at *F*, just after the extruding operation has started.

Fig. 30 shows a plain flat blank being extruded, but as the process was developed it was found better in every way to use a cup-shaped blank like that shown in Fig. 31. This shape of blank takes no longer to make than the flat blank, if cut and drawn in one operation. The chief advantage in using the cup-shaped blank lies in the fact that the metal extrudes more easily, for the work is distributed over a longer space. This fact is more readily apparent by noting the differences in the distances traveled by the punches in Figs. 30 and 31. There is, however, a limit to the proportions of this cup, for if made too deep and narrow, the punch will be too weak to stand the strain; if made too shallow, on the other hand, the object of cupping will be defeated. In general, the walls of the cup should be from 3/32 to 1/8 inch; from 3/8 to 1/2 inch is a proper depth for the cup. In some instances, as in cartridge case making, it is desirable to have the bottom of the tube as thick as possible, in which case the cup is made without reducing the thickness of the bottom. In nearly every tube, however, it is advantageous to have the bottom of the finished tube of the same thickness as the walls of the tube; therefore, after cupping, the bottom is thinned down by stamping, and the top edge of the cup is chamfered toward the inside at the same operation.

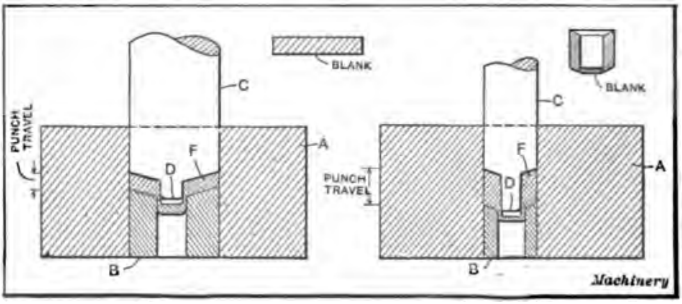


Fig. 30. Extruding from a Flat Blank

Fig. 31. Extruding from a Cup-shaped Blank

Suppose a shell is wanted with tapering walls, thickest near the bottom, as in the cartridge work illustrated at *P*, *Q*, *R*, and *S* in Fig. 34. To produce this effect, as indicated at *K*, the former is made with its sides sharply tapered towards the point, as shown in Fig. 32. Then, when the former enters the die opening, the space around the former is quite large, and the walls of the tube at this point will be correspondingly thick, as shown at *A*. At the end of the stroke, illustrated at *B*, the space around the former is very narrow, because the thick part of the former has entered the hole in the die through which the tube is being extruded. At this point, then, the walls of the tube will be very thin. To be a little more specific, let us assume that we wish to make a shell or tube, six inches in length, the walls of which are to be 1/16 inch thick at the base and 1/64 inch thick at the top. The former is 3/8 inch in diameter at its widest point. As there is a difference of 3/64 inch in the thickness of the walls of the tube, there must be twice this amount of difference in the diameters of the former at its end and base. Therefore, the former for this tube must measure 9/32 inch at the end, to produce the tube shown in Fig. 32.

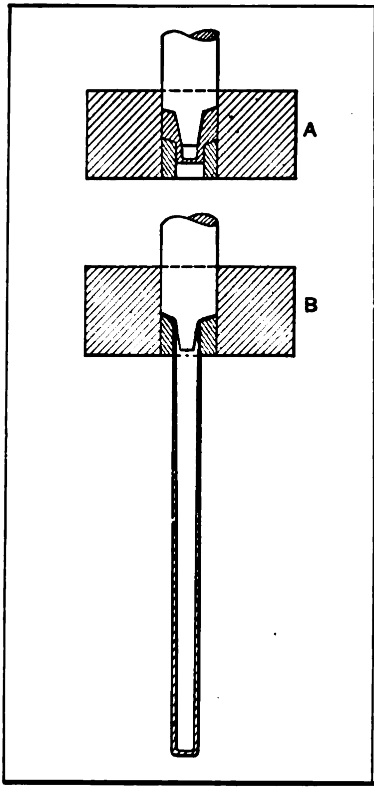


Fig. 32. Making Tubes with Taper Walls

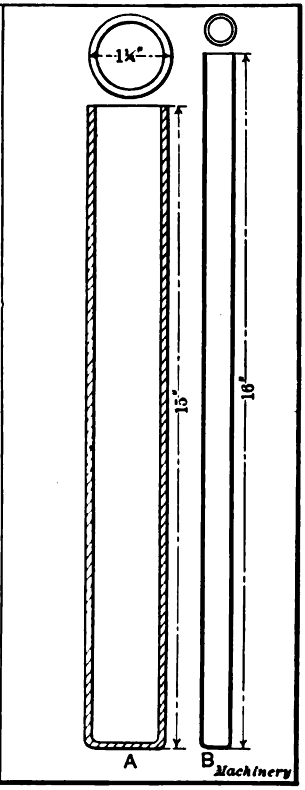


Fig. 33. Comparison of Tube-making Methods

Some idea of the speed at which the tubes are extruded from the dies may be obtained by observing the fact that in extruding an 18-inch tube, the punch moves but ½ inch. As most extruding is done without using geared presses, the tube metal moves the 18 inches in a very small fraction of a second, generating a good deal of heat while doing so. The operators of the presses are very careful to keep out of the way of the tubes that are being extruded.

Presses for Extruding

Nearly all types of presses or extrusion machines, as they are commonly called, have been tried—power presses, drop presses, screw presses and even steam hammers. Hydraulic presses have not yet been used to any extent on tubular work, because large sized work has not yet been attempted. Drop presses are not satisfactory on account of the shock of the blow and the consequent shortening of the lives of the dies. The wear and tear on the dies is great, even under the most favorable conditions, so that it is important that everything possible should be done to lighten their work. Screw presses are very powerful, and the shock of the blow is not excessive, but it is difficult to strike exactly the same blow each time, especially with the German type of press using the friction drive; therefore, their use has been given up. Steam hammers, of course, are out of the question for several very apparent reasons.

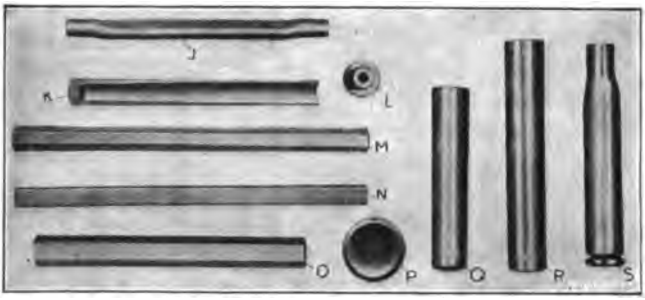


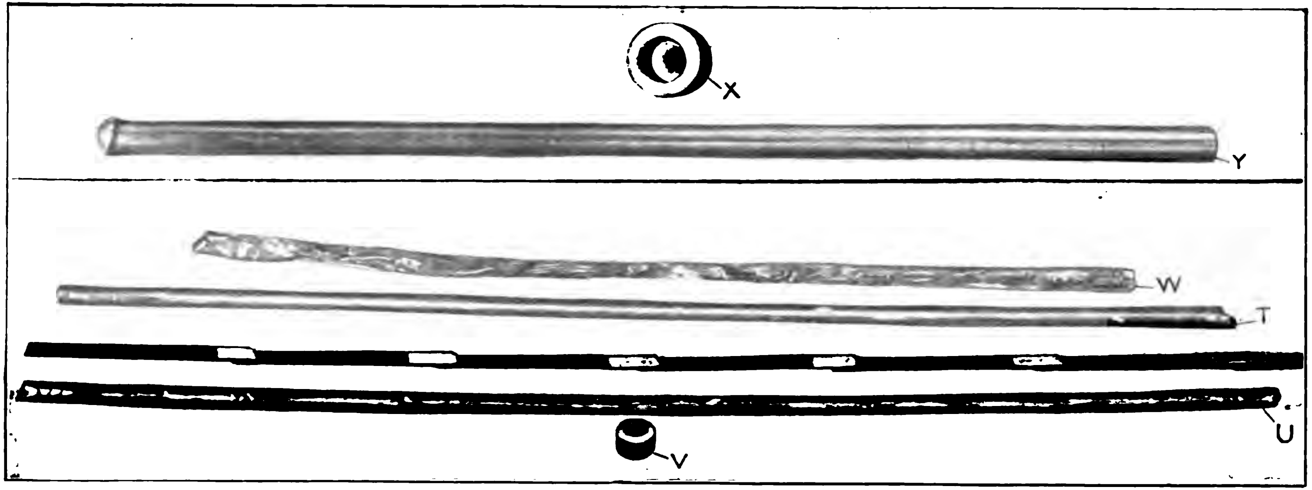
Fig. 34. Miscellaneous Examples of Extruded Work

So far, the most satisfactory style of press seems to be the crank press, of the geared or plain type. There is the danger of springing the shaft, but on the whole this type seems to be as good as any. Ferracute presses are used for extruding, and so are Bliss presses. Small tubes may be extruded on Bliss No. 52 presses, and for heavier work the No. 37 Bliss press of the geared type is very satisfactory. These presses have strokes of 1½ inch, which seems to meet all requirements.

Metals used in Tubular Extrusion

It is almost needless to say that the softer the metal is, the easier it may be extruded. Naturally, then, lead is the easiest metal to extrude, and it is used to a great extent in alloys that contain small percentages of other metals, for making collapsible tubes and similar goods. Pure tin is still more used for the better grade of collapsible tubes.

Aluminum comes next in order, and in fact, there is no better metal to extrude, if aluminum will meet the requirements of the work for which the shell is to be used. There is one slight disadvantage in



Figs. 85 and 86. Lead Tubes for Torpedo Work. Examples of Difficult Extrusion

working aluminum—it is impossible to cut and draw thick stock into the proper kind of cup to use as a blank for extruding, which means that another operation will be required. Often, by using an aluminum alloy, the extruding operation is facilitated and the cost of the extruded article reduced. A particularly valuable alloy is one that contains 98 per cent aluminum and 2 per cent zinc. Not only is this a strong alloy, but it can be extruded easily. The best lubricant known in the press-working of aluminum is soapy water

Pure zinc is a soft metal, but contrary to the general rule, is a poor metal to work in this process. It can be extruded easily enough, for it flows very nicely, but its effect on the former and die is to roughen them in a very short time, and after several hours' work the dies will be unfit for use. Minute particles seem to separate from the zinc and are forced into the surfaces of the dies.

Copper is a very satisfactory metal to extrude. Some of the best examples of extrusion have been produced from copper. The better the grade of the metal, the better it will extrude, although ordinary commercial copper works very well. Lard oil is used as a lubricant. The better mixtures of brass can be extruded fairly well, although not as well as copper. For this reason a metal consisting of 70 per cent copper and 30 per cent zinc is a better metal for this purpose than the "two-and-one" mixture for brass. In short, the more copper in the brass, the better.

Gilding metal, containing mostly copper in its composition, is a good metal to extrude. This metal is used largely by the jewelry trade as a base upon which to gold-plate; hence its name. Pure gold will work well in the extrusion process, but 14-carat gold cannot be extruded at all; it is too tough. The reason for this is not very clear, as copper is used in the 14-carat gold alloy; but the fact remains that gold and copper, two soft metals in themselves, make a very tough alloy. So far, it has been found impossible to extrude iron or steel, as the dies give out under the extreme pressure required.

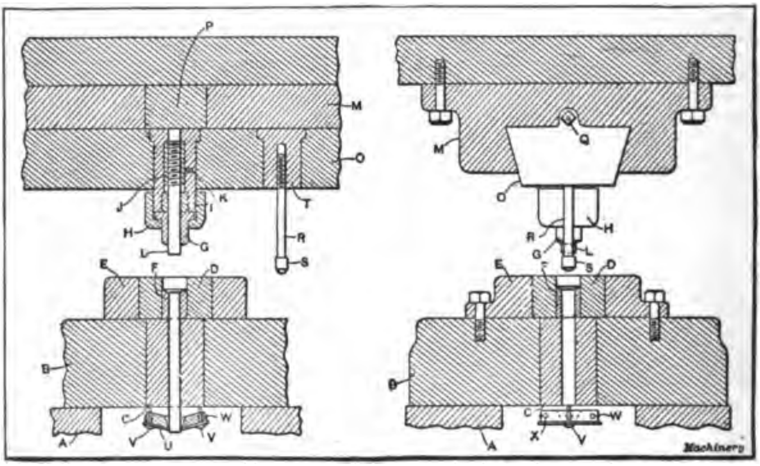


Fig. 37. A Modern Die for Extruding Tubular Shapes

The effect of extrusion upon the structure of the metal being worked is beneficial, in that the grain of the metal is toughened and made much stronger. To start with, the metal is soft. After the blanking and cupping process, the cups are annealed. When the tubes come through the dies they are as tough and springy as could be desired, and still they are not brittle.

When extruding thin tubes, especially of the softer metals, holes are punched through the bottoms of the cups to let the air into the tubes while they are being extruded; otherwise the air pressure from without would cause a tube with thin walls to collapse, because the interior would be almost a perfect vacuum. Of course, if the bottom of the tube must be kept intact, this method cannot be adopted. The effect of the air pressure is well illustrated by the flattened tube shown at *W*, Fig. 36.

A Modern Extrusion Die

Fig. 37 represents a modern style of die for extruding tubular metal shapes. As will be noticed, the principles are the same as in the original Lee dies, although several details have been changed and a few features added. In this illustration, *A* represents the bed of the press; *B* is a bolster in which the hardened steel bushing *C* is a very hard driving fit. Bolted to the bolster is the die shoe *E* which is shrunk around the die ring *D*. By shrinking the die shoe around the die ring, a very tight fit is assured. Another important reason is that the temper of the high-speed steel die ring can, by being mounted in this way, be drawn just enough to leave the die tough, enabling it to stand the strains incident to its use. The die ring is ground out after hardening and a bushing *F* is fitted. This bushing is a very important part of the die, for in the old-style dies, when the interior of the die gave out, a new die ring was required. If a bushing now breaks, it merely means that a new one is to be slipped in, without even taking the die from the press. These bushings may be made several at a time and kept in readiness for an emergency. It is very essential that the inclined face of this bushing be polished very smooth, and that the edge of the hole be slightly rounded, so as to help the metal to form itself into the shape of the tube. The size of the hole in this bushing governs the size of the tube, and it must be ground to size and lapped to a smooth finish.

The Punch and Former

Second in importance only to the die, is the punch and former. It is the function of these parts to force the metal to flow through the hole in the die and to form the inside of the tube or shell being extruded. The punch *G* is really a removable tip to the punch body *I*, being held to it by the taper sleeve or nut *H*. The reason for having the punch in two parts is to make it easier to replace in case of breakage—there are plenty of breakages in extrusion tools. The end of the punch is turned off on a bevel to agree with the face of the die, and this surface must be just as highly polished as that of the die. The outside of the punch must be a close sliding fit in the die ring, for if it is loose there will be danger of its breaking.

The former *L* sizes the inside of the extruded tube, and as the metal is constantly slipping past its end, it is polished very highly, as is also the inclined face of the punch itself. An important feature of the former is its independent movement with relation to the punch. The internal end of the former is threaded into the bushing *J* which is free to slide within the punch body *I*, but is prevented from turning by the screw *K*, engaging a groove in the bushing. When the cup-shaped blank is struck by the punch, former *L* is pushed back to the position shown in Fig. 37. As the metal flows inward, a tremendous pressure is brought to bear on the former in a downward direction, and on the punch in an upward direction. This pressure often breaks the solidly combined punches and formers. In this die, the pressure carries the former and its sliding bushing down into the tube, and by the time the limit of the movement is reached, the extrusion process has had a fair chance to start, and the pressure is consequently diminished.

The Slide and the Stripping Punch

After each extruding operation there is a thin washer-like piece of scrap left in the dies and attached to the tube, for it is impossible to extrude every particle of the metal. The means taken to clear the die of this scrap are interesting. The body of the punch *I* is driven into a slide *O*, which works in the head-block *M*. This block is, in turn, bolted to the ram of the press. The travel of slide *O* is limited by two stops, one of which is shown at *Q*. Into the head-block is driven a block of hardened steel *P*, directly in line with the dies below. When slide *O* is at one end of its travel, the punch is backed up by this block. At the other extreme of the travel of the slide, stripping punch-base *T* comes in line with the die and consequently is also, in its turn, backed up by block *P*. A threaded hole in base *T* receives the stripping punch *R* which at its lower end has a bushing *S*, the diameter of which is midway between that of the hole in the die and that of the inside of the tube. After the tube has been extruded, the slide is moved to its other position, bringing the stripping punch *R* in line with the die. At the next stroke of the press, the stripping punch enters the die, the front end of the bushing severs the tube from the scrap, and on the return, the top edge of the bushing catches the scrap and pulls it out of the die The slide is then moved back to its original position, and at the next stroke of the press another tube is extruded. Thus it will be seen that every second stroke produces a tube or shell, while the intervening stroke removes the scrap from the die. After the stripping punch becomes filled with these scrap washers, it is unscrewed from the base and cleared of the scrap.

Another improvement on this extruding die is the device beneath the die for preventing the tubes from being pulled up into the die when the stripping punch ascends. This device consists essentially of two semicircular leaves *U*, held together by a spring *W*. These leaves, or gripping jaws, are supported by two pins *V* which allow the jaws to tip slightly downward when pushed from above. Therefore the tubes are permitted to pass downward through the jaws, but the jaws resist any upward pull by gripping the tube and effectually holding it.

After the tubes have been extruded, their forms may be changed by making them square or hexagonal, or they may be straight or spirally fluted. These operations are done by running them through dies, properly shaped, with punches of the same shapes to support the interiors. Round tubes that must be very straight and true are sometimes run through round dies to correct errors. At *M*, *N*, and *O*, Fig. 34, are illustrated tubes of hexagonal and square sections.

Some Examples of Extruded Work

Perhaps the most impressive pieces of tubular extrusion done at the Metallic Shell & Tube Co. factory, are the lead tubes shown at *T* and *U*, Fig. 36. This work really does not require as much skill to produce as the majority of the extruded shapes, but it shows up well. These tubes, which are 36 inches long, are used as containers for the explosive for torpedoes. They are cut to short lengths, and the ends folded over. The blank, after being cupped, appears in front of the tubes. Lead is so easy to extrude that care was not even taken to chamfer the top face of the blank.

For really difficult work in this line, the copper tube *Y* in Fig. 35 is a fine example. It is but ⅝ inch in diameter and is 16 inches long. The walls are less than 0.010 inch thick. Fig. 33 is shown for a comparison of the two methods of making sheet-metal shells with closed ends; *A* represents the shell for a bicycle pump and is about as deep and narrow a shell as can be successfully drawn. To make this shell from copper or brass would require at least twelve operations. Contrasted with this piece of work is the copper tube at *B* which was made in three operations. In fact, it would be impracticable to use more than three operations for extruding this tube. It would be impossible to duplicate this tube by ordinary press drawing operations.

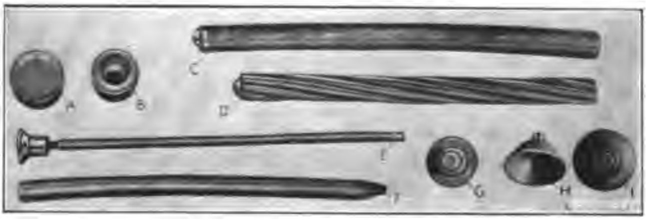


Fig. 38. A, B, C, and D, Steps in Making an Instrument Case by Extrusion; E and F, Extruded Parts for Automatic Pencils; G, Bullet Jacket; H and I, Hat-pin Guards

Instrument Cases

A very pretty illustration of an extruded product is shown in the aluminum instrument case illustrated at *D* in Fig. 38, together with the successive steps in its making. The first operation consists in blanking the disk *A*. The next operation is to cup this blank by punching the center in a die that also forms the ornamental bead on the end of the tube. Then the blank is extruded to make the tube *C* itself. Finally the tube is trimmed to length and run through the fluting die, which completes the tube, straightening it as well. The fluting die is merely a thin die having spiral grooves in it. The punch, or mandrel, is free to turn as it pushes the tube through the die.

The two parts of an automatic pencil, shown at *E* and *F*, Fig. 38, represent some neat specimens of the extrusion process. The core of the pencil shown at *E*, which has a small hole running through the tube section, was first extruded with the hole clear through the head. Afterward the piece was put in another die and the head flanged, closing in the end of the hole at the same time. The larger tube *F* was extruded in the usual manner, and the end closed in by another operation.

At *G*, Fig. 38, is shown a small aluminum bullet jacket which shows the flange of scrap that is left by the dies. In this case, however, the flange is a necessary part of the bullet jacket.

The hat-pin guard, shown at *H* and *I*, is a somewhat unusual piece of extrusion work. The former is made just the size of the hole; the punch is chamfered off to fit the inside of the bell and the die is of the same shape as the under part of the guard. In this case, as with the bullet jacket, there is no scrap and the pieces must be taken from the die either by hand or by an ejector.

At *J*, Fig. 34, is shown an electrician's wire coupling used in splicing breaks in a wire. This piece is extruded as a plain round copper tube, and then slightly flattened in the center by a simple press operation. The small bushing at *L* shows that thick walls may be extruded as well as thin ones. At *P*, *Q* and *R* are shown three stages in making a brass cartridge case, as already mentioned. At *S* the end of the shell has been reduced by closing-in in a press, and the groove has been turned at the base of the cartridge.

CHAPTER III

MAKING COLLAPSIBLE TUBES BY THE EXTRUSION PROCESS

The extrusion process is extensively used for making collapsible tubes of tin and lead, for containing dentifrice, artists' colors and other preparations. The New England Collapsible Tube Co., of New London, Conn., is employed in the work of making these collapsible tubes. The business of the company was originally established by the late Dr. Sheffield, in 1850, as a dentifrice manufacturing business. He made at that time only the tubes he required in putting out his preparations. Later, however, the demand for good collapsible tin tubes became so strong that the company commenced to make them for outside concerns, and now the tube department has grown to be far larger than the dentifrice department.

The best collapsible tubes are made from pure tin. Lead is often used for tubes for paste, glue, and ink; but for toilet preparations, like dentifrice, only the purest tin is employed. Tin ore is found in Germany, Spain, Russia, Malacca, Australia, Mexico and the United States. The amount of tin ore mined in the United States, however, is very small, and not nearly sufficient to meet the demands of this country. The very best tin is obtained from the Straits of Malacca, as this tin is particularly free from impurities. This is a very important requisite in tin for the extrusion of collapsible tubes for dentifrice, because foreign matter would not only cause the tubes to be poor, but the quality of the dentifrice would be affected, and moreover there would be constant trouble from injury to the dies.

Fig. 39 illustrates a few finished collapsible tubes and their caps. Those marked *A* have been decorated by lithographing; those marked *B* have been embossed; while those marked *C* are plain tubes onto which labels may be pasted. Collapsible tubes may be made as large as 2½ inches in diameter, and of any length up to 9 inches. The thickness of the walls of the tubes ranges from 0.005 inch to 0.010 inch, varying with the size of the tube. If desired, raised lettering may be produced upon the shoulder of the tube. The opening in the top of the tube may be of any size, either round or oblong in shape.

The cold extrusion of collapsible tin tubes is totally different from the hot extrusion process for solid shapes described in Chapter I, and it is just the reverse of the cold tubular process described in Chapter II. The extrusion of tin, however, is much more easily accomplished than the extrusion of copper and brass. Briefly stated, collapsible tin tubes are made by placing a round blank of tin in a die-cavity shaped like the head of the tube, and of the same internal diameter as the external diameter of the tube to be made. Then a punch, whose greatest diameter is the same as the inside diameter of the tube, comes down on the blank. It forces the metal into the bottom of the die, and squeezes the excess metal upward through the narrow annular opening between

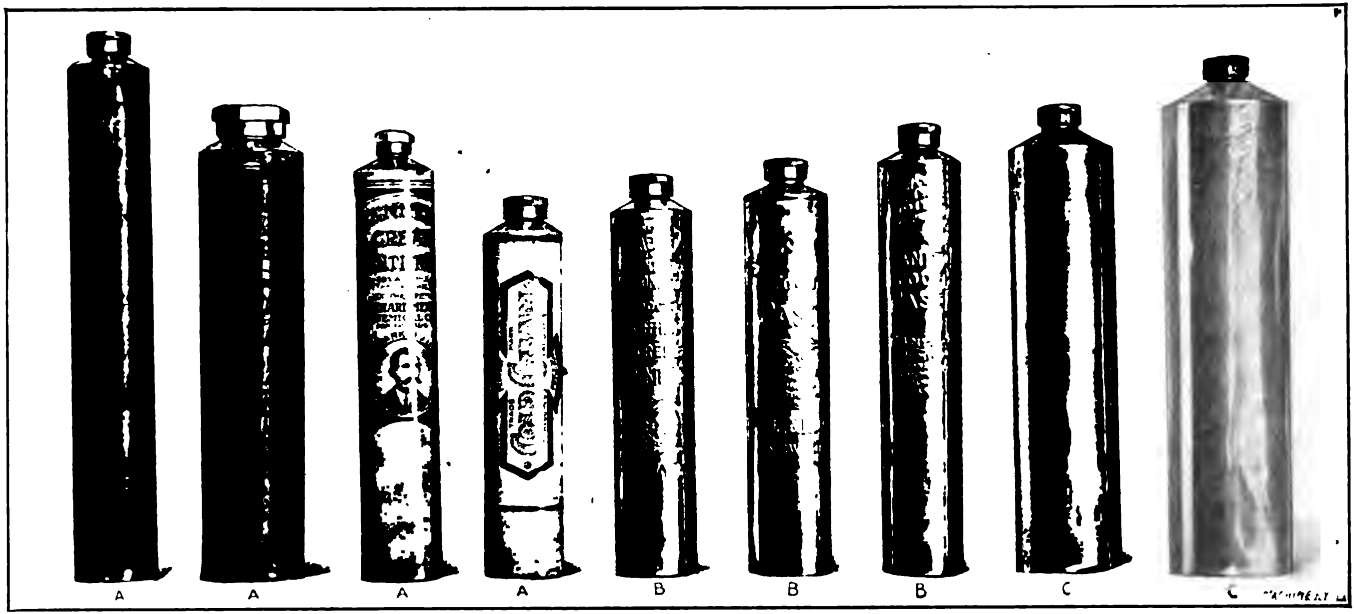


Fig. 39. Collapsible Tin Tubes made by Extrusion

the outside of the punch and the inside of the die-cavity. The tin literally "crawls" up the punch as it is extruded. When the punch ascends, it automatically swings outward to allow the operator to remove the completed tube, otherwise there would not be room to withdraw the tube from the punch. The threading of the head is done in another operation in this factory, although some companies make the die in halves, with half of the threaded section in each, necessitating the opening of the die after each stroke of the press.

The general method of making collapsible tubes is illustrated in Fig. 40, which shows the operator just completing a gross of 5-inch tubes, representing about fifteen minutes' work. This illustration also gives a good idea of the size of the press.

Preparing the Stock

The particular grade of tin used by this company for collapsible tube making comes from the Straits of Malacca and is known as Penang tin. It reaches the factory in the form of 130-pound pigs, and is then re-melted in the furnaces shown in Fig. 41 and cast in slabs weighing nine pounds each. These slabs are about six inches wide, fifteen inches long and one-half inch thick.

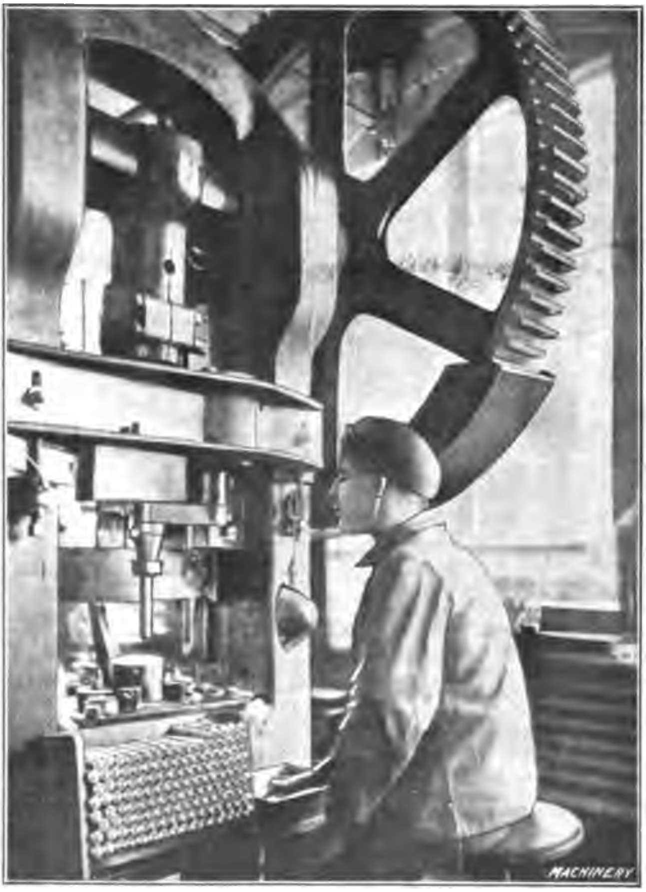


Fig. 40. Making Collapsible Tubes at the Rate of 600 per Hour

The slabs are taken to a pair of rolls and reduced to a thickness ranging from 0.110 to 0.220 inch, varying with the length of tube that is to be made. For a five-inch tube, the metal is rolled to 0.190 inch. The next operation consists in blanking the disks for the tubes. These disks, three of which appear at *P*, Fig. 42, are cut to the same diameter as the diameter of the tube that is to be made, and in blanking they are slightly "crowned" to conform to the inclined shoulder of the tube. This crowning is accomplished by merely chamfering the end of the blanking punch to the proper bevel; the die is perfectly flat. The blanking press is equipped with a roll-feed, and the rolls are knurled, so as to grip the sheets firmly. In Fig. 41 may be seen some of the sheets from which blanks have been cut, and which are sent back to the melting room for re-casting into slabs.

The Extrusion Presses

The operation of extruding collapsible tubes and the presses used are without doubt the most interesting features of the work. In Fig. 45 the details of the press and dies are well illustrated. For the large tubes, one-inch diameter and over, the E. W. Bliss Co.'s No. 63 press is used, and Figs. 45 and 46 show representative Bliss presses for making collapsible tubes and their caps. The No. 63 press is rated as a five-ton press, and its chief point of distinction, aside from its powerful construction, is its peculiar punch action, which will be described later. Referring to Fig. 45, *D* shows the die-shoe held to the bolster *E*, which latter is bolted to the bed of the press; *F* shows the end of the knock-out rod operated by lever *G*. The punch *H* is held in the arm *I*, which turns upon shaft *J*. Front plate *K* is adjustable, and its inner side is recessed for the cam that swings the punch-arm and punch away from the die. As the ram descends, this arm slowly swings so as to bring the punch in alignment with the die. It reaches the point of alignment just before the end of the stroke, so that at the time the end of the punch strikes the blank, the punch descends vertically. In Fig. 40 the arm has just started to swing outward on the upward stroke, and in Fig. 45 the arm is shown at the end of its outward swing, giving the operator ample room to withdraw the tube from the punch. Knock-out rod *F* frees the end of the tube from the die, allowing the tube to remain on the punch as it ascends.

Fig. 41. Furnaces where the Tin Ingots are cast into Nine-pound Slabs

In operating an extrusion press of this character, the operator places

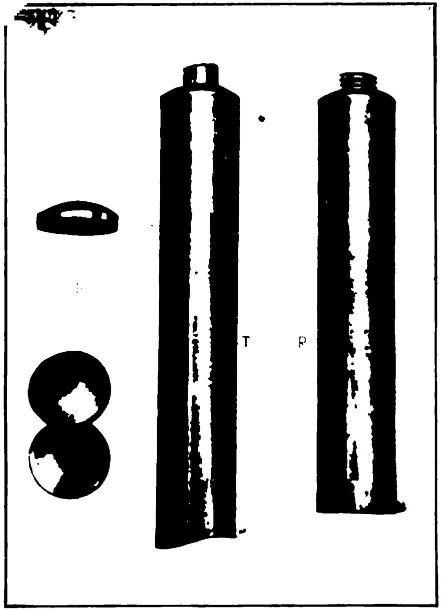


Fig. 42. The Three Operations in making a Collapsible Tube

Fig. 43. Punch and Die in Position in Press

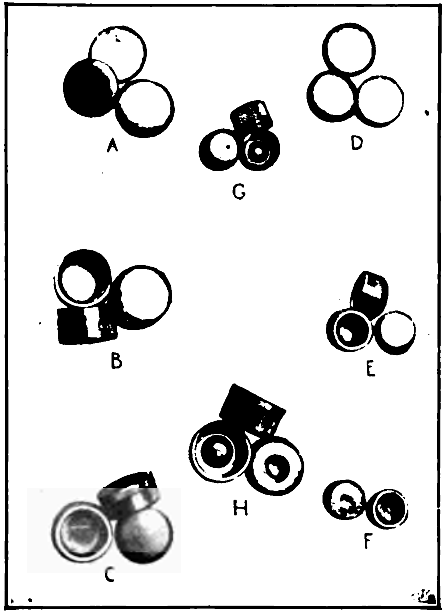


Fig. 44. Caps of Different Sizes and Styles at Various Stages of Competion

the blanks in the die with his right hand and removes the tubes from the punch with his left hand. The speed with which the metal "crawls" up the punch is surprising, but it must be remembered that the extrusion of a five-inch tube must take place while the punch is descending the last one-eighth inch. The operator is obliged to wear a glove upon his left hand on account of the heat imparted to the tube by the extrusion. A skilled operator is able to "catch" nearly every stroke of the press. When making these 1-inch by 5-inch tubes he will turn out 600 tubes per hour, and on the smaller tubes, ½-inch by 2½-inch, using a smaller press of the same type, the average production is 1500 tubes per hour.

Dies for Extruding Collapsible Tubes

Figs. 43 and 47 illustrate the parts of the dies and punches. Fig. 43 shows a close view of the tools in the press and Fig. 47 shows the tools as they appear out of the press. At *D* is shown the die-shoe, held to the press by the two ears shown in Fig. 47, and adjusted laterally by the four screws *L* indicated in Fig. 43. Within this die-shoe rests the die-ring *M*, made of tool steel and carefully hardened and tempered. This ring acts as a support to strengthen the die *N* shown within the ring; this die is also separately shown at the front of Fig. 47.

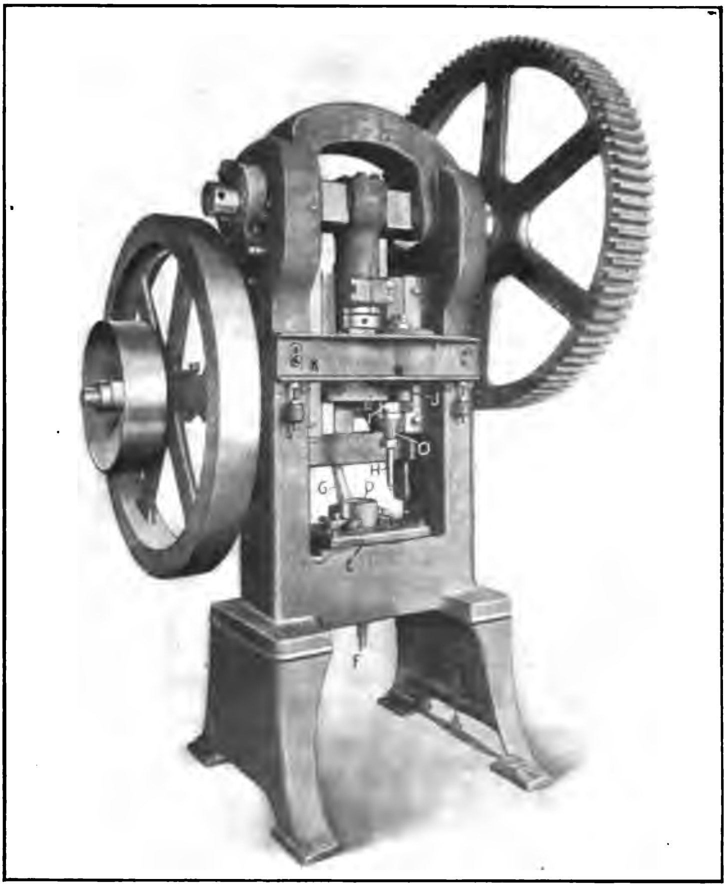


Fig. 45. Details of Arrangement of Extrusion Press

The die *N* is made of the best tool steel and its cavity is made just the size and shape of the outside of the head of the tube, except that the hole that sizes the neck extends clear through this die to admit the knock-out. Thus the knock-out is employed to form the bottom of the die as well as to eject the finished tube. If the shoulders of the tubes require lettering, a hob is made with the lettering raised. By placing this hob in the die-cavity, the letters are all stamped into the die at the same time. A collapsible tube die must be very smooth and highly polished in order that the metal will flow easily and take on a bright finish. This polishing is started with fine emery and oil and the final high polish is obtained with crocus and oil. The final polishing must be done after the die has been hardened and tempered to a faint straw color.

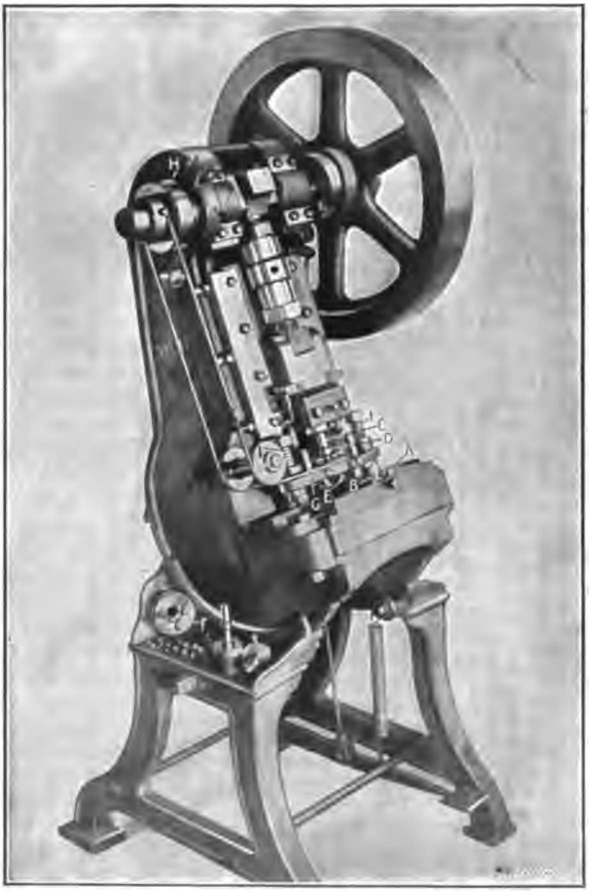


Fig. 46. Bliss Cap-forming Press with Unscrewing Attachment

The punch used in extruding collapsible tubes has several distinctive features that are peculiar to this line of work. Two of these punches are shown at *H* in Fig. 47. The working part of the punch is made about one inch longer than the tube that is to be produced, and two inches additional length is left for the shank. The shank of the punch is held in the punch-holder *O* by tightening the nut upon the tapered sleeve. The part of the punch that does the actual work is the tip end, having the largest diameter. To illustrate this more clearly, Fig. 48 shows two collapsible tube punches and dies; in one case the blank is shown in position in the dies, and in the other the result of the operation is indicated. From these it will be seen that the long pilot forms the hole at the shoulder and outlet. As the pressure upon the blank is increased, the recess in the die becomes filled with metal and the excess metal is squeezed up past the end of the rib on the punch. As the pressure is continued, the shoulder of the tube constantly becomes thinner; the displaced metal is forced into the walls of the tube, thus increasing its length. It is obvious that after

Fig. 47. The Press Tools used in Collapsible Tube Making

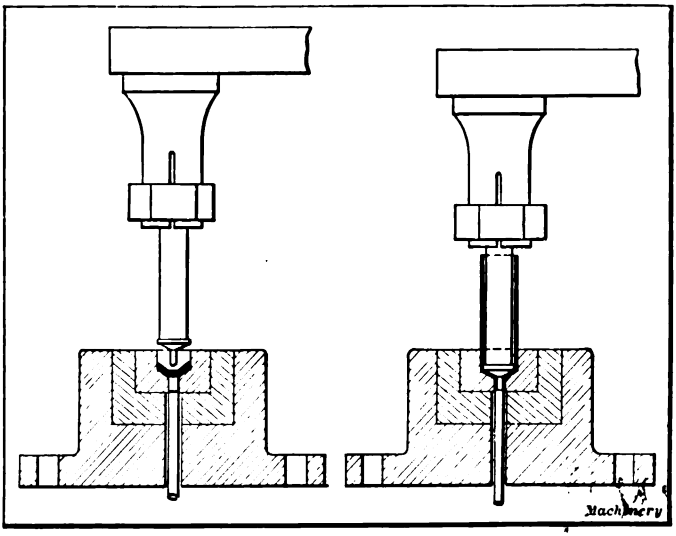


Fig. 48. Principle of Making a Collapsible Tube

squeezed past the ribbed end of the punch, its upper part of the punch is considerably smaller inside of the tube. For a one-inch tube, the die inch; the ribbed end of the punch would measure nd the body of the punch would be approximately eter. The punches are made of Jessops steel, hard-mper drawn to a light straw color, except the ch is drawn very much lower. The punch-holder *O* the swinging arm *I* shown in Fig. 45.

Fig. 49. Cap-blanking and Cap-making Presses

Trimming the Tubes

When the tubes come from the extrusion presses they appear as shown at *T* in Fig. 42. As will be noticed, the opening in the head is not cut through, nor is the head threaded. Better results are obtained by cutting the thread at the time the tube is trimmed. The trimming and threading is done in tube trimming and threading machines of a type designed especially for the work and patented by this company. At *R* in Fig. 42 the tube is shown completed.

Cap-making

The caps for collapsible tubes are made in an entirely different manner from the tubes, although the blanking and finishing operations are very much the same as those employed in the tube making. The metal for the caps for 5-inch tubes is rolled to a thickness of 0.140 inch; the blanks are cut ½ inch in diameter, and the punchings are not crowned as were the tube blanks. In the background of Fig. 49 may be seen a cap-blanking press, while in the foreground are shown the working parts of two cap-forming presses.

Forming the Caps

The operation of forming the caps is an interesting piece of press-work, and the principles should be applicable to other lines of manufacturing. By referring to Fig. 46, the operation of the tools may be clearly followed. The die is shown at *A*, and upon its top surface there is a slide *B* that facilitates the feeding of the blanks to the working part of the die, without danger to the operator's fingers. The punch *C* has its tip end threaded with the same size thread as that on the tube that the cap is to be used with. The die-cavity is of the same diameter as the outside of the cap to be formed. Thus, when the punch strikes the blank, the tin is "crowded" around the sides of the punch, being confined on the outside by the limits of the die-cavity. This operation wedges the blank tightly into the die-cavity, but as the metal is just as tightly pressed into the threads upon the punch, the cap is readily withdrawn when the punch ascends.

The manner in which the cap is removed from the threaded punch is of interest. As the punch rises from the die, a beveled shoulder *D*, on the upper part of the punch body, comes into contact with the ends of three set-screws, located at the upper ends of the gripping fingers *E*. As these fingers are centrally hinged, the effect of this contact of the bevel-edged shoulder against the set-screws on the upper ends of the gripping fingers is to throw the tips of the fingers together, causing them to grip the cap as it rises on the punch. These gripping fingers are pivoted in a circular plate that is fitted to a bearing in stripping plate *G*. One of these circular plates, of the two-finger style, is shown at *F* at the side of the press. By means of a pulley *H* on the driving shaft, run independently from above, so as to make possible a higher speed, the gripping finger plate is kept constantly revolving. Thus, as soon as the cap is gripped by the fingers, it is rapidly unscrewed from the punch. During this operation, the punch is rising, and in order that the cap will not be pulled away from the gripping fingers, the stripping plate *G* that supports this mechanism is arranged to slide upward upon pins *I*, thus keeping pace with the ascending punch. When the cap has been unscrewed, the punch continues to rise until the set-screws slide off the shoulder at the bottom, thus releasing the fingers and allowing the cap to slide into a box at the rear of the press. Some caps have a monogram embossed upon the top; this part of the work is easily included in the forming operation by engraving the design in the bottom of the die.

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