REPORT
ON THE
MANUFACTURE OF GLASS

1883

REPORT

ON THE

MANUFACTURE OF GLASS.

BY

JOS. D. WEEKS,
SPECIAL AGENT.

NEW YORK:
DAVID WILLIAMS.
1883.

TABLE OF CONTENTS.

	Page.
LETTER OF TRANSMITTAL	ix
CHAPTER I.	
STATISTICS	1–18
Scope of the report	1
Classification of glass in the tables	1
Summary of statistics for 1880	1
Comparison with previous censuses	2
Works idle in the census year	2
Works building in the census year	3
Establishments in which glass was made in the census year	3
Capital	3
Furnaces	3
The plant of factories	4
Employés	5
Wages paid	6
Intervals of payment	8
Methods of payment	8
Product	9
Materials	9
Relative productive rank of the states	9
Production of plate-glass	10
Production of window-glass	10
Production of glassware	10
Production of green glass	11
Localities in which glass was produced	11
Table I.—The plate-glass works of the United States at the census of 1880	11
Table II.—The window-glass works of the United States at the census of 1880	12
Table III.—The glassware works of the United States at the census of 1880	12
Table IV.—The green-glass works of the United States at the census of 1880	12
Table V.—Glass works idle and building in the United States at the census of 1880	13
Table VI.—Consolidated statistics of all the glass works of the United States at the census of 1880, by states	15
Table VII.—Consolidated statistics of all the glass works of the United States at the census of 1880, by states and counties	15–17
Table VIII.—Consolidated statistics of the materials used in the manufacture of glass, as reported at the census of 1880	18
CHAPTER II.	
GLASS: ITS COMPOSITION, CLASSIFICATION, AND PROPERTIES	19–23
Difficulty of definition	19
Glass, chemical and commercial	19
Chief constituents	19
Variability of composition	19
Approximate composition	19
Difficulty of classification chemically	19
Difficulty of classification commercially	20
Classification	20
1. Plate-glass	20
2. Window-glass	20
3. Flint glass	20
4. Green glass	21
Specific gravity	21
Conductivity and tension	21
Tensile and crushing strength	21
Devitrification	22
Devitrification in its relation to manipulation	22
Other properties	22
Extent of the uses of glass	22
Analysis of glass	22, 23

CHAPTER III.

	Page.
SAND	24–30
Different proportions of silica in glass	24
Silica in different kinds of glass	24
Hardness	24
Forms of silica used	24
Uses of the different grades	24
Impurities and their removal	24
Use of arsenic	25
Tests of sand	25
Analysis and color not always indicative of the quality of sand	25
Mode of occurrence of sand	25
Sea or river sand	25
Importance of good sand	25
Sand from the river Belus	25
Other river and sea sands	26
Early use of flint and quartz	26
Superiority of American sand	26
English sand	26
Sand for English plate-, window-, and flint-glass	27
Sand for bottle-glass	27
French sand	27
Belgian sand	27
German sand	27
Best German sands	27
Use of alkaline rocks for bottle-glass	28
Austrian sand	28
Sand for common Austrian glass	28
Swedish sand	28
Quality of American sand	28
New England sand	29
New Jersey sand	29
Maryland sand	29
Sand for the Pittsburgh and Wheeling glass houses	29
Illinois sand	29
Missouri sand	29
Extent and locality of other American sands	29
Analysis of glass sand	29, 30

CHAPTER IV.

ALKALIES AND OTHER MATERIALS	30–34
Chief bases used in glass-making	30
Ancient glass a soda glass and perishable	30
Sources of supply of soda for ancient glass houses	30
Modern sources of soda	31
Leblanc's discovery of soda-ash	31
Use of salt-cake	31
Source of supply of soda	31
The ammonia process	31
Manufacture of soda-ash and salt-cake in the United States	32
Use of common salt	32
Nitrate of soda	32
Potash	32
Lime	32
Use of lime a modern discovery	32
Sources of supply	33
Lead	33
Lead glass, where made	33
Other ingredients	33

CHAPTER V.

GLASS FURNACES AND POTS	34–41
Early furnaces and glass houses	34
Furnaces in Agricola's time	34
Modern furnaces	35
Fuel used	36
Gas furnaces	36
The Siemens' furnace	36
Use of Siemens' furnaces in the United States	37

Page.

GLASS FURNACES AND POTS—Continued.
Compartment or tank furnaces ... 37
Pot-clay ... 39
Composition of pot-clay ... 40
Manufacture of pots ... 40
The setting of the pots ... 41
Life of pots ... 41
Size of pots ... 41
Shape of pots ... 41

CHAPTER VI.

MIXING, MELTING, FINING, AND FAULTS ... 41–45
Influences that determine the character of glass ... 41
Constituents of the batch ... 41
Proportion of materials used for plate-glass ... 42
Proportion of materials used in window-glass ... 42
Proportion of materials used for flint (lead) glass ... 42
Proportion of materials used for flint (lime) glass ... 42
Proportion of materials used for bottle-glass ... 43
Mixing the batch ... 43
Fritting ... 43
Charging ... 43
Melting ... 43
Fusion and fining ... 43
Time required to melt and fine ... 44
Cold stoking ... 44
Loss in melting ... 44
Faults in the metal ... 44

CHAPTER VII.

GLASS-WORKING ... 45–55
Methods of glass-working ... 45
Plate-glass ... 45
Casting and annealing ... 45
Rough plate ... 46
Grinding, smoothing, and polishing ... 46
Rolled plate ... 46
Optical glass ... 46
Strass ... 46
Pressed glass ... 47
Improvements in the pressing process ... 47
Mold-marks ... 47
Molding articles with lateral designs ... 47
Molding curved hollow articles, lamps, goblets, and taper articles ... 48
Molding mouths, necks, etc ... 48
Handles ... 48
Lamp bodies with feet and screw coupling ... 48
Lamps with metallic pegs or collars ... 48
Insulators ... 48
Balls ... 48
Movable-bottom molds ... 48
Battery jars ... 48
Molds for flaring articles ... 49
Molding articles with bulging bodies ... 49
Molding articles with openings ... 49
Spring snaps for fire-polishing ... 49
Cooling heated molds by air-blast ... 49
Application of steam to glass-pressing ... 49
Application of compressed air ... 49
Inclosed air-bubbles ... 50
Blowing ... 50
Window-glass ... 50
Flattening ... 50
Defects of window-glass ... 50
Size of window-glass ... 51
Blown and patent plate ... 51
Blowing flint ware ... 51
Flint-glass cutting, engraving, and etching ... 51
Blowing in molds ... 51

Page.

GLASS-WORKING—Continued.
Fashioning art-glass 52
The Portland vase 52
Tempered, hardened, or toughened glass 52
Bastie's tempered glass 53
Difficulties of the process 53
Siemens' tempered glass 53
Tests of the Siemens' glass 54
Uses of Siemens' glass 54
Cost of Siemens' glass 54
Glass from blast-furnace slag 54
Relative composition of glass and slag 54
Additions to slag in the manufacture of glass 55
Use of hot slag 55
Color of slag glass 55

CHAPTER VIII.

HISTORY OF SOME PROCESSES OF GLASS-MAKING 56–58
Vases, cups, and other hollow ware 57
Lead glass 57
The use of molds 57
Pressed glass 58
Ancient pressed glass 58
History of the invention 58

CHAPTER IX.

ANCIENT GLASS 59–64
Discovery of glass 59
Probable method of discovery 59
Egyptian glass 59
Processes of Egyptian glass houses and character of the glass 60
Composition of Egyptian glass 60
Phœnician glass 60
Character of Phœnician glass and processes employed 61
Late Phœnician glass manufacture 61
Glass-making in the other ancient monarchies 61
Assyrian glass 61
Greek glass 61
Carthaginian glass 61
Etruscan glass 61
Introduction of glass-making into Rome 62
Amount and variety of the production of Roman glass houses 62
Later glass-making 62
Byzantine glass 62
Early glass-making in other countries 63
Glass in France 63
Spain 63
Germany 63
British islands 64
Persia 64
China 64
India 64

CHAPTER X.

MODERN GLASS 64–69
Modern glass-making dates from Venice 64
Influence of barbarians upon glass-making 65
Revival of art influenced glass-making 65
Early Venetian glass-making 65
Extent of the industry at Venice 65
Condition and restriction of workmen 65
Glass in the dark ages 66
France 66
Spain 66
Germany 67
Bohemia 67
The Low Countries 68
British islands 68
Influence of Venice on England 68
Russia 68

CHAPTER XI.

	Page.
THE PRESENT CONDITION OF GLASS-MAKING IN EUROPE	69–77
Chief glass-making countries of Europe	69
Each country has a specialty	69
England's specialties	69
France's specialties	69
Belgium's specialty	69
Germany's specialty	70
Austria-Hungary's specialties	70
Venetian glass	70
Glass in other European countries	70
Plate-glass factories in Europe	70
Production of plate-glass	70
Plate-glass	71
Prices of plate-glass in Europe	71
Window-glass in Europe	71
Flint- and bottle-glass	72
Manufacture of glass in Great Britain	72
Chief localities	72
Decline of the English glass industry	72
Imports of glass	72
Exports of glass	72
Manufacture of glass in France	73
Manufacture of glass in Belgium	73
Manufacture of glass in Germany	74
Furnaces and fuel	74
Manufacture of glass in Austria-Hungary	74
Manufacture of glass in Italy	76
Manufacture of glass in Russia	76
Manufacture of glass in Sweden	76
Manufacture of glass in Norway	77
Manufacture of glass in Spain	77
Glass in Holland	77
Glass in Portugal	77

CHAPTER XII.

HISTORY OF GLASS-MAKING IN THE UNITED STATES	77–101
Glass-making in Virginia and West Virginia	77
Glass-making in Pennsylvania	79
Glass-making in Massachusetts	88
Glass-making in New Hampshire	91
Glass-making in New York	93
Glass-making in Connecticut	94
Glass-making in Maryland	95
Glass-making in New Jersey	96
Glass-making in Ohio	97
Glass-making in Missouri	97
Glass-making in other states	97
History of the manufacture of plate-glass in the United States	98
Imports of glass into the United States	99
Table showing imports of glass into the United States in the years 1876 to 1880	100, 101

LETTER OF TRANSMITTAL.

PITTSBURGH, PA., *March* 21, 1883.

Hon. C. W. SEATON,

Superintendent of Census.

SIR: I have the honor to transmit herewith my final report on the manufacture of glass.

Referring to my preliminary report, published in Census Bulletin No. 118, under date of March 30, 1881, I beg to say that further investigation disclosed the fact that the returns received up to that time were somewhat imperfect, and the statistics given in this report have been amended in accordance with the later returns received.

Most of the glass-makers of the country appreciated the importance of a full and complete report, many of them not only forwarding their reports promptly and with full details, but lending me every assistance in their power in completing the history of glass in this country, which is herewith attached.

In undertaking the collection of these returns it was discovered that no directory of the glass works of the United States existed. While attempts had been made in recent years to prepare such a directory, they had been abandoned by those undertaking the work, and it was believed to be impossible to make a complete directory. However, with the assistance of some gentlemen well informed with the glass industry, such a directory, though imperfect, was prepared. Copies were sent to every glass works in the United States and to every one who was supposed to have any information regarding glass works, and as a result of this a directory, believed to be correct at its date, was prepared. Schedules were sent out to the names in this list, and the result is the present report.

This report covers the statistics of those establishments only that made glass from the sand, or works having furnaces and pots in which the glass was melted and made into the various forms of plate- and window-glass, glassware, and green glass. It does not include the statistics of any staining, cutting, engraving, drawing, or spinning glass, or any of the other processes of reworking glass, except in the case of establishments that cut and engrave in connection with the manufacture of the glass from the sand. In a word, the report covers the manufacture, and not the reworking, of glass.

In addition to the statistics and history of glass-making in this country, such information as could be obtained regarding the statistics of this industry in Europe and a short sketch of its history, both ancient and modern, are appended. For the purpose of completeness I have also added some statements regarding the classification of glass, its properties, the materials used, furnaces and pots employed, and the various modes of glass-making, with some quite full statements regarding tempered and slag glass.

Particular attention has also been paid to statements showing the state of the art during the census year. While every point has not been covered—indeed it was not deemed wise to consider to any extent forms or varieties of glass other than the four kinds particularly reported upon—it is believed that the report will show with reasonable fullness the condition of glass-making at the close of the census year.

It seems hardly necessary to state that it is impossible to gather from the tables given in this report any statement, even an approximate one, of the amount of profit made by the manufacturers of glass in the census year. The tables show only the value of materials and wages and the cost of product. Materials and wages added

together and subtracted from product will not give profit, as, in addition to materials and wages, there is in the cost of an article a large number of contingent expenses, such as rent, insurance, taxes, interest, discount, expense of selling, office expenses, advertising, traveling, etc., all of which must be added to the value of materials and wages before the difference between this sum and the selling price of the product will show the profit.

In forwarding this report I desire to express my great obligations to the large number of gentlemen in various parts of this and other countries who have so kindly assisted me in the preparation of this report. It is impossible to name them all, but special thanks are due to Mr. L. Lobmeyer, of Vienna, Austria; Mr. Julius Fahdt, of Dresden, Germany; Mr. Henry Chance and Mr. Thomas Webb, of England; Hon. John F. Bodine, of Williamstown, New Jersey; Hon. W. C. De Pauw, of New Albany, Indiana; Mr. J. K. Cummings, of Saint Louis, Missouri; Mr. Charles Colné, formerly of Washington, District of Columbia, who reported on glass for the Paris Exposition; Mr. Isaac Craig and Mr. James B. Lyon, of Pittsburgh, Pennsylvania; and very especially to Mr. Thomas Gaffield, of Boston, to whose intelligent assistance and ready and free loan of books this report is indebted for much of its exactness and fullness. I also have made free use of a number of works on glass. In important quotations credit is given in the text, but in many cases it has not been deemed necessary, and I desire to acknowledge here my indebtedness to the *Encyclopædia Britanniea*, Pellatt's *Curiosities of Glass Making*, Nesbitt's *Glass*, Bontemp's *Guide du Verrier*, Lardner's *Cabinet Cyclopedia*, Jarves' *Reminiscences of Glass Making*, Blancourt's *Art of Glass*, Sauzay's *Wonders of Glass Making in All Ages*, the several pamphlets of Mr. Chance referred to in the text, Gaffield's *Action of Sunlight on Glass*, and *Glass in the Old World*, by M. A. Wallace-Dunlop, and for the history, in this country especially, to Bishop's *History of American Manufactures*. I should also fail in what was justly their due did I not acknowledge my indebtedness to Miss C. V. Young and Mr. S. C. Armstrong, the chief assistants in my office, to whose patient endeavors and constant care I am under so many obligations.

Very respectfully,

JOS. D. WEEKS,
Special Agent.

CHAPTER I.—STATISTICS.

SCOPE OF THE REPORT.

The investigations which form the basis of this report were confined exclusively to those works which manufacture glass from the crude material or make the "metal", as it is termed, and do not include any statistics of those establishments in which manufactured glass is a raw material; or, in other words, this report only covers establishments in which glass is made, not those in which it is reworked, and does not, therefore, include statistics of manufactories of painted or stained glass, mirrors, chemists' ware, etc. In cases, however, where the glass is reworked in the same establishment in which it is made, as where rough plate is polished or glassware is engraved or decorated, the tables include the statistics of such reworking, it being regarded as only a part of the manufacture of glass in these works, or as having such a close relation with its manufacture as to make it practically impossible to separate the statistics of the crude from the reworked glass.

CLASSIFICATION OF GLASS IN THE TABLES.

The classification adopted in the collection of the statistics is not to be regarded as a complete classification of glass, but as one made necessary by the conditions of its manufacture in this country. This classification is as follows:

I. Plate-glass factories, including those making rough, ribbed, or polished plate for window-glass, mirrors, skylights, partitions, etc. This class also includes rolled cathedral plate.

II. Window-glass factories, including those manufacturing cylinder or sheet window-glass.

III. Glassware factories, including those manufacturing flint (lead or lime) glass, both blown and pressed, lamp-chimneys, and flint druggists' and chemists' ware.

IV. Green glass factories, including those producing green, black, amber, etc., bottles, fruit-jars, carboys, demijohns, and other hollow ware, and green druggists' ware.

If it had been possible to make a still further subdivision of these classes, it would have been done; but after very earnest efforts it was found impracticable, and the attempt was abandoned.

Under each of these classes three tabulations have been made.

A.—Including all establishments in existence in the census year, whether active, idle, or building.

B.—Including all furnaces that were idle during the entire census year. All the furnaces in this table are included in Table V. The amount of capital given, however, is only that of factories no part of which was in operation during the census year. If a glass works having two furnaces run one, the other being idle, the latter would appear in this table as an idle furnace, and no capital would be set against it.

C.—Including all furnaces that were building and were not completed during the census year. The amount of capital given in this table is that of such establishments as are entirely new, and includes no statement of capital invested in such new furnaces as are additions to old works.

SUMMARY OF STATISTICS FOR 1880.

The complete statistical results of the census of 1880 will be found in the accompanying tables. For convenience of reference, and to give a connected statement of the results of the present census, as also to compare the same as far as possible with those of previous censuses, these results have been summarized. The condensed aggregate statements for all classes of glass included in this report are as follows:

Total number of establishments		211
Total capital invested		$19,844,699
Total number of furnaces		348
Total number of pots in same		2,982
Males above 16 years	17,778	
Females above 15 years	741	
Children and youths	5,658	
		24,177
Total amount paid in wages during the year		$9,144,100
Total value of materials		8,028,621
Total value of product		21,154,571

COMPARISON WITH PREVIOUS CENSUSES.

It is impossible to make a comparison between the results given above and those for the earlier censuses. The classification differs materially from that adopted in the present investigation, so that in any event it would be impracticable to make a comparison by classes. In addition to this, however, in the statistics of glass in previous censuses there are in some cases gross omissions, (*a*) while in others the statistics of glass-cutting and decorating establishments are summarized with those making the metal, so that any comparison would be of but little value. It is possible, however, to make an approximate comparison of the aggregate of all classes between the present census and that of 1870. Assuming that the classes "plate-glass", "glassware not specified," and "window-glass" of the Ninth Census include the same establishments as are classified in this report as plate- and window-glass, glassware, and green-glass factories, the result is as follows:

	1880.	1870.
Number of establishments	211	154
Employés	24,177	15,367
Capital	$19,814,699	$13,824,142
Wages paid	9,144,100	7,589,110
Amount of materials used	8,028,621	5,901,365
Value of product	21,154,571	18,470,507

It will be seen that the increase in the number of establishments in ten years is 37 per cent.; in employés, 57 per cent.; in capital invested, 44 per cent.; in wages paid, 20 per cent.; in materials used, 36 per cent.; and in value of product, 15 per cent. It will also be noted that the percentage of increase in all of the details is greater than in the value of the product, that being hardly 15 per cent., while the increase in the others ranges from 20 to 57 per cent.

WORKS IDLE IN THE CENSUS YEAR.

From the returns received it appears that 34 establishments were idle, in whole or in part, during the entire census year. The capital invested in the works that were idle entirely was $591,000, and the number of furnaces idle was 41. The following table gives the statistics of these idle establishments for each of the four kinds of glass:

Classes.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Plate-glass	1	.....	.....	.....	1	1	8
Window-glass	10	$90,000	.....	.....	10	10	82
Glassware	15	267,000	3	.....	19	22	201
Green glass	8	234,000	1	.....	7	8	58
Total	34	591,000	4	.....	37	41	349

Some of the establishments shown in this table at which furnaces were idle also had furnaces that were in operation, and, as is before remarked, the capital of only those establishments at which no glass was made is included.

Of the 58 window-glass factories of the country, 6, with 6 furnaces, containing 48 pots, were entirely idle during the census year. Four works were also in part idle, and in these were 4 furnaces, with 34 pots, idle the entire year.

Of the 91 glassware factories, 9, with 13 furnaces and 109 pots, were entirely idle; and in factories that were operated in part, 9 furnaces, with 92 pots, were not run in the census year.

Of the 56 green-glass establishments, 8, with 8 furnaces and 58 pots, were entirely idle.

It has been almost impossible to determine in a few instances whether a glass factory should be regarded as dismantled or idle with the prospect of renewing operations. In such cases I have assumed that the owner knew the facts and have accepted his decision. Notwithstanding this, some furnaces reported as idle will probably never be in blast again, and should not have been reported at all.

a Seybert, in his *Statistical Annals of the United States*, Philadelphia, 1818, which summarizes and corrects the census of 1810, says, page 6, regarding the statistics of glass, that "returns for glass works for five states only are given, omitting Massachusetts, in which very extensive establishments existed, from which glass of a superior quality had long been exported to the other states".

WORKS BUILDING IN THE CENSUS YEAR.

The following table gives for each of the four kinds of glass the statistics of furnaces building and not completed in the census year:

Classes.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Plate-glass	1	.....	1	.....	.....	1	16
Window-glass	4	$80,000	.....	.....	4	4	36
Glassware	12	235,000	4	.....	8	12	129
Green glass	5	54,100	.....	.....	5	5	31
Total	22	369,100	5	.....	17	22	212

From the returns received it appears that furnaces were building at 22 establishments, 22 furnaces, with 212 pots, being in course of erection. As it will be noticed, 5 of these were gas furnaces, which would equal a little less than one-fourth of all the gas furnaces built or building in the census year. Of those building of all kinds, 1, with 16 pots, was building in a plate-glass works, not completed; 4 were in window-glass factories; 2, with 20 pots, were in new establishments, and 2, with 16 pots, additions to old factories; 8, with 8 furnaces and 84 pots, were entirely new glassware establishments, while 4 furnaces, with 45 pots, were built at two old works. Three entirely new green-glass works, with 3 furnaces and 16 pots, were built, and 2 furnaces, with 15 pots, were built at two old green-glass factories.

ESTABLISHMENTS IN WHICH GLASS WAS MADE IN THE CENSUS YEAR.

Consolidating these tables of idle and building, and making the necessary deductions from those giving the aggregate statistics of the production of the several classes, we have the following statement regarding the statistics of the works at which glass was made during the census year:

Classes.	No. of establishments.	Capital.	No. of furnaces.	Total number of pots.
Plate-glass	5	$2,587,000	8	84
Window-glass	49	4,703,155	76	665
Glassware	73	6,907,278	130	1,247
Green glass	42	4,607,166	74	443
Total	169	18,804,599	288	2,439

The number of hands employed and the value of materials and wages paid, as well as the total of the product, would, of course, be the same as the totals given under the heads of the different kinds of glass in the general tables, as an idle or building works would detract nothing from these items.

Regarding the table on plate-glass, it should be noted that of the 6 establishments making plate-glass 5 produced rough plate, 1 rolled cathedral plate; and 3 of the 5 producing rough plate polished the larger part of their product, the 2 others making no polished plate, though 1 had the machinery necessary to the work.

The column headed "rough, sold", under "plate-glass", gives the amount that was sold or entered into consumption without being polished, or as rough, ribbed, and cathedral plate. It should also be noted that while the first column under "product" gives the total amount of plate-glass cast at the several works, the column of "value" gives only the value of that part that was polished and what was sold as rough plate, the balance being in process of manufacture.

CAPITAL.

The total capital invested in the manufacture of all kinds of glass is $19,844,699. Of this, $2,587,000, or 13 per cent., is invested in plate-glass; $4,953,155, or 25 per cent., in window-glass; $7,409,278, or 37 per cent., in glassware; and $4,895,266, or 25 per cent., in green glass.

The state having the largest amount of capital, as well as the largest number of establishments, is Pennsylvania, which has $7,639,706, or 38 per cent. of the whole. This is followed by New Jersey, with $2,728,021, or a little less than 14 per cent. of the whole. New Jersey is followed, in their order, rating them by capital invested, by New York, Indiana, Missouri, Ohio, Massachusetts, Kentucky, West Virginia, Illinois, Maryland, Connecticut, California, Michigan, and New Hampshire, while the Mississippi works, which was building, and the District of Columbia works, which was idle, both ranked the same.

FURNACES.

The total number of furnaces in the different works was 348, containing 2,982 pots. Of these, 10 furnaces, with 116 pots, were in plate-glass works; 88 furnaces, with 767 pots, were in window-glass works; 162 furnaces, with 1,559 pots, were in glassware works; and 88 furnaces, with 540 pots, in green-glass works. Of the total number of

furnaces, 21 are reported as gas, 5 as tank, and 322 as all other kinds, these other kinds being, as a rule, the ordinary direct-firing furnace. Of the 21 gas furnaces built and building, 3 are reported as Siemens, 6 as Gill, 6 as Nicholson, 2 as Burgin, the balance being of various kinds. Of the tank furnaces, 1 was a Siemens furnace, built, and the other 4 were of various kinds, the inventions generally of the parties operating them.

The fuel used in glass-making in the United States is chiefly coal, though at all works more or less wood is used for various purposes, as also considerable petroleum and benzine for fire-polishing, annealing, and other like operations. One or two furnaces, however, are reported as being wood furnaces. Some are coal furnaces, using blast, and some few, instead of being direct-firing, use a patent method of charging the coal to the fire-grate.

THE PLANT OF FACTORIES.

Under this head are included statements showing that part of the plant about a glass works not included under the head of furnaces and pots. The following tables show the statistics of the different factories:

TABLE SHOWING THE PLANT OF PLATE-GLASS FACTORIES IN THE UNITED STATES.

Casting tables	16
Annealing ovens	186
Grinding-machines	26
Smoothing-machines	44
Polishing-machines	70
Grinding-mills	10
Steam-engines	25
Horse-power	1,570
Boilers	24
Horses	11
Mules	9
Wagons	11
Carts	7
Drays	5

TABLE SHOWING THE PLANT OF WINDOW-GLASS FACTORIES IN THE UNITED STATES.

Flattening ovens	68
Monkey ovens	16
Clay-grinding mills	52
Steam-engines	34
Horse-power	577
Boilers	35
Horses	156
Mules	56
Wagons	120
Carts	50
Drays	21

TABLE SHOWING THE PLANT OF GLASSWARE FACTORIES IN THE UNITED STATES.

Glory-holes	358
Presses	522
Annealing ovens	479
Shops worked	1,353
Grinding- and engraving-machines	716
Clay-grinding mills	63
Steam-engines	85
Horse-power	2,327
Boilers	121
Horses	162
Mules	64
Wagons	124
Carts	66
Drays	29

TABLE SHOWING THE PLANT OF GREEN-GLASS FACTORIES IN THE UNITED STATES.

Glory-holes	79
Annealing ovens	1,039
Grinding-machines	44
Clay-grinding mills	46
Steam-engines	55
Horse-power	1,198
Boilers	58
Horses	189
Mules	102
Wagons	152
Carts	64
Drays	30

TABLE SHOWING KINDS AND NUMBER OF MACHINES USED IN THE GLASS WORKS OF THE UNITED STATES.

Kind of glass.	Casting tables.	Grinding-machines.	Smoothing-machines.	Polishing-machines.	Grinding-mills.	Clay-grinding mills.	Grinding and engraving-machines.	Presses.	Grinding-machines.
Plate-glass	16	26	44	70	10	.....	.....	.....	.....
Window-glass	.....	.....	.....	.....	.....	52	.....	.....	.....
Glassware	.....	.....	.....	.....	.....	63	716	522	.....
Green glass	.....	.....	.....	.....	.....	46	.....	.....	44
Total	16	26	44	70	10	161	716	522	44

TABLE SHOWING KINDS AND NUMBER OF OVENS USED IN THE GLASS WORKS OF THE UNITED STATES.

Kinds of glass.	Flattening ovens.	Monkey ovens.	Annealing ovens.
Plate-glass	.....	.....	186
Window-glass	68	16	.....
Glassware	.....	.....	479
Green glass	.....	.....	1,039
Total	68	16	1,704

TABLE SHOWING POWER USED IN THE GLASS WORKS OF THE UNITED STATES.

Kinds of glass.	Steam-engines.	Horse-power.	Boilers.
Plate-glass	25	1,570	24
Window-glass	34	577	35
Glassware	85	2,327	121
Green glass	55	1,198	58
Total	199	5,672	238

TABLE SHOWING NUMBER AND KINDS OF DRAFT ANIMALS USED IN THE GLASS WORKS OF THE UNITED STATES.

Kinds of glass.	Horses.	Mules.
Plate-glass	11	9
Window-glass	136	56
Glassware	162	64
Green glass	189	102
Total	518	231

TABLE SHOWING NUMBER AND KIND OF VEHICLES USED IN THE GLASS WORKS OF THE UNITED STATES.

Kinds of glass.	Wagons.	Carts.	Drays.
Plate-glass	11	7	5
Window-glass	120	50	21
Glassware	124	66	29
Green glass	152	64	30
Total	407	187	85

EMPLOYÉS.

The total number of persons employed about the glass works of the United States in the census year was 24,177. Of these 17,778 were males above 16 years, 741 females above 15 years, 5,566 males under 16 years of age, and 92 females under 15 years of age. Many of the operations about a glass works, especially in the packing and the gathering of the glass, are of such character that they can be performed by women, children, and youths. This is especially true of glassware, and, as is shown by the tables, 513 of the 741 females above 15 years and 3,874 of the 5,658 children and youths are employed in glassware manufactories, the larger proportion of the balance being employed in the manufacture of green glass, in which many of the operations are analogous to those of glassware.

WAGES PAID.

The total amount of wages paid during the year to all classes of employés in the works was $9,144,100. As I have already stated in my "Report on Coke", any attempt to deduce the average daily earnings of each person employed from the figures given in the tables annexed would not only be useless, but the result obtained would convey a decidedly wrong impression. The total amount of wages paid, $9,144,100, divided by the total number of hands employed, 24,177, would give a quotient of $378. Though such a quotient is often regarded as the average yearly earnings of each employé, a little consideration will make it evident that it does not represent such earnings; that it really represents nothing but the result of the division of one number by another. The only circumstances under which a division of the total amount of wages received in any industry by the total number of men employed in that industry would be a correct statement of the earnings of the persons so employed are when the same number of men were employed during the whole year, and when, if the works were idle during any part of that year, the men were also idle, glass-making being their only occupation. It would also be necessary to know, in order that such an average might be a fair one, what the occasion of such idleness was—whether it was the fault of the manufacturer or of the men. In a word, the only way in which it would be possible to show what were the yearly earnings of each man at the glass works of the United States during the census year would be to ascertain directly from the books what each man received, and for such a statement there are no data.

A somewhat similar difficulty exists in any attempt to arrive at the average wages paid in the different classes of labor employed. This is a most difficult statement to make under any circumstances in this or in any other industry. It is very easy to give an average of the different rates of wages paid; but to get at the real average rates—that is, an average which shall consider not only the several rates, but the number of men employed at each rate, by a consideration of both of which the average rate can only be reached—is more difficult.

However, an endeavor has been made in the accompanying tables to arrive, as nearly as may be, at the range of wages paid the different classes of labor and the average wages; and if it is distinctly understood that this is only approximate, and does not claim to be the exact average wages of the different classes, no one need be led astray by the statement.

These tables show in the first column the classes of employés, in the second column the number of each class for which wages are given in the returns, in the third column the range of wages, or the highest and lowest wages paid the members of this class, and in the fourth column the average wages. This average is obtained by multiplying each rate of wages by the number of persons employed at that rate and dividing the sum of the products so obtained by the number of men employed, so that the average represents the real average wages of the different classes as returned:

RANGE AND AVERAGE RATES OF DAILY WAGES IN THE MANUFACTURE OF WINDOW-GLASS.

Classes.	Number.	Range.	Average.	Classes.	Number.	Range.	Average.
Managers	23	$1 16 to $6 00	$3 90	Cutters	144	$2 00 to $4 50	$3 14
Boss blowers	44	2 57 to 12 00	5 47	Packers:			
Blowers	424	2 18 to 12 00	5 30	16 years and upward	52	1 15 to 5 68	2 14
Gatherers or tending-boys:				Under 16 years	2	50	50
16 years and upward	424	1 76 to 6 00	2 72	Drivers	80	1 00 to 2 50	1 36
Under 16 years	34	20 to 39	35	Laborers	251	1 00 to 1 50	1 18
Master teasers	56	2 11 to 5 00	3 35	Box makers	26	75 to 1 75	1 31
Master teasers' helpers	55	1 17 to 2 50	1 83	Blacksmiths	13	1 17 to 2 50	1 95
Teasers	158	1 00 to 2 36	1 74	Engineers	5	1 50 to 3 15	1 83
Lime sifters	34	1 00 to 2 16⅔	1 70	Watchmen	5	1 00 to 1 50	1 23
Mixers	65	1 00 to 3 00	1 72	Assorters	5	2 00 to 3 00	2 40
Batch wheelers or fillers-in	55	1 00 to 2 00	1 75	Sawyers	2	1 12½ to 2 00	1 56
Coal wheelers	46	96 to 2 25	1 63	Clay grinders	2	1 00 to 1 46	1 23
Flatteners	109	2 50 to 5 77	3 82	Carpenters	6	1 75 to 1 80	1 78
Layers-out	67	77 to 2 25	1 80	Warehouse men	2	2 00 to 2 50	2 25
Layers-in	73	77 to 2 33⅓	1 61	Clerks	7	1 66 to 4 00	1 83
Leer tenders	71	96 to 2 26	1 64	Blow-furnace teasers	1	2 00	2 00
Roller-boys:				Masons	4	2 00	2 00
16 years and upward	70	38 to 1 50	78	Bookkeepers	1	4 00	4 00
Under 16 years	22	75 to 1 00	88	Pot-arch men	2	1 12½	1 12½
Pot makers	36	1 54 to 5 00	2 96	Teamsters	2	1 25	1 25
Clay trampers	89	1 00 to 2 60	1 25				
Boss cutters	22	2 88 to 7 00	4 21	Secretary	1	5 00	5 00

RANGE AND AVERAGE RATES OF DAILY WAGES IN THE MANUFACTURE OF GREEN GLASS.

Classes.	Number.	Range.	Average.	Classes.	Number.	Range.	Average.
Managers	21	$2 00 to $6 73	$4 74	Master teasers	32	$1 25 to $7 25	$2 33
Boss blowers	21	3 00 to 8 00	4 86	Fillers-in	61	1 00 to 2 00	1 51
Bottle blowers	515	2 65 to 5 50	3 94	Coal wheelers	30	1 00 to 2 25	1 46
Vial blowers	163	2 50 to 4 50	3 38	Batch wheelers	26	1 00 to 2 00	1 36
Demijohn blowers	10	2 90 to 5 00	3 78	Teasers	66	1 00 to 4 17	1 63
Carboy blowers	3	3 30 to 10 00	5 58	Mixers	45	1 00 to 2 50	1 56
Other blowers	32	3 00 to 3 25	3 23	Lime sifters	10	50 to 2 60	1 29
Gatherers:				Ware boys	62	58½ to 2 00	1 27
16 years and upward	326	54 to 1 50	97	Pot makers	16	1 50 to 4 00	2 61
Under 16 years	17	75	75	Pot makers' assistants	26	1 00 to 2 00	1 36
Sticker-up boys:				Clay trampers	41	1 00 to 1 50	1 16
16 years and upward	121	32 to 1 25	42	Grinders:			
Under 16 years	29	38 to 88	51	16 years and upward	35	83⅓ to 5 00	1 30
Finishers:				Under 16 years	3	60	60
16 years and upward	63	45 to 4 50	2 73	Boss packers	22	1 16⅔ to 3 50	2 02
Under 16 years	4	50	50	Demijohn coverers:			
Carrying-in boys:				16 years and upward	31	75 to 2 00	1 06
16 years and upward	182	38 to 75	59	Under 16 years	10	1 00	1 00
Under 16 years	301	38 to 83	54	Packers	119	83⅓ to 2 25	1 37
Laying-up boys:							
16 years and upward	150	50 to 1 50	96				
Under 16 years	26	50 to 1 00	79				

RANGE AND AVERAGE RATES OF DAILY WAGES IN THE MANUFACTURE OF PLATE-GLASS.

Founders	13	$2 00 to $3 85	$3 39	Mixers	13	$1 25 to $2 00	$1 40
Gas makers	7	1 25 to 2 00	1 76	Pot makers	6	2 31 to 3 33	2 94
Teemers or pourers	11	1 15 to 2 50	1 95	Crocus men	4	1 67 to 2 00	1 84
Roller men	12	1 15 to 1 80	1 53	Cutters	16	2 00 to 3 08	2 54
Kiln firemen	8	1 15 to 1 83	1 50	Glass packers	12	1 35 to 2 33	1 78
Furnace men	58	1 15 to 1 83	1 39	Machinists	23	1 25 to 3 00	2 39
Grinders:				Blacksmiths	6	1 73 to 4 00	2 87
16 years and upward	55	1 67 to 3 00	2 18	Firemen	10	1 25 to 1 80	1 57
Under 16 years	6	50	50	Engineers	16	1 25 to 3 00	2 41
Smoothers:				Carpenters	13	1 25 to 2 25	1 91
Males 16 years and upward	52	2 00 to 2 29	2 06	Bricklayers	9	2 00 to 3 00	2 64
Males under 16 years	3	50	50	Furnace builders	1	3 85	3 85
Females 15 years and upward	13	75	75	Teamsters	13	1 00 to 1 33	1 14
Females under 15 years	4	50	50	Sand-quarry men	10	1 50	1 50
Polishers:				Mill men	4	1 67 to 1 75	1 71
16 years and upward	65	2 00 to 3 13	2 49	Plaster burners	5	1 00 to 1 50	1 31
Under 16 years	6	50	50				

RANGE AND AVERAGE RATES OF DAILY WAGES IN THE MANUFACTURE OF GLASSWARE.

Managers	52	$3 00 to $8 11	$4 46	Cutters:			
Pressers	306	2 00 to 5 60	3 53	Males 16 years and upward	223	$1 35 to $4 16⅔	$2 29
Finishers:				Females 15 years and upward	7	50	50
Males 16 years and upward	563	76 to 6 00	3 55	Engravers	33	1 66⅔ to 4 00	2 58
Males under 16 years	134	76 to 80	79	Mold makers	120	1 50 to 6 00	3 05
Gatherers:				Machinists *	39	1 50 to 6 50	2 30
Males 16 years and upward	890	67 to 3 50	1 93	Mixers	135	1 33⅓ to 2 66⅔	1 76
Males under 16 years	6	55 to 1 50	1 31	Teasers	166	1 50 to 2 66⅔	2 11
Stickers-up:				Pot fillers	56	1 00 to 2 50	1 67
Males 16 years and upward	338	42 to 1 80	87	Pot makers	41	1 16⅔ to 3 33⅓	2 35
Males under 16 years	543	42 to 1 00	78	Clay trampers	74	1 00 to 2 58	43
Cleaning-off boys:				Packers:			
Males 16 years and upward	192	50 to 1 35	82	Males 16 years and upward	340	60 to 4 00	1 72
Males under 16 years	414	50 to 1 00	64	Males under 16 years	19	45 to 65	53
Females 15 years and upward	3	80		Females 15 years and upward	19	50 to 2 33⅓	98
Females under 15 years	12	50 to 62½	58	Drivers	103	1 00 to 2 50	1 72
Carrying-in boys:				Laborers:			
Males 16 years and upward	156	48 to 1 20	62	Males 16 years and upward	573	1 00 to 2 00	1 35
Males under 16 years	762	33⅓ to 80	56	Males under 16 years	7	67 to 83	69
Mold-holders:				Females 15 years and upward	82	60 to 75	67
Males 16 years and upward	132	50 to 2 75	83	Females under 15 years	9	50 to 67	61
Males under 16 years	285	45 to 1 00	62	Engineers	54	1 16⅔ to 3 00	2 15
Blowers	1,147	1 66⅔ to 5 60	3 47				

* The machinist receiving highest rate is probably a mold maker.

INTERVALS OF PAYMENT.

In the annexed table will be found a statement showing the intervals of payment at the different glass works in the United States so far as returns have been received. In connection with each interval of payment is also given the number of employés so paid:

Kind of glass.	WEEKLY.		EVERY TWO WEEKS.		MONTHLY.		ON APPLICATION.		NO STATEMENT.	
	Number of works.	Number of employés.	Number of works.	Number of employés.	Number of works.	Number of employés.	Number of works.	Number of employés.	Number of works.	Number of employés.
Plate-glass	2	513	.....	.....	4	443	.....	.....	.....	.....
Window-glass	37	2,575	2	100	12	919	3	178	4	118
Glassware	47	7,023	28	5,419	1	130	.....	.....	15	68
Green glass	28	4,033	4	745	12	1,423	2	296	10	194
Total	114	14,144	34	6,264	29	2,915	5	474	29	380

The frequency with which the workmen are paid is a matter of considerable importance, and determines in some degree the value of wages. When workmen are paid once a year, as they were at one time in New England, being allowed to take goods from the store in the meantime and have the same charged to their account, but being compelled to pay interest on any cash advanced, it is evident that such intervals of payment would not make the purchasing power of their wages as great as though the employé was paid weekly or every two weeks. In some of the occupations about a glass works where the men are paid by the piece, as in window-glass blowing, owing to the peculiar character of the business it is almost impossible to ascertain at the end of each week or each two weeks what amount of money is due to the blower or flattener, they being paid in accordance with the quality of the glass produced, as this can only be ascertained when the glass has been flattened and cut, or at least inspected. This sometimes takes weeks, especially in dull seasons. It is therefore customary in these works to advance to men what is termed "market money", equaling a certain amount a week, and to have final settlements at the end of the "fire". In the window-glass report, therefore, it will be understood that most of the skilled workmen, such as the blowers, gatherers, cutters, and flatteners, are paid weekly or every two weeks on account, and full settlements are had at the end of the "fire", generally in June. This is also true in some few cases in glassware manufactories, and to a greater extent in green-glass factories.

From the above table it will be noticed 4 plate-glass works, employing 443 hands, pay monthly, and 2, employing 513 hands, pay weekly. In window-glass, 37 works, employing 2,575 hands, pay weekly; 2, employing 100 hands, every two weeks; 12, employing 919 hands, pay monthly; 3, employing 178 hands, on application; and from the balance, employing 118 hands, no statement has been received. In glassware, 47 works, employing, 7,023 hands, pay weekly; 28, employing 5,419 hands, every two weeks; and 1, employing 130 hands, every month; from the balance, employing 68 hands, no returns have been received. In green glass, 28 works, employing 4,033 hands, pay every week; 4, employing 745 hands, every two weeks; 12, employing 1,423 hands, every month; 2, employing 296 hands, on application, and from the rest, employing 194 hands, no returns have been received. It will thus be seen that of all the employés in glass works 14,144 are paid weekly, 6,264 every two weeks, 2,915 monthly, 474 on application, and as to 380 no statement has been received.

METHODS OF PAYMENT.

In the following table will be found a condensed statement showing the number of establishments that had stores connected with them, the number that had no stores, and the number from which no statement has been received:

Kinds of glass.	STORES.		NO STORES.		NO STATEMENT.	
	Number of works.	Number of employés.	Number of works.	Number of employés.	Number of works.	Number of employés.
Plate-glass	2	376	4	580	.....	.....
Window-glass	12	1,628	36	2,493	10	369
Glassware	1	900	76	11,565	14	175
Green glass	12	2,259	30	3,896	14	536
Total	27	4,563	146	18,534	38	1,080

The establishments concerning which there is no statement are generally idle works or works that are building, which will account for the small number of employés concerning which no statement has been obtained.

It should not, however, be inferred from this table that at the works having stores the men are always obliged to deal at them. While this may be true in some instances—to what extent, however, I am not able to say—in other cases it is not true, as it is entirely optional with the employé whether he trades at the store or not. In a number of cases the store is only kept as an accommodation to the men, the works being so situated that this is a necessity. The returns also show that at most of the works having stores a considerable portion of the wages of the men are paid in cash.

While all the above is true, and while the small number of establishments having stores is exceedingly gratifying, this question of "truck" is a burning one between employer and employed. In most states "store-pay" is illegal, and the existence of stores in many cases is a violation or an evasion of the law.

PRODUCT.

The total value of all the glass produced in the United States during the census year was $21,154,571. The following table shows the value of the several kinds of glass produced and the percentage of each kind to the whole:

Kinds of glass.	Value of product.	Percentage of total value.
Plate-glass	$868,305	4.10
Window-glass	5,047,313	23.86
Glassware	9,568,520	45.23
Green glass	5,670,433	26.81
Total	21,154,571	100.00

MATERIALS.

The total value of all materials and the value of the materials used in each kind of glass is shown in the following tabulated statement:

Kinds of glass.	Total value of materials.	Percentage to whole.
All kinds	$8,028,021	100.00
Plate-glass	438,457	5.46
Window-glass	1,849,520	23.04
Glassware	3,292,380	41.01
Green glass	2,448,254	30.49

In Table VIII of this report are given, so far as they were ascertained, the quantities of the different materials used in all kinds of glass.

RELATIVE PRODUCTIVE RANK OF THE STATES.

The following table shows the relative productive rank of the several states and the percentage that the production of each bears to the total product:

States.	Value of production.	Percentage of value of production of each state to whole.	States.	Value of production.	Percentage of value of production of each state to whole.
The United States	$21,154,571	100.00	Indiana	$790,781	3.74
			West Virginia	748,500	3.54
Pennsylvania	8,720,584	41.22	Maryland	587,000	2.77
New Jersey	2,810,170	13.28	Kentucky	388,405	1.84
New York	2,420,796	11.44	Connecticut	160,000	0.76
Ohio	1,549,329	7.32	California	140,000	0.66
Missouri	919,827	4.35	Michigan	90,000	0.43
Illinois	901,343	4.26	New Hampshire	70,000	0.33
Massachusetts	854,345	4.04	Iowa	3,500	0.02

It will be noted that Pennsylvania stands first as a producer of glass in the United States, its percentage in value being more than three times that of any other state. About 65 per cent. of this amount is credited to Allegheny county. The pre-eminence of Pennsylvania as a glass-manufacturing state is due to some extent to its extensive supplies of mineral coal, which affords very cheap fuel to the glass houses.

The following tables give the relative productive rank of the several states in the manufacture of the several kinds of glass:

PLATE-GLASS.

State.	Value of production.	Percentage of value of production of each state to whole.
The United States	$868,305	100.00
Indiana	496,400	57.17
Missouri	322,550	37.15
Massachusetts	45,843	5.28
Kentucky	3,512	0.40

WINDOW-GLASS.

State.	Value of production.	Percentage of value of production of each state to whole.
The United States	$5,047,313	100.00
Pennsylvania	2,222,513	44.03
New Jersey	729,155	14.45
New York	540,903	10.72
Illinois	373,343	7.40
Ohio	358,000	7.09
Maryland	332,060	6.58
Indiana	229,397	4.54
Massachusetts	104,002	2.06
Michigan	90,000	1.78
Missouri	68,000	1.35

GLASSWARE.

The United States	$9,568,520	100.00
Pennsylvania	4,881,312	51.01
New York	1,157,571	12.10
Ohio	1,076,320	11.25
West Virginia	748,500	7.82
Massachusetts	704,500	7.36
New Jersey	400,000	4.18
Kentucky	215,336	2.25
Connecticut	160,000	1.67
Missouri	136,487	1.43
Maryland	85,000	0.89
Iowa	3,500	0.04

GREEN GLASS.

The United States	$5,670,433	100.00
New Jersey	1,681,015	29.64
Pennsylvania	1,616,759	28.51
New York	722,322	12.74
Illinois	528,050	9.31
Missouri	392,780	6.93
Maryland	170,000	3.00
Kentucky	169,563	2.99
California	140,000	2.47
Ohio	115,000	2.03
New Hampshire	70,000	1.23
Indiana	64,984	1.15

PRODUCTION OF PLATE-GLASS.

As stated, the total value of the plate-glass produced and sold in the census year was $868,305; the total amount cast was 1,700,227 square feet. Of this amount, 1,042,000 square feet, valued at $794,000, were polished and sold, and 484,543 square feet, valued at $113,555, were either sold as rough plate-glass or were in the process of completion at the works on the 31st of May. The balance, 173,684 square feet, represents the cast plate that had been destroyed in the process of manufacture. The amount of plate-glass sold unpolished, or as cathedral plate, was 377,227 square feet. This would make the total sold, including rough plate and polished plate, 1,419,227 square feet, valued at $868,305. From the returns received it appears that the value per square foot of the polished plate-glass sold was 76⅕ cents.

PRODUCTION OF WINDOW-GLASS.

The total production of window-glass in the United States was 1,864,734 boxes of 50 square feet, valued at $5,047,313, or an average of $2 70⅔ per box. No attempt was made to ascertain the number of square feet of each size sold, nor what proportion was single and what proportion double thick, as upon inquiry it was found that such an attempt would be useless.

PRODUCTION OF GLASSWARE.

An attempt was made to arrive at the total number of pieces of certain kinds of glassware made; but though returns were received from a large number of works giving the number of tumblers, goblets, lamps, lamp-chimneys, and flint bottles or "prescriptions", they were by no means complete. Some of the figures received, however, were

quite suggestive. In Massachusetts, for example, no flint bottles or "prescriptions" were made, but in this state 46,415 dozen tumblers, 111,712 dozen lamp-chimneys, and 14,087 lamps were made. In New York the returns show 288,639 dozen lamp-chimneys and 75,301 lamps. This return, however, is imperfect. In Ohio the reports show 409,713 dozen tumblers, 743,140 dozen lamp-chimneys, and 19,426 lamps. The returns from Pennsylvania in this regard are very imperfect. So far as returns have been received, the make of tumblers was 2,500,000 dozen, of lamp-chimneys 2,719,649 dozen, and of lamps 128,090 dozen.

PRODUCTION OF GREEN GLASS.

The same lack of statement of detailed production as obtains in flint glass also exists as regards green glass. The chief productions, however, are green and black bottles, beer-bottles, fruit-jars, demijohns, carboys, and vials. In New Jersey the number of green and black bottles is given as 107,547 gross; of fruit-jars, 51,749 gross, and of beer-bottles, 32,060 gross. In New York, 49,882 gross of green and black bottles, 28,752 gross of fruit-jars, and 12,049 gross of beer-bottles are reported as made. In Pennsylvania the reports show 55,846 gross of green and black bottles, 67,770 gross of fruit-jars, and 27,198 gross of beer-bottles.

LOCALITIES IN WHICH GLASS WAS PRODUCED.

The states ranking highest in the production of glass are Pennsylvania, New Jersey, New York, and Ohio, each of them producing glass to the value of more than a million and a half dollars during the census year. The following table will show the rank of those counties producing more than $50,000 in aggregate product:

Counties.	States.	Value of production of county.	Percentage of value of production of county to total value.	Counties.	States.	Value of production of county.	Percentage of value of production of county to total value.
Allegheny	Pennsylvania	$5,668,212	26.79	Portage	Ohio	$168,298	0.80
Philadelphia	do	1,621,959	7.67	Middlesex	Connecticut	160,000	0.76
Kings	New York	1,318,081	6.24	Berkshire	Massachusetts	149,845	0.71
Cumberland	New Jersey	1,132,450	5.35	Oswego	New York	149,735	0.71
Gloucester	do	947,805	4.48	Clark	Indiana	140,400	0.66
Belmont	Ohio	794,920	3.76	Oneida	New York	140,000	0.66
Ohio	West Virginia	714,000	3.38	San Francisco	California	140,000	0.66
Floyd	Indiana	650,381	3.07	Orange	New York	127,182	0.60
Saint Louis	Missouri	597,277	2.82	Bristol	Massachusetts	125,000	0.59
Baltimore	Maryland	587,000	2.77	Jefferson	Kentucky	123,075	0.58
La Salle	Illinois	523,343	2.47	Steuben	New York	120,000	0.57
Beaver	Pennsylvania	503,587	2.38	Onondaga	do	116,940	0.55
Salem	New Jersey	447,530	2.12	Lawrence	Pennsylvania	102,511	0.48
Fayette	Pennsylvania	361,315	1.71	Rock Island	Illinois	93,000	0.44
Jefferson	Missouri	322,550	1.52	Wayne	Michigan	90,000	0.43
Jefferson	Ohio	309,102	1.46	Monroe	Pennsylvania	80,000	0.38
Middlesex	Massachusetts	307,500	1.45	Suffolk	Massachusetts	72,000	0.34
Madison	Illinois	285,000	1.35	Montgomery	Pennsylvania	72,000	0.34
Kenton	Kentucky	265,330	1.25	Hillsborough	New Hampshire	70,000	0.33
Wayne	Pennsylvania	257,060	1.22	Ulster	New York	70,000	0.33
Muskingum	Ohio	232,060	1.10	Tompkins	do	60,000	0.28
Barnstable	Massachusetts	200,000	0.95	Niagara	do	55,000	0.26
Wayne	New York	180,664	0.85	Tioga	Pennsylvania	54,000	0.26

TABLE I.—THE PLATE-GLASS WORKS OF THE UNITED STATES AT THE CENSUS OF 1880.

States.	No. of establishments.	Capital.	Number of furnaces.					Number of hands employed.					Total amount paid in wages during the year.	Total value of materials.	Products.			Total value of products.
			Total.	Gas.	Tank.	Other kinds.	Pots.	Total.	Males above 16 years.	Females above 15 years.	Males 16 years and under.	Females 15 years and under.			Total cast.	Total polished.	Sold rough.	
															Square feet.	*Square feet.*	*Square feet.*	
The United States	6	$2,587,000	10	2	....	8	116	956	822	91	36	7	$292,253	$438,457	1,700,227	1,042,000	377,227	*$868,305
Indiana	2	1,142,000	5	....	....	5	64	513	419	53	35	6	160,850	298,733	970,000	642,000	130,000	496,400
Kentucky	1	250,000	2	....	....	2	16	35	32	1	1	1	1,008	2,750	20,684	.....	20,684	3,512
Massachusetts	2	45,000	2	1	....	1	20	58	57	1	.....	.....	10,395	24,049	209,543	.....	209,543	45,843
Missouri	1	1,150,000	1	1	....	....	16	350	314	36	.....	.....	126,000	112,925	500,000	400,000	17,000	322,550

* This does not include the value of cast plate in process of manufacture, nor of rough plate broken up and used as cullet, but includes only the value of polished plate and that part of the rough plate that was sold.

TABLE II.—THE WINDOW-GLASS WORKS OF THE UNITED STATES AT THE CENSUS OF 1880.

States.	No. of establishments.	Capital.	NUMBER OF FURNACES. Total.	Gas.	Tank.	Other kinds.	Pots.	NUMBER OF HANDS EMPLOYED. Total.	Males above 16 years.	Females above 15 years.	Males 16 years and under.	Females 15 years and under.	Total amount paid in wages during the year.	Total value of materials.	PRODUCTS. Boxes of 50 square feet each.	Total value of products.
The United States	58	$4,953,155	88	.....	.....	88	767	3,890	3,755	1	132	2	$2,139,536	$1,840,530	1,864,734	$5,047,313
Illinois	4	235,000	6	.....	.....	6	53	225	222	.....	3	.....	145,703	101,474	115,271	373,343
Indiana	1	175,000	3	.....	.....	3	30	169	169	.....	.....	.....	103,000	105,000	91,759	229,397
Iowa*	1	25,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maryland	4	365,000	5	.....	.....	5	42	222	222	.....	.....	.....	131,454	147,277	141,600	332,000
Massachusetts	2	75,000	4	.....	.....	4	32	99	98	1	.....	.....	44,947	39,245	41,866	104,002
Michigan	1	65,000	1	.....	.....	1	8	54	50	.....	4	.....	30,000	38,113	30,000	90,000
Missouri	1	40,000	2	.....	.....	2	14	48	48	.....	.....	.....	32,000	27,706	24,000	68,000
New Jersey	9	723,355	15	.....	.....	15	116	699	622	.....	77	.....	266,294	289,803	296,685	729,155
New York	9	575,000	11	.....	.....	11	96	410	409	.....	1	.....	195,576	224,568	216,748	540,903
Ohio	6	455,000	6	.....	.....	6	56	273	269	.....	4	.....	146,861	106,510	127,122	358,000
Pennsylvania	20	2,279,800	34	.....	.....	34	307	1,661	1,646	.....	43	2	1,043,701	772,834	780,283	2,222,513

* Not in operation during the census year.

TABLE III.—THE GLASSWARE WORKS OF THE UNITED STATES AT THE CENSUS OF 1880.

States.	No. of establishments.	Capital.	NUMBER OF FURNACES. Total.	Gas.	Tank.	Other kinds.	Pots.	NUMBER OF HANDS EMPLOYED. Total.	Males above 16 years.	Females above 15 years.	Males 16 years and under.	Females 15 years and under.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
The United States	91	$7,409,278	162	17	2	143	1,559	12,640	8,253	513	3,824	50	$4,452,417	$3,292,380	$9,568,526
Connecticut	1	130,000	1	.....	.....	1	10	160	130	2	28	.....	65,000	70,000	160,000
District of Columbia*	1	25,000	1	.....	.....	1	6	.....	.....	.....	.....	.....	.....	.....	.....
Illinois*	1	20,000	2	.....	.....	2	35	.....	.....	.....	.....	.....	.....	.....	.....
Iowa	2	32,000	2	1	.....	1	20	35	24	2	9	.....	2,000	3,248	3,500
Kentucky	1	250,000	2	1	.....	1	22	209	106	10	92	1	105,292	60,466	215,330
Maryland	2	55,000	2	.....	.....	2	17	85	60	.....	25	.....	22,000	26,000	85,000
Massachusetts	6	603,000	15	.....	.....	15	143	789	673	56	60	.....	328,000	266,570	704,500
Missouri	2	100,000	2	.....	.....	2	21	217	120	.....	97	.....	61,339	43,035	136,487
New Jersey	3	310,000	10	.....	.....	10	89	900	525	25	350	.....	250,000	100,000	402,000
New York	14	775,080	24	.....	.....	24	215	1,847	1,157	30	652	7	591,576	426,826	1,157,571
Ohio	13	579,750	18	5	.....	13	191	1,225	781	81	363	.....	452,659	309,270	1,076,320
Pennsylvania	44	3,978,406	75	8	2	65	727	6,227	4,062	207	1,919	39	2,262,901	1,778,961	4,881,312
West Virginia	4	550,522	8	2	.....	6	82	946	615	100	228	3	311,650	268,084	748,500

* Not in operation during census year.

TABLE IV.—THE GREEN-GLASS WORKS OF THE UNITED STATES AT THE CENSUS OF 1880.

States.	No. of establishments.	Capital.	NUMBER OF FURNACES. Total.	Gas.	Tank.	Other kinds.	Pots.	NUMBER OF HANDS EMPLOYED. Total.	Males above 16 years.	Females above 15 years.	Males 16 years and under.	Females 15 years and under.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
The United States	56	$4,895,266	88	2	3	83	540	6,694	4,948	136	1,574	33	$2,259,894	$2,448,254	$5,670,433
California	1	75,000	1	.....	.....	1	7	113	80	.....	33	.....	45,924	48,070	140,000
Illinois	2	190,000	4	.....	.....	4	36	567	419	.....	97	.....	196,324	196,368	528,000
Indiana	1	125,000	2	.....	.....	2	14	180	107	.....	73	.....	20,357	30,000	64,984
Kentucky	3	295,000	3	.....	.....	3	17	278	226	.....	52	.....	44,022	70,888	169,563
Maryland	2	76,000	3	.....	.....	3	17	305	242	.....	63	.....	80,800	66,405	170,600
Massachusetts*	1	100,000	1	.....	.....	1	11	.....	.....	.....	.....	.....	.....	.....	.....
Mississippi†	1	25,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....	.....
Missouri	2	140,000	4	.....	.....	4	24	350	227	.....	123	.....	167,759	168,205	392,790
New Hampshire	1	50,000	2	.....	.....	2	8	102	80	8	14	.....	25,600	34,000	70,000
New Jersey	15	1,694,666	31	.....	1	30	172	1,979	1,615	21	341	2	783,744	698,543	1,681,615
New York	9	583,000	13	1	1	11	62	821	550	20	245	6	259,609	293,297	722,322
Ohio	4	160,100	5	.....	.....	5	30	190	120	.....	70	.....	45,000	43,553	115,000
Pennsylvania	14	1,331,500	18	1	1	16	134	1,866	1,291	87	463	25	590,704	798,925	1,616,759

* Not in operation during the census year. † Building.

TABLE V.—GLASS WORKS IDLE AND BUILDING IN THE UNITED STATES AT THE CENSUS OF 1880.

1.—FURNACES THAT MADE NO GLASS IN THE CENSUS YEAR.

Classes.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Plate-glass	1				1	1	8
Window-glass	10	$90,000			10	10	82
Glassware	15	267,000	3		19	22	201
Green glass	8	234,000	1		7	8	58
Total	34	591,000	4		37	41	349

2.—ALL FURNACES BUILDING AND NOT COMPLETED IN THE CENSUS YEAR.

Classes.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Plate-glass	1		1			1	16
Window-glass	4	$80,000			4	4	36
Glassware	12	235,000	4		8	12	129
Green glass	5	54,100			5	5	31
Total	22	369,100	5		17	22	212

PLATE-GLASS.

3.—FURNACES THAT MADE NO GLASS IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Kentucky	1				1	1	8
Total	1				1	1	8

4.—FURNACES BUILDING AND NOT COMPLETED IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Missouri	1		1			1	16
Total	1		1			1	16

WINDOW-GLASS.

5.—FURNACES THAT MADE NO GLASS IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Illinois	1				1	1	10
Iowa	1	$25,000			1	1	8
Massachusetts	2				2	2	16
Missouri	1				1	1	8
New Jersey	2	10,000			2	2	14
New York	1	10,000			1	1	8
Pennsylvania	2	45,000			2	2	18
Total	10	90,000			10	10	82

WINDOW-GLASS—Continued.

6.—FURNACES BUILDING AND NOT COMPLETED IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Illinois	1	$35,000	.....	.....	1	1	10
New Jersey	1	.....	.....	.....	1	1	6
New York	1	.....	.....	.....	1	1	10
Ohio	1	45,000	.....	.....	1	1	10
Total	4	80,000	.....	.....	4	4	36

GLASSWARE.

7.—FURNACES THAT MADE NO GLASS IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
District of Columbia	1	$25,000	.....	.....	1	1	6
Illinois	1	20,000	.....	.....	2	2	16
Massachusetts	3	6,000	.....	.....	7	7	70
New Jersey	2	110,000	.....	.....	3	3	28
New York	2	30,000	.....	.....	2	2	11
Ohio	2	.....	2	.....	.....	2	24
Pennsylvania	4	76,000	1	.....	4	5	48
Total	15	267,000	3	.....	19	22	201

8.—FURNACES BUILDING AND NOT COMPLETED IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Iowa	1	$20,000	1	.....	.....	1	13
Maryland	1	30,000	.....	.....	1	1	8
Massachusetts	1	.....	.....	.....	1	1	10
New Jersey	1	.....	.....	.....	1	1	8
Ohio	3	95,000	2	.....	1	3	38
Pennsylvania	5	90,000	1	.....	4	5	52
Total	12	235,000	4	.....	8	12	129

GREEN GLASS.

9.—FURNACES THAT MADE NO GLASS IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Massachusetts	1	$100,000	.....	.....	1	1	11
Ohio	2	44,000	.....	.....	2	2	12
New Jersey	4	80,000	.....	.....	4	4	29
Pennsylvania	1	10,000	1	.....	.....	1	6
Total	8	234,000	1	.....	7	8	58

10.—FURNACES BUILDING AND NOT COMPLETED IN THE CENSUS YEAR.

States.	No. of establishments.	Capital.	FURNACES.				
			Kind and number.				Total number of pots.
			Gas.	Tank.	Other kinds.	Total number.	
Ohio	1	21,100	.....	.....	1	1	6
New Jersey	1	10,000	.....	.....	1	1	5
New York	1	23,000	.....	.....	1	1	5
Pennsylvania	2	.....	.....	.....	2	2	15
Total	5	54,100	.....	.....	5	5	31

TABLE VI.—CONSOLIDATED STATISTICS OF ALL THE GLASS WORKS OF THE UNITED STATES AT THE CENSUS OF 1880, BY STATES.

States.	No. of establishments.	Capital.	NUMBER OF FURNACES AND POTS.					NUMBER OF HANDS EMPLOYED.					Total amount paid in wages during the year.	Total value of materials.	Total value of products.
			Total.	Gas.	Tank.	Other kinds.	Pots.	Total.	Males above 16 years.	Females above 15 years.	Males 16 years and under.	Females 15 years and under.			
The United States	211	$19,844,699	348	21	5	322	2,982	24,177	17,778	741	5,566	92	$9,144,100	$8,028,621	$21,154,571
California	1	75,000	1	.....	.....	1	7	113	80	.....	33	.....	45,924	48,070	140,000
Connecticut	1	130,000	1	.....	.....	1	10	160	130	2	28	.....	65,000	70,000	160,000
District of Columbia*	1	25,000	1	.....	.....	1	6	.....	.....	.....	.....	.....	.....	.....	.....
Illinois	7	445,000	12	.....	.....	12	110	732	632	.....	100	.....	342,027	297,842	901,343
Indiana	4	1,442,000	10	.....	.....	10	168	862	695	53	108	6	284,207	433,733	790,781
Iowa	3	57,000	3	1	.....	2	28	35	24	2	9	.....	2,000	3,248	3,500
Kentucky	5	795,000	7	1	.....	6	55	522	364	11	145	2	150,322	134,104	388,405
Maryland	3	436,000	10	.....	.....	10	76	612	524	.....	88	.....	234,254	239,682	587,000
Massachusetts	11	823,000	22	1	.....	21	206	946	828	58	60	.....	383,342	329,864	854,345
Michigan	1	65,000	1	.....	.....	1	8	54	50	.....	4	.....	30,000	35,113	90,000
Mississippi†	1	25,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....	.....
Missouri	6	1,430,000	9	1	.....	8	75	965	709	36	220	.....	381,098	351,871	919,827
New Hampshire	1	50,000	2	.....	.....	2	8	102	80	8	14	.....	25,600	34,000	70,000
New Jersey	27	2,728,021	56	.....	1	55	377	3,578	2,762	46	768	2	1,300,038	1,088,346	2,810,176
New York	32	1,033,680	48	1	1	46	373	3,078	2,116	50	899	13	1,046,812	944,691	2,420,796
Ohio	20	1,194,850	29	5	.....	24	277	1,688	1,170	81	437	.....	644,520	459,333	1,549,320
Pennsylvania	78	7,639,706	127	9	3	115	1,168	9,784	6,999	294	2,425	66	3,897,306	3,350,660	8,730,584
West Virginia	4	550,522	8	2	.....	6	82	946	615	100	228	3	311,650	208,064	748,500

* Not in operation during census year. † Building.

TABLE VII.—CONSOLIDATED STATISTICS OF ALL THE GLASS WORKS OF THE UNITED STATES AT THE CENSUS OF 1880, BY STATES AND COUNTIES.

CALIFORNIA.

Counties.	Number of establishments.	Capital.	NUMBER OF FURNACES AND POTS.					NUMBER OF HANDS EMPLOYED.				Total amount paid in wages during the year.	Total value of materials.	Total value of products.
			Total.	Gas.	Tank.	Other kinds.	Pots.	Total.	Males above 16 years.	Females above 15 years.	Children and youths.			
San Francisco	1	$75,000	1	.....	.....	1	7	113	80	.....	33	$45,924	$48,070	$140,000

CONNECTICUT.

Middlesex	1	$130,000	1	.....	.....	1	10	160	130	2	28	$65,000	$70,000	$160,000

DISTRICT OF COLUMBIA.

Washington *	1	$25,000	1	.....	.....	1	6	.....	.....	.....	.....	.....	.....	.....

* Not in operation during census year.

ILLINOIS.

Total for State	7	$445,000	12	.....	.....	12	110	732	632	.....	100	$342,027	$297,842	$901,343
Cook *	1	20,000	2	.....	.....	2	16	.....	.....	.....	.....	.....	.....	.....
La Salle	4	235,050	6	.....	.....	6	60	387	337	.....	50	195,508	168,755	523,343
Madison	1	140,600	2	.....	.....	2	14	280	230	.....	50	101,519	92,707	285,000
Rock Island	1	50,000	2	.....	.....	2	20	65	65	.....	.....	45,000	36,380	93,000

* Not in operation during census year.

TABLE VII.—STATISTICS OF GLASS WORKS, BY STATES AND COUNTIES, ETC.: 1880.

INDIANA.

Counties.	Number of establishments.	Capital.	NUMBER OF FURNACES AND POTS.					NUMBER OF HANDS EMPLOYED.				Total amount paid in wages during the year.	Total value of materials.	Total value of products.
			Total.	Gas.	Tank.	Other kinds.	Pots.	Total.	Males above 16 years.	Females above 15 years.	Children and youths.			
Total for State	4	$1,442,000	10	.....	.....	10	108	862	695	53	114	$284,207	$433,733	$790,781
Clark	1	142,000	2	.....	.....	2	12	163	131	13	19	56,850	70,133	140,400
Floyd	3	1,300,000	8	.....	.....	8	92	699	564	40	95	227,357	363,600	650,381

IOWA.

Total for State	3	$57,000	3	1	.....	2	28	35	24	2	9	$2,000	$3,248	$3,500
Johnson*	1	20,000	1	1	.....	.....	13	.....	.....	.....	.....	.....	.....	.....
Keokuk	1	12,000	1	.....	.....	1	7	35	24	2	9	2,000	3,248	3,500
Scott†	1	25,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....

*Building. †Idle.

KENTUCKY.

Total for State	5	$795,000	7	1	.....	6	55	522	364	11	147	$150,322	$134,104	$388,405
Jefferson	3	295,000	4	.....	.....	4	28	169	132	1	36	32,917	37,079	123,075
Kenton	2	500,000	3	1	.....	2	27	353	232	10	111	117,405	97,025	265,330

MARYLAND.

Total for State	8	$436,000	10	.....	.....	10	76	612	524	.....	88	$234,254	$239,682	$587,000
Allegany*	1	30,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....
Baltimore	7	406,000	9	.....	.....	9	68	612	524	.....	88	234,254	239,682	587,000

*Building.

MASSACHUSETTS.

Total for State	11	$823,000	22	1	.....	21	206	946	828	58	60	$383,342	$329,864	$854,345
Barnstable	2	266,000	5	.....	.....	5	50	217	180	25	12	100,000	85,000	200,000
Berkshire	4	120,000	6	1	.....	5	52	137	155	2	.....	55,342	63,294	149,845
Bristol	1	110,000	2	.....	.....	2	20	130	124	4	2	50,000	32,000	125,000
Middlesex	3	300,000	7	.....	.....	7	70	352	306	24	22	151,000	125,500	307,500
Suffolk	1	87,000	2	.....	.....	2	14	90	63	3	24	27,000	24,070	72,000

MICHIGAN.

Wayne	1	$65,000	1	.....	.....	1	8	54	50	.....	4	$30,000	$35,113	$90,000

MISSISSIPPI.

Jackson*	1	$25,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....

*Building.

MISSOURI.

Total for State	6	$1,450,000	9	1	.....	8	75	965	709	36	220	$381,098	$351,871	$919,827
Jefferson	1	1,150,000	1	1	.....	.....	16	350	314	36	.....	120,000	112,925	322,550
Saint Louis	5	280,000	8	.....	.....	8	59	615	395	.....	220	261,098	238,946	597,277

NEW HAMPSHIRE.

Hillsborough	1	$50,000	2	.....	.....	2	8	102	80	8	14	$25,600	$34,000	$70,000

TABLE VII.—STATISTICS OF GLASS WORKS, BY STATES AND COUNTIES, ETC.: 1880.

NEW JERSEY.

Counties.	Number of establishments.	Capital.	NUMBER OF FURNACES AND POTS.					NUMBER OF HANDS EMPLOYED.				Total amount paid in wages during the year.	Total value of materials.	Total value of products.
			Total.	Gas.	Tank.	Other kinds.	Pots.	Total.	Males above 16 years.	Females above 15 years.	Children and youths.			
Total for State	27	$2,728,021	56	.....	1	55	377	3,578	2,762	46	770	$1,300,038	$1,088,346	$2,810,170
Atlantic *	1	.....	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....
Burlington *	3	120,000	4	.....	.....	4	34	.....	.....	.....	.....	.....	.....	.....
Camden	4	290,000	5	.....	.....	5	34	244	198	.....	46	106,622	104,880	282,385
Cumberland	10	805,021	24	.....	.....	24	172	1,783	1,232	45	506	586,632	407,335	1,132,450
Gloucester	5	1,175,000	14	.....	1	13	84	1,051	854	1	196	426,900	373,909	947,805
Hudson *	1	30,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....
Salem	3	298,000	7	.....	.....	7	37	500	478	.....	22	179,884	202,231	447,530

* Idle.

NEW YORK.

Total for State	32	$1,933,600	48	1	1	46	373	3,078	2,116	50	912	$1,046,812	$944,691	$2,420,796
Broome *	1	23,000	1	.....	.....	1	5	.....	.....	.....	.....	.....	.....	.....
Columbia	1	10,600	1	.....	.....	1	1	12	6	.....	6	6,000	6,377	13,140
Duchess	1	50,000	1	1	.....	.....	.....	104	68	.....	36	11,625	13,755	27,145
Erie	1	30,000	1	.....	.....	1	5	60	42	.....	18	22,166	16,974	42,909
Jefferson †	1	10,000	1	.....	.....	1	8	.....	.....	.....	.....	.....	.....	.....
Kings	12	930,600	22	.....	1	21	185	1,854	1,158	36	660	630,857	483,593	1,318,081
Monroe †	1	25,000	1	.....	.....	1	6	.....	.....	.....	.....	.....	.....	.....
Niagara	1	45,000	1	.....	.....	1	7	120	76	3	41	18,000	23,055	55,000
Oneida	2	160,000	2	.....	.....	2	20	83	83	.....	.....	63,179	68,518	140,000
Onondaga	1	130,000	2	.....	.....	2	16	73	72	.....	1	41,388	40,589	116,940
Orange	2	70,000	4	.....	.....	4	29	220	119	.....	101	51,962	49,773	127,182
Oswego	3	160,000	4	.....	.....	4	32	152	152	.....	.....	47,394	63,156	149,735
Steuben	1	75,000	2	.....	.....	2	18	108	107	1	.....	51,000	48,000	120,000
Tompkins	1	40,000	1	.....	.....	1	10	60	60	.....	.....	20,000	23,256	60,000
Ulster	1	25,000	2	.....	.....	2	13	100	60	10	30	25,000	41,010	70,000
Wayne	2	150,000	2	.....	.....	2	18	132	113	.....	19	58,241	60,634	180,664

* Building. † Idle.

OHIO.

Total for State	20	$1,104,850	29	5	.....	24	277	1,688	1,170	81	437	$644,520	$450,333	$1,549,320
Belmont	9	485,350	15	3	.....	12	151	829	528	51	250	235,805	225,872	704,920
Franklin	1	50,000	1	.....	.....	1	10	50	50	.....	.....	16,000	13,200	45,000
Jefferson	3	210,000	5	2	.....	3	56	386	253	30	103	122,202	90,843	309,102
Licking *	1	22,000	1	.....	.....	1	6	.....	.....	.....	.....	.....	.....	.....
Muskingum	3	272,000	4	.....	.....	4	28	250	180	.....	70	90,060	72,318	232,000
Portage	3	155,500	3	.....	.....	3	26	173	159	.....	14	80,513	57,100	168,298

* Idle.

PENNSYLVANIA.

Total for State	78	$7,639,706	127	9	3	115	1,168	9,784	6,999	294	2,491	$3,897,306	$3,350,660	$8,720,584
Allegheny	51	5,481,000	85	5	3	77	797	6,053	4,442	141	1,470	2,686,425	2,139,658	5,668,212
Armstrong *	1	30,000	1	.....	.....	1	10	.....	.....	.....	.....	.....	.....	.....
Beaver	4	256,487	7	2	.....	5	79	544	375	11	158	193,000	211,000	503,587
Fayette	3	171,800	5	.....	.....	5	44	313	310	.....	3	137,959	84,043	361,215
Lawrence	2	62,000	2	.....	.....	2	18	125	122	.....	3	46,900	42,638	102,511
Montgomery	1	100,000	2	.....	.....	2	13	75	70	.....	5	26,000	40,000	72,000
Monroe	1	30,000	1	.....	.....	1	5	80	65	.....	15	25,000	36,120	80,000
Philadelphia	11	1,242,419	18	2	.....	16	158	2,237	1,358	128	751	655,022	696,393	1,621,950
Tioga	2	63,000	2	.....	.....	2	16	45	43	.....	2	23,000	29,515	54,000
Wayne	2	230,000	4	.....	.....	4	28	312	214	14	84	104,000	71,293	257,000

* Building.

WEST VIRGINIA.

Total for State	4	$550,522	8	2	.....	6	82	946	615	100	231	$311,650	$208,064	$748,500
Brooke	1	50,000	1	.....	.....	1	10	128	90	13	25	15,200	15,500	34,500
Ohio	3	500,522	7	2	.....	5	72	818	525	87	206	296,450	192,564	714,000

TABLE VIII.—CONSOLIDATED STATISTICS OF THE MATERIALS USED IN THE MANUFACTURE OF GLASS, AS REPORTED AT THE CENSUS OF 1880.

States.	Mixing sand.	Grinding sand.	Soda-ash.	Nitrate of soda.	Salt-cake.	Salt.	Lime.	Lime-stone.	Litharge.	Pearl-ash.	Arsenic.	Manga-nese.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Bushels.*	*Tons.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Grand total	155,447	39,500	49,626	2,859	7,877	1,909	869,886	2,597	2,313,203	592,932	713,974	191,146
California	1,200	.....	520	.....	.....	55	6,875	.....	.....	.....	.....	.....
Connecticut	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Illinois	9,767	.....	2,495	.....	648	611	49,607	300	.....	.....	26,109	.....
Indiana	7,124	32,300	2,854	.....	.....	83	47,842	.....	.....	.....	32,000	.....
Iowa	25	.....	10	2	.....	.....	650	.....	.....	.....	.....	400
Kentucky	3,543	.....	840	49	337	25	10,300	12	7,000	20,000	302	1,600
Maryland	5,344	.....	1,902	36	36	40	62,865	.....	.....	.....	2,710	1,500
Massachusetts	2,205	.....	392	75	255	.....	2,348	346	298,260	130,111	6,697	9,049
Michigan	650	.....	225	.....	.....	2	3,500	.....	.....	.....	939	.....
Missouri	8,042	7,200	3,071	31	.....	233	47,275	360	.....	.....	24,000	3,960
New Hampshire	500	.....	200	.....	200	.....	2,800	.....	.....	.....	.....	.....
New Jersey	26,282	.....	8,274	120	1,320	163	174,680	455	20,000	100	38,453	12,000
New York	16,122	.....	5,865	194	26	204	98,854	.....	559,257	142,456	6,600	27,505
Ohio	10,008	.....	3,244	332	233	101	45,635	.....	210,000	28,000	28,916	16,436
Pennsylvania	61,452	.....	18,419	1,841	4,822	302	309,122	1,124	1,218,686	268,496	547,266	110,178
West Virginia	3,183	.....	1,315	179	.....	.....	7,533	.....	.....	3,769	.....	8,518

States.	Fire clay, American.	Fire clay, English.	Fire clay, German.	Pots.	Coal.	Coke.	Wood.	Lumber.	Casks and barrels.	Nails.	Straw and hay.
	Pounds.	*Pounds.*	*Pounds.*	*Number.*	*Tons.*	*Tons.*	*Cords.*	*M. feet.*	*Number.*	*Kegs.*	*Tons.*
Grand total	9,196,655	110,000	7,927,236	13,655	646,898	28,410	63,867	53,585	914,619	15,150	21,298
California	120,000	24,000	56,000	60	1,650	.....	375	128	100	50	72
Connecticut	.....	.....	.....	16	1,800	300	50	.....	.....	.....	.....
Illinois	817,000	.....	16,000	627	35,242	400	4,212	2,012	4,500	544	941
Indiana	662,000	.....	30,000	1,100	61,050	71	460	1,767	.....	1,040	467
Iowa	37,500	.....	.....	1	400	40	.....	18	800	10	1
Kentucky	165,000	.....	1,000	202	12,829	962	60	1,115	400	690	1,155
Maryland	68,000	.....	624,000	587	15,723	.....	1,848	2,210	1,200	593	409
Massachusetts	253,679	60,000	152,800	150	10,899	1,017	1,184	301	53,475	148	325
Michigan	75,000	.....	100,000	120	3,600	.....	600	300	.....	60	40
Missouri	951,350	.....	.....	601	36,070	781	3,203	1,154	1,500	512	617
New Hampshire	.....	.....	25,000	75	1,000	200	1,000	80	.....	25	25
New Jersey	629,000	.....	2,251,998	2,118	61,530	.....	29,144	10,529	31,000	3,596	3,002
New York	242,000	.....	1,595,650	1,661	52,200	2,484	11,247	5,201	147,977	1,698	2,328
Ohio	700,425	.....	147,600	835	54,945	3,935	1,488	3,098	86,835	670	1,375
Pennsylvania	3,541,981	26,000	2,927,188	5,170	278,575	16,277	8,996	24,834	516,520	5,062	9,787
West Virginia	933,720	.....	.....	332	19,319	1,923	.....	838	70,312	452	754

CHAPTER II.—GLASS: ITS COMPOSITION, CLASSIFICATION, AND PROPERTIES.

DIFFICULTY OF DEFINITION.—It is extremely difficult, if not impossible, to give a definition of glass that shall be simple and yet embrace all substances to which the term is properly applied.

GLASS, CHEMICAL AND COMMERCIAL.—In chemistry many compounds of silica, borax, tin, antimony, and other substances are called glass, being known as "silicate glass", "phosphate glass", or "borax glass", according to the material of the compound. Indeed, any product of fusion that is hard and brittle and has the peculiar luster called vitreous is chemically known as glass. Commercially, however, the word glass is, with few exceptions, chiefly the enamels applied only to the silicates, or the compounds of silica, generally in the form of sand, with lime, soda, potash, the oxide of lead, and similar bases. The manufactured glass of commerce, however, is not a simple silicate, but, with one exception (water glass), is a fused mixture of two or more simple silicates. Flint glass, for example, is a double silicate of potash and lead; window-glass a tersilicate of potash, soda, and lime. In the process of manufacture, however, these simple silicates are not first separately produced and then fused, but the making of the "metal", as the fused glass is termed, is a double process, though a continuous one, the simple silicates of lime, or soda, or lead, or potash, as the case may be, being first formed in the pot of the glass-maker from the materials charged, and then, without any break in the continuity of the process, these simple silicates are fused in the same pot, and at the same melting, into the vitrified, non-crystalline material we know as glass. (*a*)

CHIEF CONSTITUENTS.—It will thus be seen that the principal and essential constituents of glass are silica or sand and an alkali, or sometimes a metallic oxide. The chief alkalies used are soda, lime, and potash, and the chief oxide is that of lead. Other oxides, as those of zinc, tin, and antimony, are sometimes used; and other materials, as manganese, oxide of iron, arsenic, etc., are found in glass, but they are there as impurities, or as materials used to correct impurities.

VARIABILITY OF COMPOSITION.—While these are the chief constituents, and while it is possible to indicate approximately the composition of the different kinds of glass, this composition, even in different specimens of the same kind, is by no means definite. The relative quantities of silica and the alkalies vary greatly. Flint or lead glass, for example, is made harder or softer as the proportion of sand is increased or decreased, though in these varying degrees of hardness it would be termed a silicate of potash and lead. The crystal, flint glass, and Strass of Ure's classification differ greatly in their properties, appearance, and composition, but each is regarded as a silicate of potash and lead. In a word, while glass is regarded as a chemical compound—a silicate—unlike most chemical compounds, it has no fixed definite composition in the several varieties. Indeed, though constant attempts have been made to produce as a commercial article a glass of that fixed, definite composition that experience has shown to be the best for a given kind, but little success has been attained, except, perhaps, at times at the celebrated plate-glass works of Saint-Gobain, France. The conditions of manufacture, especially in melting and the varying quality of the ingredients, preclude this. (*b*)

APPROXIMATE COMPOSITION.—Keeping in mind this variability in the composition of glass, the proportion of the essential ingredients in the chief varieties included in the report of the special agent may be given approximately as follows:

Kinds of glass.	Silica.	Soda.	Lime.	Potash.	Oxide of lead.	Oxide of iron.	Alumina.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cast plate	74.0	12.0	5.5	5.50	.....	.....	.....
Window	73.0	13.0	13.0	.....	.....	.....	.....
Lead flint	52.0	.....	.....	13.67	33.28	.....	.....
Lime flint	73.3	14.5	12.7	.....	.....	.....	.....
Green bottle	60.0	.....	20.0	3.00	.....	1	10

DIFFICULTY OF CLASSIFICATION CHEMICALLY.—It has been as difficult to make a classification of glass as to define it. This difficulty chiefly arises from the variability of composition, already noted, as well as from different writers considering glass from different standpoints, some regarding it chemically, others commercially. The

a Ure defines glass as "a transparent solid formed by the fusion of siliceous and alkaline matter". (See *Ure's Dictionary*, article, Glass.) Fownes, in his *Chemistry*, says: "Glass is a mixture of various insoluble silicates with excess of silica, altogether destitute of crystalline structure." Lardner, in his *Cabinet Cyclopædia*, includes "all mineral substances which, on the application of heat, pass through a state of fusion into hard and brittle masses, and which, if then broken, exhibit a lustrous fracture". The definition of Dr. Benrath, of Germany, recently published, is perhaps the best. He says: "By glass, in the technical sense of the term, we understand a silicate or silicate mixture which at a high temperature is thin fluid, and which, as the temperature falls, passes gradually through the tenaciously fluid into the solid condition; in which, furthermore, the unassisted eye can perceive no crystalline structure, and which is impenetrable to both liquid and gaseous fluids."

b A discussion of the reasons for this lack of uniformity of composition belongs properly to chemistry.

classification used in late English works, that of Ure, (*a*) is not at all satisfactory, as while it professes to be a chemical classification, it is neither that nor a commercial classification. It seems well-nigh impossible to make a chemical classification that shall be satisfactory. (*b*)

DIFFICULTY OF CLASSIFICATION COMMERCIALLY.—A similar difficulty, though from other causes, presents itself in any attempt to classify glass on any basis, especially on a commercial basis. The names that have attached themselves to the different kinds of glass are almost innumerable. Without attempting a classification, then, that shall be complete, it will be sufficient for the purposes of this report, as it chiefly considers glass as an article of commerce, to mention some of the most prominent of these commercial varieties. (*c*)

CLASSIFICATION.—In gathering the statistics of glass at the present census a classification into four general varieties was used. This classification, somewhat extended, to include sub-varieties not made in this country, is as follows:

1. PLATE-GLASS is glass which is cast upon a flat, smooth, cast-iron table and immediately rolled into sheets or plates of a required thickness by heavy rollers. Without being allowed to cool, the plates are laid in annealing ovens. It is chemically a silicate of lime and soda or potash.

Rough plate is the crude plate-glass as it comes from the annealing oven.

Rolled plate, or *rolled cathedral plate*, is rough plate from one-eighth to one-quarter of an inch in thickness.

Ribbed plate is a rough plate, with regular corrugations or ribs.

Polished plate, to which the term plate-glass is usually applied, is the rough plate that has been submitted to the successive operations of grinding, smoothing, and polishing to prepare it for use for windows, mirrors, etc.

These are the only varieties of plate-glass produced in this country, and are all the varieties that are produced from cast glass. Formerly a blown glass, made somewhat heavier than sheet or window glass, and called *blown plate*, was made in England, and is still made in Germany to some extent.

Patent plate is also a name applied in England to ordinary sheet glass ground and polished by Chance's patent process.

2. WINDOW-GLASS.—This is more properly termed *sheet* or *cylinder glass*. It is the ordinary window-glass of commerce, and is blown in cylinders, which are opened and flattened out into sheets, some as large as 60 by 40 or 80 by 30 inches. It is a silicate of lime and soda or potash.

Colored or *painted glass*, so far as the same is used for windows, may be included in this class. This is a silicate of lime and soda with the necessary coloring matter. It receives different names, according to the method of applying the color. It is termed *pot metal* (*d*) when the color permeates the whole body of the glass, *flashed* or *double glass* (*d*) when the colors are confined to the surface, and *stained glass* when the colors are burned into the surface in the glass-stainer's kiln.

Crown-glass is also a variety of blown window-glass that is no longer made in this country, though it is still made in England. It is first blown, and then by peculiar and very skillful manipulations formed into a circular table with a bullion or bull's-eye in the center. From this table moderate-sized window-plates are cut which show a crowned surface.

3. FLINT GLASS.—This term has a wide application, and includes table and other glassware, both blown and pressed, chimneys, and a large class of bottles and vials, articles often differing widely in chemical composition.

---

a This classification is as follows (see *Dictionary of Arts*, etc., article, "Glass").

1. Soluble glass: a simple silicate of potash or soda, or both of these alkalies.
2. Crown-glass: a silicate of potash and lime.
3. Bottle-glass: silicate of lime, soda, alumina, and iron.
4. Common window-glass: silicato of soda and lime, sometimes also of potash.
5. Plate-glass: silica, soda or potash, lime, and alumina.
6. Ordinary crystal glass: silicate of potash and lead.
7. Flint-glass: silicate of potash and lead.
8. Strass: silicate of potash and lead, still richer in lead.
9. Enamel: silicate and stannate, or antimoniate of potash, or soda and lead.

We must remember with regard to this table that crown-glass always contains soda, that alumina and iron are accidental, not essential, constituents of bottle-glass, and that enamels vary greatly in their composition. Tin is not present in transparent enamels.

b Tomlinson's classification, quoted in *Lippincott's Encyclopædia of Chemistry*, vol. ii, page 3, is one of the best.

c It may be well to note that glass is divided into two general classes, natural and artificial glass, and these are again subdivided. Natural glass is that produced entirely by natural agencies, without any assistance from man. It includes the mineral obsidian, an impure, semi-transparent glass, varying in color from gray to black, found in the vicinity of volcanoes, and which was used in the manufacture of works of arts by the ancient Romans and Egyptians, and in later times by the Mexicans; and the fine capillary glass called Pelé's hair, found at the volcano of Kilauea, in the Sandwich Islands, and water glass, found in certain springs. Water glass is also found absorbed in certain basaltic rocks, and attempts have been made, with considerable success, to use decomposed basalt for manufacturing bottle-glass. Artificial glass is that produced in the arts. It includes, in addition to that made in the glass houses, various slags resulting from metallurgical operations, as blast-furnace slag, which is a lime glass with an excess of lime, and slag-wool, which is an artificial Pelé's hair. It also includes many chemical glasses. A classification of glass according to method of manufacture is also sometimes made as "cast glass", "blown glass," and "pressed glass". A classification according to use also sometimes obtains as window-glass, bottle-glass, chemical glass, and one, according to place of manufacture, as Venetian, Egyptian, etc.

d Pot metal and flashed glass are also made in flint glass.

It includes *lime glass* or the *common flint*, sometimes also called *German flint*, and, by many American manufacturers, *crystal glass*. It is a silicate of lime and soda or potash. The celebrated Bohemian glass is a lime glass, as is also the "*Gobeleterie*" of the French, which is a silicate of lime and soda, potash being used only in a better glass.

A second general subdivision of flint glass is:

Lead glass.—This is a silicate of potash and lead which has literally the ring of metal, and is distinguished from the lime glass by this ring and its greater specific gravity. It is also, as a rule, more brilliant. This glass is the crystal (*cristaux*) of the French and the true flint of the English.

Strass is a glass very rich in lead, used in the manufacture of artificial gems.

Optical glass is both a lead and lime glass, the former known in instrument-making as flint, and the latter as crown, but differing from the "crown" mentioned under "window-glass". These glasses are of different densities and refractive powers, and are used in the manufacture of achromatic object-glasses. The terms "flint" and "crown" glass are, according to Bontemps, applied on the continent of Europe exclusively to optical glass.

4. GREEN GLASS.—This is a coarse, greenish glass, often termed bottle-glass, it being used chiefly for common bottles. It is called in this country hollow ware, though the German *hohlglas*, or hollow glass, comprises all glass worked into the form of vessels or tubes. The American green glass is a silicate of lime, soda, alumina, and iron, the last two ingredients being found as impurities in the sand, the iron giving the glass its greenish hue.

To these varieties might be added many others, which it would exceed the scope of this report to mention. There are some varieties, however, that deserve notice. Among these are water glass, or soluble glass, a silicate of soda or potash, or both, which is highly alkaline, and is used in the manufacture of soap, as a vehicle in painting, a mordant in fixing colors, in the preparation of artificial hydraulic cement, and in the silification of calcareous stone.

Enamel is a silicate, borate, stannate, or antimoniate of potash or soda and lead.

Hardened, toughened, or *tempered glass* is not annealed, as is usual with glass, but is tempered in a hot, oily mixture, as in M. de la Bastie's process, or in peculiarly constructed molds, as in Siemens' process.

Spun glass is a glass drawn into threads finer than silk and woven into small articles.

Ground glass.—The obscuring of the surface of sheet glass or flint-glass is accomplished by the friction of a stone wheel, or a movable rack with pebbles or little stones, water, and sand, or by the sand-blast, or by the fumes of hydrofluoric acid.

In *figured* and *cut glass* the ground surface is removed in set forms and designs by the use of wheels of stone, wood, or cork, or by the use of hydrofluoric acid, producing both—

Etched and embossed glass.

Iridescent glass is a reproduction by art of the beautiful iridescent colors of ancient glass that has been long buried.

To these varieties may be added the beautiful products of ancient and modern Venetian glass mentioned in the chapter on modern glass.

SPECIFIC GRAVITY.—The specific gravity of glass is a property of considerable importance in connection with the manufacture of object-glasses for achromatic telescopes and of artificial gems, though in the production of common glass but little attention is given to it. In general the power of refracting light increases with the increase of its specific gravity, though density and power of refraction are not strictly parallel.

The specific gravity of glass, as well as its brilliancy, varies with its composition, the heavier glasses being the most brilliant, as well as the softest. Lime glass is the lightest, bottle-glass comes next, and lead glass is the densest. Its density is also influenced by the degree of heat to which it has been exposed during its vitrification, being always least when the temperature has been greatest. The following are the specific gravities of the glasses named:

Lime glass:	
Bohemian	2.396
Plate-glass:	
Saint-Gobain	2.488
Cherbourg	2.506
Window-glass	2.732
Bottle-glass	2.732
Lead glass:	
Common flint	2.9 to 3.255
Optical	3.3 to 3.6

CONDUCTIVITY AND TENSION.—Glass is a bad conductor of heat and electricity, but all kinds are not equally adapted to become insulators, glasses rich in alkali being bad insulators. The tension and enforced equilibrium in the interior of a mass of glass rapidly cooled, as exhibited, for example, in Prince Rupert's drops, is well known.

TENSILE AND CRUSHING STRENGTH.—The tensile strength of glass is given at from 2,500 to 9,000 pounds per square inch, according to kind; crushing strength, 6,000 to 10,000 pounds per square inch. A sample of Millville

(New Jersey) flooring glass, one inch square and one foot between the end supports, broke under a certain load of about 170 pounds. These facts would indicate that glass is considerably stronger than granite, except as regards crushing, in which the two are about equal.

DEVITRIFICATION.—The devitrification of glass is one of its most important properties, not only because of its bearing on the manufacture and manipulation of glass, but because the devitrified glass, often called Reaumur's porcelain, can replace porcelain for most of its uses. Devitrification is a crystallization of glass, the ordinary glass being non-crystalline. In the manufacture of glass by the ordinary process it is cooled suddenly, the excessive brittleness and internal tension thus caused being reduced by annealing. On the other hand, when the fused metal is cooled slowly, the mass assumes a crystalline structure, becomes tough, fibrous, opaque, much less fusible, so hard as to cut other glass, is not so easily filed, and is a better conductor of electricity and heat.

DEVITRIFICATION IN ITS RELATION TO MANIPULATION.—This property exerts a great influence in the manufacture of glass. It explains, indeed, why, in the making of bottles, so much care is taken to avoid the repeated reheating of the mass which is to be formed into these articles. It would be thoroughly devitrified in a short time; the glass would become hard, difficult to fuse, and would present a multitude of solid grains disseminated in a matter still soft. In the same manner it is evident why green glass, and even common white glass, and still more so bottle-glass, can only be shaped by the lamp of the enameler, when the work is performed with great dispatch. If he work so slowly that he is obliged to reheat several times the glass tube which he is blowing. the mass devitrifies, and all the phenomena show themselves which have just been described. In vain does he then try to blow a bulb, as all the force of his lungs will not avail, and the glass is no longer soft. Beside, the material then becomes striated, semi-opaque, and almost infusible.

OTHER PROPERTIES.—These and the other properties of glass, together with its wide range of uses in the arts, contribute to render it one of the most curious and interesting of manufactured articles. Composed of materials that are opaque and of but little luster or brilliancy, it is itself exceedingly brilliant and of a most beautiful polish. Perfectly transparent, unless impure, and transmitting light freely, it may readily be obscured or ground so as to soften and diffuse the light. It can be cut in various forms, increasing its richness and brilliancy; it may be engraved in most charming and delicate tracery and figure-work, or it may be tinted with any color, either opaque or transparent, without the least loss of brilliancy or polish. Though not malleable, (*a*) its ductility is so great that it may be spun in a moment into filaments as small as a spider's web and miles in length, or blown to such gauze-like thinness as to float upon the air. The synonym of brittleness itself, its elasticity as spun glass permits of its being readily bent and woven into cloth, and even tied into knots, while a ball of glass dropped upon an anvil will rebound two-thirds the distance of its fall. Though hard and brittle when cold and incapable of being wrought, when heated it is softened, tenacious, and pliable, and is capable of being molded into any form, while it retains in cooling its beautiful polish. In ordinary use glass resists the action of water and alkalies, and, with a single exception, of all acids, preserving all its beauty, retaining its surface, and not losing the smallest portion of its substance by the most frequent use. (*b*)

EXTENT OF THE USES OF GLASS.—For many centuries these properties of glass have caused it to be admired and sought for by all classes. It was the material of many of the most common utensils in the Roman household in the days of the empire, when porcelain was unknown, as it is of our homes to-day. Not only is it thus devoted to common uses, but art, taking advantage of its properties, has given us the grace and beauty of the Portland, Naples, and Milton vases, the almost unearthly splendor of the emblazoned windows of the mediæval churches, and the rare color and graceful design of the well-nigh imperishable mosaics. To use the words of Dr. Johnson:

> Who, when he first saw the sand and ashes by casual intenseness of heat melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life as would in time constitute a great part of the happiness of the world? Yet, by some such fortuitous liquefaction, was mankind taught to procure a body at once in a high degree solid and transparent, which would admit the light of the sun and exclude the violence of the wind, which might extend the sight of the philosopher to new ranges of existence, and charm him at one time with the unbounded extent of the material creation and at another with the endless subordination of animal life, and, what is yet of more importance, might supply the decay of nature and succor old age with subsidiary sight. Thus was the first artificer of glass employed, though without his own knowledge or expectation. He was facilitating and prolonging the enjoyments of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures, and was enabling the student to contemplate nature, and the beauty to behold herself. (*c*)

ANALYSES OF GLASS.—In the accompanying tables will be found analyses of plate-, window-, flint-, and bottle-glass.

---

a One of the problems regarding glass alleged to have been asked by Aristotle was, "Why is glass not malleable?" The statements about malleable glass may be regarded as fables.

b This is strictly true of glass only under circumstances of ordinary use. All glass is affected by caustic alkalies, especially in concentrated solutions, as it is thus deprived of silicic acid. The action of mineral acids upon well-compounded glass is less energetic, though not only such acids, but even pure water, exerts a decomposing influence upon glass, producing its effect, however, very slowly under ordinary circumstances.

c *Rambler*, No. IX.

ANALYSES OF PLATE-GLASS.

Kinds of glass.	Analysts.	Silica.	Soda.	Potash.	Lime.	Magnesia.	Manganese.	Sesquioxide of iron.	Alumina.
French:									
Saint-Gobain	Peligot	73.00	11.50		15.50				
Saint-Gobain (sulphate)	Pelouze	73.05	11.79		15.10				
French	Dumas	75.90	17.50		3.80				2.80
Do	do	73.80	12.10	5.50	5.60				3.50
English:									
Chance's	Benrath	70.71	13.25		13.38			1.92	
Chance's (second quality)	do	72.90	12.45		13.26			1.93	
British Plate-Glass Company	Mayer and Brazier	77.36	13.06	3.01	5.31			0.91	Trace.
London-Thames Plate-Glass Company	do	78.68	11.36	1.34	6.09			Trace.	2.68
Belgian:									
Charleroy	Benrath	73.31	13.00		13.34			0.83	
German	Jaeckel	72.31	11.42	14.96					0.81
Hanoverian	Emmerling	73.79	13.94	0.60	8.61	0.12	0.32	0.68	0.58
Venetian	Berthier	68.60	8.10	6.90	11.00	2.10	0.10	0.20	1.20

ANALYSES OF WINDOW-GLASS.

Kinds of glass.	Analysts.	Silica.	Soda.	Lime.	Alumina.	Sesquioxide of iron.
French	Dumas	68.00	10.10	14.30	7.60	
Do	do	69.65	15.22	13.31	1.82	
English	do	69.00	11.10	12.50	7.40	
Chance's	Cowper	71.40	15.00	12.40	0.60	
Russian	Benrath	71.27	20.10	8.14	1.98	

ANALYSES OF FLINT-GLASS.

Kinds of glass.	Analysts.	Silica.	Soda.	Potash.	Lime.	Lead.	Magnesia.	Manganese.	Sesquioxide of iron.	Alumina.
LIME GLASS.										
French	Pelouze	72.10	12.40		15.50					
Do	do	77.30	16.30		6.40					
French tubes	Berthier	69.20	3.00	15.80	7.60		2.00		0.50	1.20
Bohemian tubes	Rowney	73.13	3.67	11.49	10.43		0.26	0.46	0.13	0.30
Bohemian drinking-glass	Berthier	71.70	2.50	12.70	10.30		0.20		0.30	0.40
Bohemian common glass	Dumas	69.40		11.80	9.20					9.60
American, O'Hara Glass Company, Pittsburgh	De Brunner	71.92	14.55		5.14		2.04	Trace.	Trace.	6.22
LEAD GLASS.										
English crystal	Faraday	51.93		13.67		33.28				
English crystal, London	Berthier	59.20		9.00		28.20			0.40	
Do	Salvétat	57.50	1.00	9.00		32.50				
English crystal, Newcastle	Berthier	51.40		9.40		37.40			0.80	1.20
French crystal	Sauerwein	48.10		12.50	0.60	38.00			0.50	
Do	Salvétat	51.00	1.70	7.60		38.20			1.30	
Do	do	54.20	0.90	9.20		34.60			0.50	
Do	Benrath	50.18		11.62		38.11			0.40	
Flint-glass	Faraday	44.30		11.75		43.05				
Do	Dumas	42.50		11.70	0.50	43.50				1.80
American, New England Glass Company	Fletcher	53.98	6.71	7.60		29.78			1.93	
Do	do	54.12	5.58	7.98		31.27			1.05	

ANALYSES OF BOTTLE-GLASS.

Kinds of glass.	Analysts.	Silica.	Soda.	Potash.	Lime.	Magnesia.	Manganese.	Sesquioxide of iron.	Alumina.
French:									
Sauvigny	Berthier	60.00	3.10		22.30		1.20	4.00	8.00
Saint-Étienne	do	60.40	3.20		20.70	0.60		3.80	10.40
Épinac	do	59.60		3.20	18.00	7.00	0.40	4.40	6.80
Sèvres	Dumas	53.55		5.48	29.22			5.74	6.01
Clichy	do	45.60		6.10	28.10			6.20	14.00
Bohemian champagne bottles	Maumené	58.40	9.90	1.80	18.60			8.90	2.10
Do	do	62.21	5.69	1.91	22.93			6.10	1.16
Do	do	63.34	4.17	2.10	21.34			4.42	4.72
German	Benrath	69.82	18.28	1.50	7.82			2.58	
Do	do	62.78	19.14	11.24	6.11			0.73	
Do	do	64.41	15.76	10.50	5.81			3.52	
Russian	do	65.77	11.75		16.58			5.90	
Do	do	68.38	19.03		10.19			2.40	

Chapter III.—SAND.

Different proportions of silica in glass.—The chief constituent of glass, as well as the only one that enters into the composition of all its varieties, is silica. Though present in all glass, its relative proportion differs greatly, not only in the several varieties, but in different samples of the same variety, and sometimes in different specimens from the same pot or "melting". Indeed, as to its content, not only of silica, but of other ingredients, glass is a most capricious substance.

Silica in different kinds of glass.—Lead glass contains the least percentage of silica, ranging from 42 to 60 per cent., and cast-plate contains the greatest percentage, some analyses showing as high as 79 per cent., the average being about 74 per cent. Window-glass averages about 70 per cent., lime-glass 72 per cent., and green bottle glass 60 per cent.

Hardness.—The hardness of glass depends, as a rule, on the percentage of silica it contains, though it is somewhat affected by the alkali or oxide used as a base. Lead, for example, tends to make glass softer and more fusible and lustrous, while lime renders it refractory and less susceptible to the action of acids and alkalies. The relative hardness of different specimens of either lead or lime glass depends, however, on the amount of silica, that being the harder and less liable to melt which has the most. It would follow, from what has been said, that green glass is the hardest, followed in their order by lime-flint glass, window-glass, plate, and, lastly, lead glass, which is the softest.

Forms of silica used.—Silica is now used in glass-making almost universally in the form of sand. This also seems to have been the practice at the earlier glass houses. (*a*) In modern glass houses, however, until some fifty years since, silica for the finer grades of glass was procured by an expensive process of crushing and washing flint (*b*) and quartz. This process is still used to some extent, especially in those districts where good sand either cannot be obtained or is too expensive to permit of its use. Bohemian glass, for example, is made almost entirely from quartz so prepared. In some parts of Germany and Austria, especially in the making of bottles, certain siliceous rocks, as basalt and trachyte, containing large percentages of soda and potash, are used, but at the present time, and for many years, sand has supplied most of the silica used in glass. Sand is generally less expensive, and in many cases is of greater purity and value as a material, glass made from many native sands being superior in every respect to that made from the artificially-prepared flint and quartz sands. (*c*)

Uses of the different grades.—For the finer grades of glass, especially where freedom from color, perfect transparency, and great brilliancy are essential, only the purest qualities of sand can be used, as slight impurities, especially small amounts of iron, will seriously impair all of these desirable properties. When, however, color is secondary to cheapness of production, as in the manufacture of green bottles, sands with considerable iron and clay are not only used, but in some cases are preferred, as these materials are fluxes, and consequently require less flux in the "batch" or mixture of materials.

Impurities and their removal.—The chief impurities in sand are oxide of iron, alumina, generally in the form of clay, loam, gravel, and organic matter. Most of these can be removed by burning and washing, (*d*) but the iron and part of the organic matter can only be removed or neutralized by the use of chemicals. Of these impurities iron is by far the most dreaded, as it not only destroys the "color", the limpid whiteness of the glass, giving it a greenish cast, but it is exceedingly difficult to remove or neutralize its effect. Manganese is used to correct this

a This is not universally true. Agricola says, in Book XII of *De Re Metallica*, that "white stones, when melted, are the best ingredients for glass". Pliny states that "of white stones very transparent glass is made".

b From this use of flint in its composition is derived the term "flint-glass".

c As showing what but a few years ago was regarded as nearly pure sand, it may be mentioned that Dr. Lardner, in his *Cabinet Cyclopædia*, London 1832, article, "Porcelain and Glass," page 28, gives an analysis of flint which he terms "silica in a state nearly approaching to purity". This flint contained 98 per cent. of silica and 0.25 per cent. of iron. Compared with the Berkshire sand, which contains 99.78 per cent. of silica and virtually no iron, this flint was very impure silica.

d Burning is necessary where the sand contains much organic matter. Generally the heat of the furnace in the melting of glass is sufficient, the carbonized matter being carried away as carbonic acid by the aid of arsenic. In washing the sand to remove the clay, gravel, loam, and similar impurities, it is first crushed and pulverized, if necessary. The pulverizer used at some of the works of this country is the well-known ore-mill of the rolling-mills, which consists of a large circular pan, in which revolve, like wagon-wheels, two large cast-iron wheels four feet in diameter. Running water pouring into the pan facilitates the grinding and carries the sand to a sieve, where the larger pieces and the gravel are separated. The sieve is cylindrical or octagonal, made of brass wire, about three feet in length and a foot and a half in diameter, and revolves like a flour-bolting machine. After passing through the sieve the sand is carried along a trough by water into the washer, where it settles to the bottom of the box, while the water "wastes" over the top, carrying away the clay and loam. The sand is then elevated and discharged into another trough at a higher level, where it is again washed. Sometimes this operation is repeated several times. The sand is finally carried to the draining-room, where it is drained of water, and then to the drying-room, where it is dried by artificial heat. As the sand dries it drops into a funnel-shaped trough, and from that passes into a conveyer, and thence to an elevator. The sand comes from the drier fine and almost as white as flour.

greenish color, and is often termed "glass-maker's soap", but glass so decolorized is liable under the action of sunlight to acquire a purplish tint or "high color". Window-glass in which manganese has been used often assumes this tint to such an extent as to lead to the belief that it was originally colored. The only safeguard against this "high color" is the use of sand containing little or no iron, and therefore not requiring any "doctoring" of the batch. (*a*) As to the amount of iron allowable in sand for glass-making, it may be said that that containing more than one-half of one per cent. is not considered suitable for any glass, while for plate- and window-glass and the finer grades of table ware the less the amount of iron the better. That used at the table-glass houses in the neighborhood of Pittsburgh and near Boston contains only a trace of iron.

USE OF ARSENIC.—The organic matter which carbonizes in the pot during the melting of the glass materials is removed as carbonic acid by the use of arsenic, which is the great "decarbonizer" in glass-making, as manganese is the "decolorizer". The arsenic is added to the batch prior to charging it into the pots.

TESTS OF SAND.—In examining sand as to its value for glass-making the best test is microscopic examination. Sand should be perfectly white, not very fine, uniform, even grained, with angular rather than rounded grains. Sand which is very fine, or the grains of which are smooth and rounded, can only be used with difficulty and great uncertainty as to the result. Such sand is liable to settle to the bottom of the batch, preventing an even mixture, of the materials and producing an uneven glass. Sand should not effervesce or lose color when heated with an acid, as loss of color indicates the presence of clay, loam, or other foreign substances, while effervescence indicates the presence of lime. Oxide of iron can be discovered by boiling the sand in hydrofluoric acid and dropping into the solution thus formed a few drops of yellow prussiate of potash in solution. The beautiful blue precipitate indicates the presence of iron, even in the most minute quantities.

ANALYSIS AND COLOR NOT ALWAYS INDICATIVE OF THE QUALITY OF SAND.—These are simple, qualitative tests, but only indicate in a general way the quality of the impurities present. For an accurate knowledge of the quantity a quantitative analysis is necessary. It should, however, be noted that while such an analysis, aided by the appearance and color of the sand, indicates in some measure its purity and value, it is by no means conclusive as to its adaptability for glass-making, as a sand of a yellowish tint may be purer than one much whiter. Mr. Henry Chance, of Birmingham, England, whose two papers on crown and sheet glass are the best in the language, speaking of color and analysis as indications of purity and value, says:

> The sand used by our firm is obtained from Leighton Buzzard, and, although of a yellowish tint, is more free from iron than many kinds of sand which are whiter in appearance. The whiteness of a sand is a very uncertain test of its purity. Again, two kinds of sand which are shown by analysis to be precisely similar in their composition may produce different results as regards both color and quality of glass. (*b*)

Mr. Chance suggests that this may be due to a difference in the power of the sands, arising from the condition in which the silica exists, to neutralize the bases.

MODE OF OCCURRENCE OF SAND.—Most of the sand used in glass-making occurs as sandstone, and is quarried in blocks, and must be crushed and prepared for use. The Fontainebleau (France) sand and some of the Berkshire (Massachusetts) and Juniata (Pennsylvania) sands are of this character. In other cases, while the sand occurs as rock and must be quarried, it rapidly disintegrates on exposure to air and moisture, as at some of the Juniata (Pennsylvania) mines. At other quarries, where the formation is saccharoidal or sugar-like, the sand-rock has a very weak bond, and is readily detached from place with a pick, rapidly falling into fine sand. This is the nature of the sand at Crystal City, Missouri, and at some of the Berkshire (Massachusetts) mines.

SEA OR RIVER SAND.—While most of the sand used is quarried or mined, some glass is still made, as was the earliest glass, from river or sea sand. As a rule, however, this is only employed for the coarser and cheaper kinds.

IMPORTANCE OF GOOD SAND.—The quality of the sand has always been an item of great importance to glass manufacturers, and the possession of a pure sand well adapted to glass-making has determined in many cases the location and successful operation of the glass houses, not only of antiquity, but of modern times. The sand used in the earliest glass works was river or sea sand, and these ancient factories were, therefore, generally placed at the mouths of rivers, as at Belus, Alexandria, Cumes, and Volterno. These locations were selected, not only because they furnished an abundance of good sand, but because they were the great doorways of commerce, and offered a ready market for the products of the glass-makers' art.

SAND FROM THE RIVER BELUS.—The most remarkable and widely-used deposit of glass sand known to the ancient world, as well as the purest, was that of the river Belus, which flows from Mount Carmel and enters the sea near Tyre and Sidon, the sand made famous by Pliny's oft-repeated fable of the discovery of glass. Not only was glass made in great quantities from this sand by the skillful Sidonians (*c*)—the lovely Greek and other vases, the varied beads and amulets found in the tombs so thickly scattered over every shore "washed by the Mediterranean

a For the results of a most ingenious and long-continued series of experiments on the action of sunlight on glass those interested are referred to the monographs of Mr. Thos. Gaffield, of Boston, Massachusetts, especially to his paper on "The Action of Sunlight on Glass", read before the American Association for the Advancement of Science at Boston in 1880.

b On the Manufacture of Glass. A lecture delivered before the members of the Chemical Society, March 19, 1868, by Henry Chance, M. A. London. Harrisons & Sons: 1868.

c Homer ascribes every object of art or ornament to the skill or genius of a god or a Sidonian.

sea"—but many of the glass works of other countries drew their supplies of sand for their best glass from this river of the Phœnicians. The Venetian glass works sent boats thither in the days of their greatest renown to collect sand for the factories of Venice and Murano, and it is more than probable that the brilliant mosaics of Saint Mark, and the delicate and precious vases and wares that have reflected so much honor upon Venetian glass, owe some of their marvelous color and beauty to the purity of the Phœnician sand; indeed, it was believed at one time that it was the only sand that could be vitrified. (*a*)

Other river and sea sands.—The sands from the banks and coasts of other rivers and seas were also used largely in the ancient glass-houses. Those of Egypt used Nile sand; the Volterno and the rivers of Gaul and Spain furnished sand for the glass made on their banks, while in latter times the Tyne, in England, has been a source of supply for the bottle houses of that district. Pliny mentions that in his time a fine white sand was found on the shore between Cumæ and Liternum which produced "*vitrum purum ac massa vitri candidi*". He adds that in Gaul and Spain sand was similarly used.

Early use of flint and quartz.—Though sea and river sand was thus the earliest form of silica used in the manufacture of glass, flint and quartz were employed at least before the beginning of the Christian era. Pliny states that glass of the most excellent quality was made in India from white stones. If any glass was made in India in Pliny's time, the use of quartz was probably exceptional, as most of the glass of that time and for some centuries after was made from native sand. From the fourteenth to the nineteenth century, however, it was made from flint or quartz. Agricola, who wrote in the sixteenth century, declares that white stones make the best glass, and should only be employed in the manufacture of crystal. Neri, who wrote in the seventeenth century, notes:

> That those stones which strike fire with a steel are fit to vitrify, and those which strike not fire with a steel will never vitrify; which serves for advice to know the stones that may be transmuted from those that will not be transmuted into glass.

Blancourt, who wrote at the close of the same century, states that the Venetians make use of a white flint from the river "Ticinus, where there is a great abundance of them; as also in the river Arnus, both above and below Florence, and in other places". He also mentions the use of a hard white marble which is found in Tuscany, and gives directions that "that ought to be chosen out which is very white, which has no black veins, nor yellow nor red stains in it".

Ferrandus Imperatus makes mention of a glass stone called "quocali", "like in appearance to white marble, being somewhat transparent, but hard as flint, and put into the fire it turns not to lime. It is of a light green, like a serpentine stone, and having veins like Venice talc. This being cast into the fire, ceases to be transparent, and becomes white and more light, and at length is converted into glass."

When Blancourt wrote, sand was displacing flint, a degeneracy in the art of glass-making which he laments "Nothing," he says, "but the Parcimony and Covetousness of the times has brought sand into use again, because glasses made of that may be afforded cheaper."

Superiority of American sand.—As has already been stated, sand is almost universally used in the glass houses of to-day, quartz or flint being used only when good sand cannot be readily obtained. The superiority of the deposits of glass sand in the United States is universally conceded. At the London exposition of 1851 Messrs. Thomas Webb & Son, of Stourbridge, England, exhibited some glass of remarkable beauty and transparency made from Berkshire (Massachusetts) sand. They write me regarding this sand: "It was the *finest* we have ever used". Bontemps, whose eminence as an authority on all matters pertaining to glass cannot be questioned, in his report to the English government on the Paris exposition of 1855 states that a "magnificent sample of English flint-glass", Osler's candelabrum, the glass of which he asserts to be far superior to that of any other exhibitor, "was made with American sand." (*b*) In his *Guide du Verrier*, one of the best works on glass in any language, M. Bontemps also several times speaks of American sand as superior to the best French. (*c*) Mr. Henry Chance, in a lecture on glass, speaks of American sand as the "finest of all", and states that the best flint-glass exhibited at the Paris exposition of 1867, that of Messrs. Copeland, of Stourbridge, "surpassing in purity of color all other specimens of glass, whether British or foreign, (*d*) was made from American sand." But little of this sand, however, has been used in England. The great expense of importing, and the discovery of the excellent German sands, which are referred to on page 27, which can be supplied to the English glass works at a much less cost, have interfered with the use of the American sand.

English sand.—But little sand suitable for the finest grades of glass, such as plate-glass and the lead flint, is found in Great Britain. One of the earliest used in modern times in England was obtained from the commons near Lynn, in Norfolk, and was used by the manufacturers of the north and the midlands for many years. This was displaced by sand from Alum bay, in the Isle of Wight, which furnished for fifty years most of the silica used for flint-glass. An analysis of this sand shows only 97 per cent. of silica, 2 per cent. of alumina, magnesia, and oxide of iron, and 1 per cent. of moisture. Stony Stratford, Aylesbury, Reigate, and Hastings have

---

a See *Strabo Geography*, Book XVI.

b *Reports on the Paris Universal Exposition*, Part II, *Report on Glass*, by G. Bontemps, pages 384 and 385. London, 1856.

c See *Guide du Verrier*, G. Bontemps, pages 46 and 532. Paris, 1868.

d *On the Manufacture of Glass*, by Henry Chance, page 3.

contributed sand to the English glass houses at different periods, and perhaps the best England has produced, except the Alum Bay variety, was that from Hastings; but an unfortunate advance in price drove the trade to France, which at that time took off its export duty, and so opened the markets of England to the French sand. (*a*)

SAND FOR ENGLISH PLATE-, WINDOW-, AND FLINT-GLASS.—The makers of the best flint-glass now use the French and German sands exclusively. The magnificent exhibit at the Paris exhibition of 1878 of Thomas Webb & Son, of Stourbridge, was made from these sands. Some of the manufacturers of plate-glass use Belgian sand; others the sand which is found in large quantities in Lancashire. (*b*) Messrs. Pilkington Bros., the large makers of blown window-glass at St. Helen's, use the Lancashire sand. Messrs. Chance, of Birmingham, obtain the sand for most of their glass from Leighton Buzzard, about 40 miles north of London; but for their optical glass, which is very noted, they use French sand. Most of the English sand requires washing. A fair average analysis of the Leighton Buzzard sand, which may also be regarded as showing the composition of the Lancashire, is 99 per cent. of silica, 0.30 per cent. of alumina, 0.20 per cent. of carbonate of lime, and 0.50 per cent. of oxide of iron. Large deposits of sand are found in Wales as sandstone, but the glass produced from it does not seem to be good in quality or in color.

SAND FOR BOTTLE-GLASS.—Regarding sand for the English bottle works, Ure states that—

> The laws of this country (England) till lately prohibited the use for making common bottles of any fine materials. Nothing but the common river sand and soap-boilers' waste (manganese) was allowed. (*c*)

As to the present practice, Mr. Chance writes:

> I believe that bottle-glass makers, color being a matter of minor importance, use whatever sand of a suitable character may be nearest to their works. Or, to put it in another form, a bottle-glass maker will place his works where he can have his sand and other materials as near at hand as possible.

FRENCH SAND.—Of the French sands, that taken as sandstone from the quarries in the forests of Fontainebleau is the best and the most widely used. Much of the finest glass of England and Belgium, and, until recently, of Germany, is made from it, and it is to its purity that the beautiful color of the French and Belgian plate-glass is attributed. One analysis shows: silica, 98.8 per cent.; magnesia and oxide of iron, 0.7 per cent.; moisture, 0.5 per cent. Another, and one that Mr. Henry Chance regards as an average analysis, shows: silica, 99 per cent.; alumina, 0.50 per cent.; carbonate of lime, 0.50 per cent.; oxide of iron, trace. Sand from the quarries in the forest of Compiègne, and also from the vicinity of Nemours, is largely used, and is stated to be "almost chemically pure and scarcely inferior to that imported at great cost from the United States". (*d*) In the south of France prepared quartz is still used. (*e*) The same statement as to sand for bottle-glass made in connection with English sand will apply to the French bottle houses as well. French manufacturers of this kind of glass locate their works where the materials are the cheapest, without reference to the purity of the sand. (*e*)

BELGIAN SAND.—Concerning Belgian sand but little has been learned. Bontemps mentions a locality near Namur which he classes with the French sands of Fontainebleau, Compiègne, and Nemours. (*f*) While the quality of the Belgian sand is on the whole good, it does not equal the French, and as a result considerable of the latter sand is used in the Belgian works.

GERMAN SAND.—For many years the best German glass was made either from French sand or prepared quartz and flint. Certain glass works on the Bohemian border still use the prepared quartz or flint for making window-glass and a good white glass for table ware, and a few, by reason of shorter and cheaper carriage, still draw their supplies from France. All the other works, with the exception of certain bottle houses, use German sand.

BEST GERMAN SANDS.—The sand for the plate-glass, window-glass, and the glassware houses of Germany comes chiefly from two very extensive deposits, one at Herzogenrath, near Aix-la-Chapelle, and the other in the Niederlausitz, near Hohenbocka, in the province of Brandenburg, in Prussia. These sands are exceedingly pure, one rivaling the Berkshire (Massachusetts) sands, as will be seen from the analyses on page 34.

---

a A recent English journal contains the approximate dates at which these several deposits of sand became available.

Lynn	1750
Alum bay	1820
Aylesbury	1835
Stony Stratford	1835
Reigate	1835
Hastings	1856
Brooklyn	1851
Fontainebleau (France)	1860

It further remarks that it is more than probable that some of the northern manufacturers on the Tyne and Wear used sea-borne sand at the earliest period of glass-making. "It is possible that Venice may have sent us a supply when she sent us her glass-makers."

b For this and the following facts regarding the sand used by English glass-makers I am indebted to the kindness of Mr. Henry Chance, who has written to me very fully on this subject.

c *Ure's Dictionary*, vol. 1, page 925. New York, 1854.

d Bontemps' *Report on the Exhibition of* 1855, page 385.

e See Bontemps' *Guide du Verrier*, page 48.

f *Idem.*, page 46.

HERZOGENRATH SAND.

	Per cent.
Silicic acid	99.24
Alumina	0.20
Lime	0.053
Magnesia	0.033
Oxide of iron	0.005
Water	0.469

HOHENBOCKA SAND.

[Analysis by Bischof.]

	Per cent.
Silicic acid	99.760
Alumina	0.040
Lime	0.011
Magnesia	0.012
Oxide of iron	0.055
Oxide manganese	0.015
Potassium	0.039
Loss by ignition	0.240

Some of the German flint-glass works still use the Fontainebleau sand, and a few window-glass and lamp-chimney works, especially in Silesia and Westphalia, find it more profitable to use a white sand found near their works; but most of the German glass, with the exception of green glass, is made from sand from the two deposits of which analyses are given above.

USE OF ALKALINE ROCKS FOR BOTTLE-GLASS.—For bottle-glass the same conditions hold as noted before, only the German bottle-glass makers endeavor to find material containing as much alkali as possible. Mr. Julius Fahdt, the editor of *Die Glashütte*, Dresden, to whose courtesy I am indebted for much of the information regarding German sand, writes regarding the siliceous material used in bottle works:

> The most favorable deposits are of thanolite, found on the frontiers of Bohemia, on the banks of the Elbe; granite is also used, and is found frequently with 5 per cent. of alkalies (potassium and sodium); basalt, fluor-spar, and trachyte are used. Granite and trachyte are calcined and ground; basalt, fluor-spar, and thanolite are not calcined. Sometimes for light-colored glass a small proportion of white sand is used.

Mr. Friederich Siemens, who, in addition to his well-known scientific attainments, is the largest manufacturer of bottles in Germany, if not in the world, writes as follows regarding the use of these rocks:

> For common green bottle-glass the German and Austrian glass-makers use natural stones, such as granite, feldspar, basalt, thanolite, and trachyte. These rocks, containing a certain quantity of alkali, with 65 to 75 per cent. of silica, are a most valuable material, being both cheap and fusible. I began the use of these rocks for making bottle-glass at the time of the introduction of my continuous glass-melting tanks, some ten years ago, and other glass-makers very soon adopted my method of making glass from these rocks.

The success that has attended the use of these alkaline rocks in Germany and Austria should lead our glass-makers to attempt their use.

AUSTRIAN SAND.—For native sand, for its finest grades of glass, the works of Austria-Hungary depend almost entirely upon Germany, the Hohenbocka deposit furnishing the larger part, the Herzogenrath bed not being so situated as to supply them. This German sand is so well adapted to glass-making that it is carried long distances, and is used in close proximity to extensive quartz mines. This is true of certain glassware factories in Styria, which use this sand exclusively. This German sand is not only as pure as the best and most carefully prepared quartz, but, notwithstanding the great distance over which it is transported, it is much cheaper than the prepared quartz. Mr. Fahdt gives the relative cost of sand and prepared quartz in Vienna as follows: 1 centner (123.46 pounds) sand, including freight, 1 reichsmark (24 cents); prepared quartz, 1.47 florin (72 cents) per centner; that is, 3 to 1 in favor of the sand. Many Austrian glass works, however, still use quartz. In Bohemia, for example, the most renowned manufacturers use only the prepared quartz sand.

SAND FOR COMMON AUSTRIAN GLASS.—For the common grades of glass the works depend on the sand-beds in their immediate vicinity. The remark in regard to the use of thanolite, basalt, etc., in Germany, will apply to Austrian bottle manufacture as well.

SWEDISH SAND.—In Sweden quartz is still used to some extent, the glass houses having been located with reference to the supply of this material. Most of the native sand used comes from the shores of lake Wetter, the best from the north end of the lake. The sand for the best glass is imported from France.

QUALITY OF AMERICAN SAND.—The superiority of American sand has already been referred to. Not only does this country furnish the purest and best sand, but extensive deposits of a grade suitable for the manufacture of the finest glass exist in many localities. If in the quality of the metal, or in brilliancy of our glass, we are behind our European competitors, it is not attributable to our sand. These deposits are also in many cases well situated in reference to fuel and to transportation. As examples of these deposits, those of Berkshire county, Massachusetts; Juniata county, Pennsylvania; Hancock county, West Virginia; Fox river, Illinois; and Crystal City, Missouri, may be instanced. These are all exceedingly pure sands, as the analyses given will show. The first named is used very extensively by the flint-glass makers of the East. The Juniata and the Hancock sands supply

many of the works of Pittsburgh and Wheeling. Fox River sand supplies the plate-glass works of New Albany, Jeffersonville, and Louisville, and Crystal City furnishes the sand for the fine plate-glass made at that place.

NEW ENGLAND SAND.—At present all of the sand used in the glass works of New England comes from Berkshire. In this section sand for some works, being of a good quality, was at one time procured from Demerara, brought as ballast. The war of 1812 cut off this source of supply, and Plymouth beach furnished sand until a better was discovered at Maurice river, New Jersey. This was in turn superseded by the Berkshire sand. (*a*) It is stated that an embargo put upon the exportation of flint stones from England to this country at a time when it was believed that no flint was to be found here led to the suspension for a time of certain factories in which prepared flint was used. Berkshire county also furnishes most of the sand for the best flint-glass made in New York, New Jersey, and eastern Pennsylvania. The sand for the window and green glass made in the interior of New York, as well as part of that used in Ontario, comes from Oswego and Oneida counties; that used for common glass near New York city, as well as all through New Jersey and eastern Pennsylvania, is mined in New Jersey. Some sand for the Philadelphia glass houses is procured in West Virginia.

NEW JERSEY SAND.—The sand used in the southern part of New Jersey is chiefly derived from a deposit of sand which can be traced through the state. This sand is uniform, and is often used, without washing, for the manufacture of window-glass.

MARYLAND SAND.—A good glass sand is found at Will's mountain, near Cumberland, Maryland, of which Dr. Chandler, of the School of Mines, Columbia College, New York, says: "I am satisfied that the sandstone is in every respect well fitted for the manufacture of glass of the best quality."

SAND FOR THE PITTSBURGH AND WHEELING GLASS HOUSES.—The large quantities of sand required in Pittsburgh and Wheeling and the factories in their neighborhood come from various points in the Allegheny mountains, mainly from Juniata and Fayette counties, Pennsylvania, and Hancock county, West Virginia. A new deposit is reported from the latter place, which it is claimed analyzes 99.90 per cent. of pure silica.

ILLINOIS SAND.—The Fox River sand, some 60 miles from Chicago, is also a very valuable deposit. No analysis of this sand has been made, but it supplies the plate-glass works at New Albany, Jeffersonville, and Louisville, and some of the flint-glass works of the West. It is a beautiful sand, needs no washing, and has given the very best results in use.

MISSOURI SAND.—The Crystal City deposit is also one of the most important beds in the West, and is of great purity and inexhaustible in quantity, and the cost of mining is merely nominal. There is also a deposit of considerable importance at Pacific, Missouri, which seems to be of the same formation as that at Crystal City. The sandstone from this mine hardens instead of disintegrating by the action of air, but water, to a certain extent, breaks the bond. This sand is regularly supplied to the glass works at Cincinnati and many of the works in the West, except those making plate-glass. The mine produces about 1,750 tons per month.

EXTENT AND LOCALITY OF OTHER AMERICAN SANDS.—I have only referred to the most important of the sand-mines from which our glass houses draw their supplies. The extent of the deposits of sand suitable for glass-making that are not developed, or, if opened, worked only to a limited extent, is almost incalculable. The saccharoidal sandstone of Missouri, for example, has been traced for miles through some ten counties, the vein varying from 80 to 133 feet in thickness. At Minneapolis and Saint Paul a rock 175 feet thick is found, furnishing a good quality of glass sand. (*b*) In many states other than those named glass sand has been discovered and reported upon by the state geologists and chemists, and these reports contain descriptions and analyses of many excellent glass sands, of which, as yet, no use has been made. To those reports those desiring information as to the character and extent of these deposits are referred.

ANALYSES OF GLASS SAND.—In the following table will be found analyses of the most prominent glass sands in Europe and this country:

ANALYSES OF FOREIGN GLASS SANDS.

Constituents.	FRANCE.		ENGLAND.		GERMANY.	
	Fontaine-bleau.*	Fontaine-bleau.†	Leighton Buzzard.*	Alum Bay.†	Herzogen-rath.‡	Hohen-locka.§
Silica	99.00	98.80	99.00	97.00	99.240	99.760
Alumina	0.50	.....	0.30	.....	0.200	0.040
Lime	.....	.....	.....	.....	0.053	0.011
Magnesia	.....	.....	.....	.....	0.033	0.012
Manganese	.....	.....	.....	.....	.....	0.015
Sesquioxide of iron	Trace.	.....	0.50	.....	0.005	0.055
Carbonate of lime	0.50	.....	0.20	.....	.....	.....
Magnesia and sesquioxide of iron	.....	0.70	.....	.....	.....	.....
Water	.....	0.50	.....	1.00	0.469	.....
Alumina, magnesia, and sesquioxide of iron	.....	.....	.....	2.00	.....	.....
Phosphorus	.....	.....	.....	.....	.....	0.039
Loss	.....	.....	.....	.....	.....	0.240
Total	100.00	100.00	100.00	100.00	100.00	100.172

*Authority: H. Chauco. †Authority: Spon. ‡Authority: Julius Fahdt. §Authority: Bischof.

a Reminiscences of Glass Making, by Deming Jarves, second ed., page 111. New York, 1865.

b Report on Glass, by Mr. Charles Colné, assistant secretary of United States commission to the Paris Exposition of 1878, page 314.

ANALYSES OF GLASS SANDS OF THE UNITED STATES.

Constituents.	MASSACHUSETTS, BERKSHIRE COUNTY.					NEW JERSEY.		PENNSYLVANIA.		Will's Mountain, Cumberland, Maryland. ‖	Speer, Hancock county, West Virginia. ‡	MISSOURI.	
	Gordon's.*	Gordon's.*	Brown's.*	Cheshire quartz, A.	Cheshire quartz, B.	Downer's, Glassborough, †	Hilliard's, Maurice river. †	Speer's, Fayette county. †	Juniata county. §			Crystal City. ¶	Lincoln county. **
Silica	99.78	99.61	99.69	.....	.....	98.824	98.850	99.720	98.84	98.35	99.90	99.62	99.55
Alumina	0.22	0.39	0.31	.....	.....	0.935	0.980	0.080	0.17	.....	.....	.....	0.33
Lime	.....	.....	.....	.....	.....	0.056	0.056	0.110	Trace.	.....	.....	.....	0.08
Magnesia	.....	.....	.....	.....	.....	0.015	0.022	0.06	Trace.	.....	.....	.....	.....
Chlorine	.....	.....	.....	.....	.....	0.0054	Trace.	.....	.....	.....	.....	.....	.....
Manganese	.....	.....	.....	.....	.....	.....	.....	.....	Trace.	.....	.....	0.07	.....
Sesquioxide of iron	.....	Trace.	Trace.	.....	.....	0.165	0.130	Trace.	0.34	0.42	.....	.....	Trace.
Iron	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....
Various	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.22	.....
Undetermined	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Loss	.....	.....	.....	.....	.....	.....	.....	0.030	0.23	.....	.....	.....	.....
Total	100.00	100.00	100.00	.....	.....	100.0004	100.038	100.000	99.48	.....	.....	100.00	99.96

* Authority: S. Dana Hayes.
† Authority: Professor Cook.
‡ Authority: Otto Wuth.
§ Authority: A. S. McCreath.
‖ Authority: C. F. Chandler.
¶ Authority: Crystal City Plate-Glass Company.
** Authority: Chauvenet.

CHAPTER IV.—ALKALIES AND OTHER MATERIALS.

CHIEF BASES USED IN GLASS-MAKING.—As has already been stated, the essential elements of glass are silica, which acts the part of an acid, and some one or more bases, either alkaline or metallic. The bases most commonly found in glass are soda, potash, lime, and oxide of lead. These bases, however, are not mixed in the "batch", as the combined materials ready for melting are termed, in the form in which they are found in the glass. Soda, for example, is not used in the glass houses as soda, but as the carbonate (soda-ash) or sulphate of soda (salt-cake), or as chloride of sodium (common salt) or nitrate of soda. In the process of melting these compounds are decomposed, the soda uniting with the silica, forming the glass, the balance of the compound passing off as gas or in the "glass-gall" or "sandiver", as the scum on the top of the melted glass is called.

ANCIENT GLASS A SODA GLASS AND PERISHABLE.—Glass is frequently named from the base that enters most largely into its composition, as "soda glass", "potash glass," "lime glass," and "lead glass". Ancient glass was a soda glass containing from 3 to 8 per cent. of lime, the lime being present as an impurity, and not as an ingredient purposely used in its manufacture. It is to this impurity, however, as will be seen further on, that we doubtless owe the preservation of many of the specimens of ancient glass that have come down to us. Soda glass, or glass with an excess of soda, is really soluble glass, even dampness in course of time disintegrating it. Blancourt, in the amusing preface to his *Art of Glass*, states that Venetian glass "will dissolve in the earth or in cold and moist places if there be more salt in it proportionately than sand". Bernard Palissy notes the disintegration of the glass in the windows of the churches of Poitiers and Brittany, and ascribes it to "the damp and rain which have melted part of the salt of the glass". As most of the specimens of the glass-makers' art of the ancient world have come to us buried in *tumuli* or tombs, it is probable that even the fragments of most of this ancient soda glass have dissolved, and that only has been preserved which contained considerable lime and was buried in localities calculated to preserve it from dampness.

SOURCES OF SUPPLY OF SODA FOR ANCIENT GLASS HOUSES.—The chief source of supply for soda for the earliest glass houses was Egypt. Phœnicia obtained its supply from that country; and Pliny, in his description of glass-making at Rome, states that "sand and Egyptian soda in the proportion of one part of sand to three of crude soda were used". Not only did these very early glass houses obtain their soda from Egypt, but until a somewhat recent period the "natron of Egypt" was largely used in glass-making in Venice and the south of France. This Egyptian soda, which contained carbonate, sulphate, and muriate of soda, is found native on the banks of the natron lakes that abounded in a valley extending northwest from Memphis, and by reason of its abundance was the seat of a large glass industry, remains of ancient glass works being found there by the scientists of the Egyptian expedition of Napoleon I.

MODERN SOURCES OF SODA.—In modern times, and until within the last few years, the chief source of soda for glass has been the ashes of certain plants, chiefly those of the sea and sea-shore. Among the saline products of these ashes so used were the Spanish barilla from the ashes of the *salsola* plant; the Scottish and Irish kelp, which as late as sixty years ago furnished the soda for the English crown- and sheet-glass; the barec or varec of Bretagne and Normandy; and the Spanish soda of Alicant and rochette of Syria. These products contained potash and some lime as well as soda, and were simply mixed with sand and melted. They were quite impure, and, as a result, the glass produced, compared with that of to-day, was inferior, being exceedingly variable in character and poor in color.

LEBLANC'S DISCOVERY OF SODA-ASH.—The unsatisfactory quality of these impure sodas (the best, the Spanish barilla, containing only from 14 to 30 per cent.), as well as the limited quantity produced and uncertain supply, led the French government to offer a prize of 12,000 francs for the discovery of a method of converting common salt into soda. Leblanc not only secured the prize by his discovery of 1792, but opened a new era in glass-making. (*a*) The plate-glass manufacturers of France were the first of the glass-makers to use the new product, the carbonate of soda or soda-ash, and were soon followed by the makers of window-glass, with a decided improvement in quality and color.

USE OF SALT-CAKE.—The carbonate of soda prepared by Leblanc's method contains a considerable proportion of undecomposed sulphate, and the glass manufacturers soon found some advantage in the cost of glass by the substitution of this sulphate, or "salt-cake", for the carbonate. As early as 1781 experiments were made with sulphate of soda, and in 1803 Baader began its use in the glass houses of the Bavarian forests; but it was not until 1825 that it was employed in the French glass houses. In England kelp was used until 1831, when it was displaced to a large extent by carbonate of soda. The introduction of sulphate was still more recent, but at present nearly all the window-glass of England and the continent is made with salt-cake. The manufacturers of plate-glass still use soda-ash, as they believe that it produces a glass of a somewhat better color. In this country, though many experiments had previously been made, but little sulphate was used until about 1875, soda-ash being the form of soda employed for window-glass. Messrs. Robert C. Schmertz & Co., of Pittsburgh, were the first to use it regularly and continuously, but it is now largely consumed. Sulphate glass is less liable to devitrify or to become "ambitty", and will bear more lime than carbonate glass, and hence gives a harder glass with a better polish and less liability to "sweating". It is of a bluish color, while the carbonate glass is of a yellowish tint.

SOURCE OF SUPPLY OF SODA.—The chief source of supply of the soda of the present day is the alkali works of England, which are mainly located in Lancashire and near Newcastle-on-Tyne. It is estimated that the total annual soda production of the world expressed in terms of pure Na_2CO_3 is 708,725 tons, of which 432,000 tons are manufactured in Great Britain. Twelve per cent. of British soda and 23 per cent. of the total soda of the world are produced by the ammonia method. The English soda enters into the manufacture of the glass of most of the countries of the world, and is almost the only kind used in this country.

THE AMMONIA PROCESS.—In 1866 Mr. Ernest Solvay began at Brussels the manufacture of soda by a process that has since been called by his name, the Solvay, or, as it is sometimes termed, the ammonia process. This method bids fair to supersede the Leblanc. The Solvay soda is fully equal in quality to the Leblanc, and can at present be produced more cheaply. This has had a marked effect on the production of the Leblanc soda. Of twenty-five alkali works which were in operation in the neighborhood of Newcastle-on-Tyne, England, a very few years ago, twelve have been closed, and of these no fewer than eight were actually dismantled, in despair of its ever again being possible, except at a loss, to manufacture soda in them by the Leblanc process. The alkali-making districts of Lancashire have advantages over the Newcastle district in the price of salt, in facilities for supplying the American market, and in nearness to some of the centers of soda consumption; but even there seven or eight of the alkali works are standing idle, and but few of the others are working to their full capacity. In Belgium the production of Leblanc soda has died out, while in France, Germany, and Austria it is only maintained by the aid of import duties and the large demand for the by-product, hydrochloric acid. There are now eighteen ammonia-soda works running in Europe and one in the United States, and seven more are approaching completion. (*b*) This process is not only of interest to this country because of its cheapening the cost of soda, but also because it holds out the prospect that we may make our own soda for our glass works. The importance of such an industry to us may be gathered from a statement of the imports, which, for the three calendar years 1879, 1880, and 1881, were as follows:

	1879.		1880.		1881.	
	Quantity in pounds.	Value.	Quantity in pounds.	Value.	Quantity in pounds.	Value.
Soda-ash	81,072	$1,825,450	96,766	$2,345,461	74,158	$1,555,320
Caustic-soda	44,980	648,269	43,274	635,894	47,180	656,588
Sal-soda	66,471	424,414	53,896	155,497	48,797	138,768

a A full account of this discovery and its results may be found in Mr. Henry Chance's lecture "On the Manufacture of Crown and Sheet Glass", *Journal of the Society of Arts*, February 15, 1856.

b See paper by Mr. Walter Welden before the English Society of Chemical Industry.

MANUFACTURE OF SODA-ASH AND SALT-CAKE IN THE UNITED STATES.—Though the materials for the manufacture of soda-ash and salt-cake are to be found in great abundance in this country, but little is produced. Mr. Charles Lennig, of the Tacony chemical works, Philadelphia, produces some 1,500 tons annually of the sulphate, and the Merrimac Chemical Company, of South Wilmington, Massachusetts, and E. Gressili & Sons, of Cleveland, Ohio, were also producers at the close of the census year. The product of these works is used for window-glass, and is equal to any of foreign make, that of the Tacony works analyzing from 97 to 98 per cent. of sulphate, 1 per cent. of salt undecomposed, one-half to 1 per cent. of excess of sulphuric acid, and some little insoluble residue. As this sulphate or salt-cake is really a by-product or residuum of the manufacture of muriatic acid, its production in this country is limited by the demand for the acid. Recent developments and the ammonia process, however, promise to change this state of affairs. The salt-wells of Michigan and of New York have been looked upon as the source of a considerable supply, this view being held by British alkali manufacturers who have examined these localities. Recently a small works using the ammonia process in a modified form has been successfully operated in Michigan, and it is stated that the Solvay Process Company is erecting extensive works at Syracuse, New York.

USE OF COMMON SALT.—Both the carbonate and the sulphate of soda are prepared from common salt. This has led to many attempts to effect the direct union of silica and salt without the intervening process, but thus far with but little success. At present the only glass made from common salt is the black bottle-glass of Newcastle, England.

NITRATE OF SODA.—Nitrate of soda is used as an oxidizing agent in the "batch", and is therefore a decolorizer, though the soda enters the composition of the glass. The chief source is the beds in the province of Tarapaca, Peru; but some immense deposits have also been found in Nevada.

POTASH.—The use of potash in glass-making is comparatively recent, though some of the best and most expensive glass now made, such as the Bohemian white and the English flint, are potash glasses. Some few specimens of ancient glass show small quantities, from 1 to 2 per cent., which was probably derived as a chance material from the sodas prepared from plants and weeds, in which some potash is always present. As early as the fifteenth century, if not earlier, the value of potash as a glass-making material was known, and it appears that at that time potash made from the lees of wine was used in the Venetian glass houses. In France, in the middle ages, potash made from fern was used. The enormous forests of America began very soon after the discovery of this continent to furnish large quantities, and enormous tracts of timber have been burned solely for the ashes. Blancourt, at the close of the seventeenth century, speaks of the use of potash from wood-ashes, and mentions Virginia and New England as sources of supply for the latter. The sources of supply at the present time are many. Much of that used in modern glass houses is still made from wood-ashes, about 20,000 tons being thus produced annually, the Canadas and Russia furnishing the larger part, though the Bohemian glass manufacturers procure theirs from the forests of Bohemia and Hungary. This potash, as it is made by lixiviating wood-ashes, is an impure carbonate, which must be calcined and refined, the quality of the glass depending upon the degree of purification. Refined potash is known as pearlash. Pure carbonate is also obtained from the alkaline residuum of the manufacture of nitric acid and from caustic potash. In France beet-molasses and the ashes of beet-cake and grape-cake have considerable value as sources of potash, some 12,000 tons per annum being made in Europe from the beet alone. Carbonate of potash, the form in which it is used in glass-houses, is also prepared artificially from the sulphate by Leblanc's method. Of the remaining salts of potassium, only tartar, the bitartrate of potassa, which is decomposed, when heated, into carbonate of potassium and carbon, finds sporadic application where it is required to use the finely-divided carbon of decomposed nitrate of potash as a reducing agent, for example, in the production of copper, ruby-glass, or ruby-fluor. The sulphate of potassa, though applied as long ago as 1826 by Long, in Constein, on the Danube, has never yet attained to general importance in the glass industry.

LIME is, next to silica, the most important of glass-making materials. It is a constituent of nearly all the glass of all ages and countries, with the exception of that made with lead, and it is even present in many specimens of lead glass, though, as before stated, its presence in ancient glass was probably by chance and not by design. The action of lime is to render the soda or potash glasses harder and less soluble, and, when used in the proper proportion in the "batch", to promote the fusion of the materials and improve the quality of the glass. An excess of lime, however, makes the glass too hard. In the manufacture of table ware lime furnishes a cheap substitute for lead, and, though as a rule the lime-flint is less brilliant than the lead-flint, many of the recent specimens of lime glass, especially those that are "fire-polished", are exceedingly beautiful, approaching in brilliancy the true crystal of the English flint houses. The makers of lime glass, however, do not, as a rule, seek to compete with lead glass in brilliancy, but in lightness and beauty of form, as is the case with the Bohemian glass-workers, or to furnish a cheap substitute for lead glass for articles of utility, as is the case with the pressed-ware manufacturers of this country or the manufacturers of "Gobeleterie" of France. Lime also enters largely into the composition of modern plate- and window-glass, giving it the hardness and insolubility necessary to protect it from the weather and prevent its "sweating", which is so marked a fault of glass with an excess of alkali.

USE OF LIME A MODERN DISCOVERY.—Though the true relation of lime to the manufacture of glass as a hardener and preserver is really a very modern discovery, and though the proper proportion of lime to soda and

potash has only been arrived at slowly and by many careful experiments, it is true that it was used to some extent in the glass houses as early as the days of Pliny. He says:

To the materials of glass they begin to add the magnetic stone; then they joined shiny stones of all kinds; then shells and fossil sands.

He also notes that the use of lime in his time was an advance in the art of glass-making. Ferrantes Imperatus recommends the shells of cretaceous fishes, as the oyster, as "very proper for making glass". Notwithstanding these indications that the use of lime was not entirely unknown from the time of Pliny, it has been but recently that its value as an essential constituent of glass has been recognized. Blancourt was somewhat afraid of it, and declares that "it is much stronger than ordinary salt", but directs that it "being well purified you may put two pounds of it to an hundred pounds of salt of Polverine", or soda. He would think the glass-makers of to-day, who, in some forms of glass use measure for measure, must be guided by "parcimony", of which he elsewhere speaks. It is probable that until very recently lime has been used only as a cheap substitute for soda and potash, the difficulty of using it in furnaces, constructed and heated as the older furnaces were, interfering with its adoption, until recent investigation had shown its value and recent improvements had made its employment possible.

SOURCES OF SUPPLY.—It is unnecessary to speak of the sources of supply of lime, as all glass-making countries have it in abundance, and it is used in the batch as chalk, lime, or limestone. Lime, however, that contains ferrous carbonate of iron must not be used in a mixture intended for white glass. Indeed, except for bottle-glass, it is important to have the lime, as well as all the other materials, as pure as possible. Mr. Chance notes that glass made with limestone is harder and more difficult to grind than that made with chalk, and it moreover causes the glass to cool and set more rapidly. In this country, however, limestone is coming into more general use, some of the Pittsburgh window-glass works using no lime at all, but only powdered limestone.

LEAD.—The use of lead as a glass-making material, except in the production of artificial gems, is an English invention of the seventeenth century, (*a*) and grew out of the use of mineral fuel in the glass houses of that country in the place of wood, which up to that time had been the fuel of glass-making, as it still is in many sections of the world. (*b*) This fuel required covered pots to protect the glass from impurities, which so reduced the amount of heat that reached the materials as to demand a better flux, and lead was substituted. The result was not only to permit the use of the cheaper fuel, but the production of that most beautiful and brilliant of all glasses, the English flint. Lead is used both as litharge and as red lead, and is a most powerful flux, promoting the fusion of materials at a very low temperature. The glass made with it is more dense, has a greater power of refraction, and is less liable to breakage from sudden changes of temperature. It is soft and is easily worked and scratched, but is of surpassing brilliancy, being only excelled by the diamond. The glass used for the manufacture of artificial gems is a lead glass, and it is to the employment of this material that they owe their brilliancy, while at the same time an excess of lead renders them soft and easily scratched; a fact that soon becomes apparent to the wearer of these gems. It is very probable that the use of lead in a small way in the manufacture of these gems, which antedated its use in flint glass, was the suggestion to the English that resulted in the discovery of the latter. Lead is also used in the manufacture of optical glasses, and the history of its use for this purpose is exceedingly interesting, but cannot be repeated here.

LEAD GLASS, WHERE MADE.—Lead is used in the manufacture of glass to a greater extent in England than anywhere else, though France and Belgium, and, to a less degree, Germany, make some true lead flint. In this country lead glass is made but to a limited extent. Some few factories still make lead-flint table ware and chimneys, but most of the table ware is lime glass. In the past, however, considerable lead glass was made here, and red lead of an excellent quality for glass is still made at East Cambridge, near Boston. The first lead furnace in the United States is believed to have been built by Mr. Deming Jarves, of the New England glass works, East Cambridge, in 1818, for the manufacture of lead for glass. This furnace was a success, and enabled the company to continue the manufacture of glass at a period when no foreign red lead was to be procured. (*c*) Red lead is generally preferred to litharge on account of its finer state of subdivision, and because its decomposition in the glass pot assists in purifying the materials, as an excess of lead not only makes the glass soft and gives it a yellowish tinge, but acts injuriously upon the melting vessels.

OTHER INGREDIENTS.—Among the other ingredients found in glass are the following: *Iron*, which is almost always present in several of the materials, especially sand, and is a most unwelcome element, imparting a greenish color to the glass. *Manganese* in the form of the black oxide is introduced to correct the action of the iron, but the researches of Mr. Thomas Gaffield, of Boston, show that the action of manganese as a decolorizer is not permanent. (*d*)

---

a Dr. Lardner, in his *Cabinet Cyclopædia*, says: "The manufacture of flint glass was begun in England in 1557 at Savoy House, in the Strand, and in Crutched Friars." Bontemps, in his *Report on Glass at the Paris Exposition of* 1855, shows that this is a mistake, so far as relates to lead flint, and states that it could not have been made prior to 1665.

b It seems that lead was used in the manufacture of glass much earlier than this, certainly in the Roman period; but it is still true that the English are entitled to the credit of its first use in lead glass as now made.

c *Reminiscences of Glass Making*, second edition, page 110.

d This is probably the "magnetic stone" of Pliny, and its use as a decolorizer has been known for centuries.

Carbon in the form of powdered charcoal, coke, or anthracite is used in "batch" of sulphate of soda to facilitate the decomposition of the sulphate. *Arsenic* promotes the decomposition of the other ingredients and the removal of carbonaceous matter. In excess, however, it produces milkiness. *Alumina* is almost always present in glass, generally from the action of the materials of the glass on the pots. *Cullet* is the waste glass produced in every manufactory, which, being more fusible than the new material, facilitates the melting.

Chapter V.—GLASS FURNACES AND POTS.

Early furnaces and glass houses.—But little is known regarding the form or construction of the furnaces used by the earliest glass-makers. One of the paintings at Beni Hassan, one of the earliest records of the art remaining, pictures an Egyptian glass-melter seated before an upright circular furnace about 2½ to 3 feet high and one-third this in diameter, from which he is evidently gathering the molten glass through a square hole at the bottom. This would indicate that the glass materials were charged at the top of the furnace and drawn at the bottom: an operation somewhat analogous to smelting iron, but one that would give very impure glass. If this was the practice of the early glass-makers, this method probably gave place at an early day to a crucible of some kind, in which the materials were melted, the heat being applied outside and fuel not being in direct contact with the glass. It is quite certain that the early glass-making furnaces contained until long after the beginning of the Christian era but a single small pot, the entire work of mixing, melting, blowing, and finishing being done at each little establishment by a single glass-worker, assisted in the earlier and less skilled part by slaves or servants, and the minute division of labor which is so distinguishing a feature of modern industrial life, and the aggregation of capital and workmen in one large establishment, were unknown in these early days, especially in industries in which so much depended on individual skill, and where the art was regarded as a mystery or secret not to be divulged. The great variety in form and character, and especially in the color of the glass of these works, as evidenced by the very many fragments remaining, would also indicate that glass-making was carried on not in large establishments, producing, as at the present day, quantities of glass of the same form and color, but in many little establishments, each working on a small scale, and each producing glass differing in color and shape.

Furnaces in Agricola's time.—Though we have but little knowledge of the early glass furnaces, it is well known that those of four hundred years ago did not differ much in principle or in construction from the ordinary direct-firing furnace of to-day. The description given by Agricola, one of the earliest of modern writers on glass, of the furnaces used at the beginning of the sixteenth century is so near like that given in Dr. Lardner's *Cabinet Cyclopædia* of fifty years ago that the latter can almost be regarded as a translation of the *De Re Metallica*. Agricola describes three forms of furnaces as in use in the glass houses of his time. In the first, called the "Fornax Calcaria", a small furnace somewhat resembling a bee-hive coke oven in shape, the materials were dried, purified so far as they could be by heat, and partially combined in a cindery or slaggy mass called "frit", which was afterward broken up and remelted in working furnaces. The greater purity of modern materials and the better methods of working have made this preliminary purifying and "fritting" unnecessary, and the term "frit" is now applied to the unmelted mixture of sand, soda, lime, etc., which is charged into the pots, or, in other words, to the "batch". Fifty years ago, however, this process of fritting was still in use. At the present time the calcar furnace or arch is only used to dry and calcine the sand, unless it may still be retained in some glass-making sections where the old methods are still in vogue, or as an annex to the bottle furnace, where impure materials are used. In some cases the calcar arch is used to heat the "batch" prior to "filling in", it being thought better to charge it heated into the hot pots.

Agricola's second furnace was the melting or working furnace. I quote the description of this as given by Blancourt, with his comments and improvements: (*a*)

> The second furnace or oven Agricola mentions is that where the workmen labor, or the working furnace; but the description he gives us of it is not just, for he makes all these ovens round, whereas they ought only to be round within, but oval without. Moreover, he adds two months in form of chimneys, wherein a servant throws coals day and night, which is no more now in use, since we only use dried wood, as I have observed, which also makes the iron grates he mentions for the mouth and ash-hole of no more use among us. This oven, whose diameter ought to be always proportional to the height, is divided into three parts, each of the three parts being vaulted. That below is the place where the servant flings in the wood to keep a continual fire, and without smoke; and this lower oven is called the crown, and the mouth the Bocca; but there is neither grate nor ash-hole, the wood being cast in on the coals, care being taken to take them out when there are too many with a great iron hollow shovel. This oven, made like a crown, to which Agricola allows but one hole in the middle

a See Blancourt, *Art of Glass*, London, MDCXCIX, pages 20–23.

of its height, about one foot in diameter, has, notwithstanding, several holes all round it for vent of the flame, which ascends into a second oven through the middle, where are placed the pots filled with the ingredients that make the glass, upon which that flame perpetually reverberates. The second part of this oven, whereof the vault is round, serves for the workmen. Agricola allots to each of these ovens eight arches; nevertheless we commonly make but six. Between each arch there is an opening or hole, made in fashion of a window, archwise, called the great work-hole, through which the pots are put in and those taken out which contain the metal. These great holes are stopped each with a cover made of the same lute and brick that the oven is, to preserve the workmen's eyes from the too vehement heat, and likewise to keep it the stronger in the oven. In the middle of every one of these covers there is a hole somewhat more than a palm wide, which is called the little working-hole, through which the workmen take with their hollow irons the colored or finer metal out of the pots, wherewith they make what sort of vessels they please. It serves also to scald their vessels when they have occasion, and which rest upon hooks made on purpose on the sides of those holes, which are called, according to their terms, the little working-holes. The upper vault of this furnace, which is above that where the metal is melted and the workmen work, serves to put the vessels that are new made upon, there to cool by degrees, that place having only a moderate heat; otherwise the vessels would break if they were too soon exposed to the cold air. We might also divide that upper vault into two, the half of it being enough for cooling the vessels; and on the other might be made *Balnæ Mariæ*, of diverse degrees of heat, sand furnaces, or of ashes for purifications, digestions, distillations, and other uses, and may serve for the preparation of the ingredients wherewith we make tinctures for glass and crystal, whereof we shall treat in the sequel of this book. The ovens of the great glass houses are round within and oval without, like those of the little glass houses whereof we have already made mention; but there is this difference: that any ingenious workmen can build those of the little glass houses, but there is only one race of masons in all France who have the secret of building the great ones. They came from Caule, in the county of Eu, and those only can succeed in it. What and how nice observations soever others have made to imitate them, there was never any one yet could arrive to it, insomuch that all those who have any great glass houses throughout the whole kingdom are obliged to have recourse to that family to build their furnaces, and that for want of a due proportion which must be observed, because they must have three degrees more of heat than the little glass houses, and one inch difference in the arch and body of the oven is enough to spoil the whole process. These ovens are built like those we have before mentioned, except as to the proportions which augment the heat three degrees beyond the others; they have six arches—two of which serve to heat the matter before you put it in the pots, and another to heat the pots before you put them into the oven when there is occasion to change them. In this oven each working-hole has but one pot in it, and in the farther end of the oven on the other side of the workmen there is a great pot, wherein the matter (or ingredients) is prepared, out of which you take it with an iron ladle of 10 or 12 feet long, to fill the pots of the gentlemen who work at the rate the pots are emptied; after that the great pot is filled again with other matter to be refined and prepared as before. The materials which serve for building these furnaces are bricks for the outward parts, and for the inner parts a sort of fuller's-earth, which is gotten from Beliere, near Forges, and which is the only earth in France which has the property of not melting in this excessive heat; and it is of this same earth that the pots are also made, which will hold the melted metal for a long time.

It will be noted that this oven of Agricola and Blancourt is virtually the direct-firing wood or coal furnace of to-day with the upper part above the reverberating arch used as an annealing oven. This third division is still in use in Bohemia for the same purposes as described by Blancourt.

MODERN FURNACES.—The glass-melting furnace of modern times is a modified form of the reverberatory furnace, which assumes different shapes, and is built of different sizes, according to the kind of glass to be made or the fuel used. Furnaces for plate-, window-, and bottle-glass are generally oblong or square, the pots being placed in two banks or rows, one on each side, while those for flint-glass are circular or elliptical. In the construction of furnaces the principal ends to be attained are the production and maintenance of an intense heat, (*a*) its uniform distribution through the furnace and around the pots, and its direct and most intense application to the fusion of the glass-making materials. Without entering into a detailed description of the varying shapes and sizes of the ordinary furnace in use in this country, it may be said in general that these furnaces consist of two parts, the combustion or melting chamber and the cave or ash-pit, which also serves as a draught passage. These are separated by the fire-grate and "siége", the raised bank or narrow platform in the melting chamber on which the pots are placed. The grate or fuel-space is square, and occupies the center of the furnace, and the fuel is charged generally from both ends. The grate is usually on the same level as the floor of the glass house. Under, and connected with it, is the arched subterranean passage or chamber known as the cave or ash-pit, extending the entire length of the furnace, both ends opening outside the building, thus forming a passage by which air for combustion is fed to the grate. Sometimes two of these passages, crossing under the grate-bars at right angles to each other, are built, so that either can be used according to the direction of the wind. There are doors at both ends of these archways to regulate the draught. Within the furnace around the grate space in the case of circular furnaces, or on both sides of it in quadrangular furnaces, is the raised bank or platform termed the "siége", on which the pots are placed. The fire thus lies below the bottom of the pots and in the center of the furnace. The number of pots in a furnace varies from four to eighteen or more. Each pot is reached for charging or working the metal by a small arched opening or working-hole in the side of the furnace, situated directly over the pot, except in the flint furnace, where covered pots are used. In this case the mouth of the pot is on a level with the working-hole, and the number of working-holes in a furnace thus equals the number of pots. Furnaces other than flint frequently have no chimneys or flues, the only exit for the products of combustion being the working-holes. As the fire is in the center, and the pots are around the sides, the flame is thus made to play around the pots, securing a most direct and intense heat. In some furnaces, however, there are as many flues or chimneys as there are pots, the flues

a There is a wide difference of opinion as to the heat of a glass-melting furnace. Sanzay, in *Wonders of Glass Making in All Ages*, New York, 1875, states it to be 1,000° to 1,500° C. The *Encyclopedia of Chemistry*, Philadelphia, gives the proper temperature of a glass furnace at 20,000° F. This last figure is doubtless a "guess", and it might as well have been put at 50,000°. Mr. Page, of the Berkshire (Massachusetts) glass works, gives the heat of a glass furnace as between 2,800° and 3,600° F., or an average of 3,200°.

being placed between. The same result, however, is obtained, the flame striking the pots on its way to the flues. Furnaces are often constructed with a double arch, the lower one the reverberating arch, the upper one forming the top of the furnace, and the space between the two arches forms a chamber for the reception of the products of combustion, which pass out by a common flue at the top. Frequently, instead of this outer arch, the outside walls of the furnace are curved up in the form of a truncated cone or open chimney, and in others the separate flues open into the glass house itself, which thus becomes a chimney, discharging the products of combustion at the top of the house. The roof of the furnace is arched, the arch being built as low as is consistent with stability, in order to reverberate or throw the heat with the greatest intensity upon the pots. The inside dimensions of these furnaces vary so much that it is possible to give only a general idea of their dimensions. A ten 44-inch pot window-glass or green-bottle furnace would be about 20 feet long by 12 feet wide; a ten 36-inch pot flint furnace about 12 to 13 feet in diameter, the materials used being fire-brick or sandstone, or both.

FUEL USED.—The fuel used in the early glass houses was wood, (*a*) which was dried or baked to expel all moisture before using. In view of the fact that even at the present time it is difficult to secure the intense and even temperature necessary to properly melt and "fine" glass with wood, the success of the ancient glass-workers is all the more commendable. It is possible that when only one pot or crucible was used this may have been surrounded with charcoal, and a more intense and even heat produced than with wood; but when furnaces with more than one pot became common, and the glass was thus melted by the flame playing on the pots, it would greatly increase the difficulty of melting with wood, and preclude the use of charcoal. It is generally stated that mineral coal was first used in England in glass-making in 1635 by Sir Robert Mansel, who obtained a monopoly of the manufacture of flint-glass in consideration of his being the first person who employed pit-coal instead of wood in his furnace. This, however, is not correct. Blancourt states:

> In the time of Agricola they made use only of coals in the glass houses; but the use of wood, which is among the moderns, is much better; for, being first of all thoroughly dried, it does not smoke like coal, which always makes the glass dull and obscure.

As Agricola published his *De Re Metallica* in 1546, Mansel's claim to being the first to use pit-coal can hardly be sustained. Indeed, it is disproved by the English records themselves, as before 1611 Sir William Slingsby had obtained a patent for making glass with sea-coal; and in 1615 a royal proclamation was issued prohibiting the use of wood in glass-making and ordering it to be made with sea- or pit-coal only. Sir Robert seems, like many a reputed inventor, to have filched the honor belonging to another. In England at the present time coal is almost exclusively employed, but of late years it has been found that oven-burned coke can be used to advantage, as it produces less smoke and soot, and is therefore better adapted to some of the finer glasses. In France both coal and coke, and sometimes wood, are used. Belgium uses coal exclusively. In Germany wood is largely employed, beside considerable peat and turf. Both coal and lignite are also used. Where wood is used, it is baked until brown, to expel all of the water, and peat must also be dry and afford only a small amount of ash. In this country coal is used almost entirely, though as late as 1865 wood was still used in Boston. It was the excellent quality of the coal at Pittsburgh that led to the erection of the first works in that city.

GAS FURNACES.—So far the description and remarks concerning furnaces apply more properly to what are known as "direct-firing" furnaces, or those heated by fuel charged directly into the fire-pot or hearth of the furnace. In 1861 the first successful gas furnace for glass, the now well-known Siemens furnace, was first used. In this and other forms of the gas furnace the solid fuel is first converted into gas in a producer outside of the furnace, and is then burned, generally in connection with heated air. This application of gas is one of the most marked and important improvements in glass-making of modern times. Beside the saving in fuel and the possibility of using inferior fuel which the gas furnace permits, it reduces the time of melting and increases the production as well as greatly improves the quality of the product.

THE SIEMENS' FURNACE.—The first use to which the Siemens' regenerative gas furnace was put, now so well known in all parts of the world, was the manufacturing of glass in pots. In using this furnace the principle and construction of the ordinary furnace were changed only so far as was necessary to apply the regenerative principle and heat with gas. In these furnaces the gas and air employed are separately heated by the waste heat from the flame by means of what are called "regenerators" placed beneath the furnaces. These are four chambers filled with fire-brick, stacked loosely in checker-work, the waste gases passing through one pair of regenerators and heating them, while the air and gas are being heated, prior to burning, by passing through the other pair, which had been similarly heated. When this second pair has been somewhat cooled the direction of the draught is changed, the waste gas passing through the cooled pair, heating them, while the air and gas are passing through the heated pair. This is again changed when the regenerator is cooled, and so the cool air and gas are passed alternately through each pair of regenerators, which are thus alternately cooled and heated. The economy of fuel is not only great, but the heat produced is intense, and actual working, it is claimed, shows a saving of 47½ per cent. of fuel over the direct-firing furnace in glass-making by the use of this furnace. (*b*) The loss in pots is reduced; and there are no "cutting drafts"

a Plutarch states that "tamarisk wood is the best for the glass furnaces".

b The saving of fuel in gas-firing is stated never to be less than 30 per cent., and is often as high as 75 per cent.

on the outside, the pots only cutting from the inside. The durability of the furnace is also increased. The following table shows the extent to which these furnaces were used in 1879:

SIEMENS' FURNACES USING POTS.

Countries.	Plate-glass.	Window- and bottle-glass.	Flint-glass.
Great Britain	5	5	2
France	7	4	11
Belgium	4	1	1
Other countries	6	10	15

SIEMENS' FURNACES WITH TANKS.

Great Britain	6

SIEMENS' FURNACES WITH CONTINUOUS TANKS.

Great Britain	4
France	10
Belgium	1
Other countries	3

USE OF SIEMENS' FURNACES IN THE UNITED STATES.—Though, as this table shows, the Siemens pot-furnaces are used to a considerable extent in all glass-making countries of Europe, but few have been built at the glass houses of this country. One reason, no doubt, is that good coal is so cheap at our glass-making centers as not to make economy of fuel a necessity, and in addition to this the heavy first cost of the furnace and the royalty asked have interfered with its adoption. Their use in this country during the census year was confined almost exclusively to plate-glass works.

Other forms of gas pot furnaces, however, have been recently introduced to some extent, especially in the vicinity of Pittsburgh. These are known locally as the Nicholson and the Gill furnaces. Of the principle of the former I have not been able to secure any description; but it is an improved form of a French furnace, and differs from the Siemens in not having the alternate regenerators. The dimensions of one built in 1880 for Messrs. McKee & Bros., glassware manufacturers of Pittsburgh, were as follows: Height of stack, 80 feet; diameter at the foundation, 22 feet 10 inches; in the furnace at the floor, 18 feet 10 inches in the clear, and contains 12 pots, each 44 by 60 inches, of a capacity of 3,800 pounds each, or 45,600 pounds at a single melt. It is expected to make four rounds and a half per week, equal to 102½ tons of metal. There are three large gas-producers, in which ordinary coal dust or slack, a very cheap material, is used. The so-called Gill glass furnace is an improvement on the Boetius principle, which has been so successfully used in Germany. This furnace has flues arranged around the outer walls of the fireplace, or in the walls between the fireplaces, for the purpose of conveying air to the combustible gases evolved from the fuel. It is claimed that its original cost is much less than the Siemens or any other form of gas furnace; that the direct-firing furnaces can be remodeled; that the heat received is intenser, more uniform, and is more easily controlled, while the quantity of fuel is much reduced below that of the ordinary furnace, and an inferior quality can be used. The life of the pots is also greater.

COMPARTMENT OR TANK FURNACES.—While the application of gas to pot furnaces marks a most important advance in glass-making, the invention of the tank furnace and its use with gas is a still more important and marked improvement, and promises to have a great influence on the future of the industry. In this furnace the use of the melting-pot is entirely abandoned. In the first Siemens tank furnace of 1861 the batch was charged, melted in, and worked from a tank which occupied the whole bed. This in use was found to have some drawbacks, and in 1872 a still further development of the tank furnace was effected by dividing the tank, by means of two transverse floating bridges, into three compartments, in the first of which the batch was melted, in the second the glass was refined, while the third held the thoroughly purified glass, from which it was worked out continuously. These floating bridges, however, were rapidly destroyed by the heat of the molten glass, and a still further improvement, which has largely increased the melting capacity of the furnace, has been made by the substitution of a floating refining vessel in place of the floating bridges. In this latest form the batch is charged from time to time through a door at one end of the furnace. The glass, upon melting, sinks and travels on toward the gathering holes, at the other end, in a partially refined condition. Opposite each gathering hole a refining vessel is floated, which gathers the molten glass at the lowest possible depth in the tank and raises it to the surface to be completely refined in a compartment prepared for that purpose, from whence, on sinking, it can only flow into the working-out compartment. From this last compartment the glass may be worked out continuously, the flow of the metal therein, and its assortment in the different stages of its manufacture, being entirely effected by the varying densities of the particles subjected to the heat of the furnace. Owing to this important feature it will be seen

that only the best glass, which is the heaviest, can reach the compartment of the vessels from which it is to be gathered, the imperfectly-melted metal remaining in the tank as long as needful for proper fusion. The refining vessels are made of pot clay, and vary somewhat in size and form, according to the character and quality of glass intended to be produced. The gathering compartment is sometimes made entirely open, sometimes covered wholly or partially with a hood; but in all cases the vessels are floated on the metal in the tank, and are constructed so as to be easily removed when worn out. By the employment of these refining vessels dividing bridges in the tanks are no longer required, and thus that part of the structure which in the first forms of continuous glass-melting furnaces was subject to the most wear is done away with. Another advantage is found in the circumstance that the ends of the blowing-canes, which sometimes break off in the glass, may be easily picked out from the bottom of a refining vessel, instead of its being necessary from time to time to empty a tank, in order to remove as useless the glass discolored by the accidental introduction of iron. The color of the glass made in a tank may be altered from time to time, as required, without interrupting the blowers; and for this purpose it is only necessary to cease charging batch into the furnace for a few hours, when some of the new glass mixture is introduced, and further charges are made at regular intervals. According to the productive capacity of a tank, the change of color will be effected in from three to five days, and only a few hundred-weight of mixed metal is formed, which has to be ladled out. For works requiring the regular production of glass of different colors or characters, in insufficient quantities of each sort to warrant the erection of a special furnace for each variety, the tank may be divided into two or more compartments, or several large pots may be set in a furnace, each of which shall have the desired number of refining vessels. By surrounding these pots with sand they will be much strengthened, so that they may be made larger than usual, and thus form several small tanks in one furnace, which can easily be removed when required. In this manner the continuous melting process may be applied to both large and small productions, and will therefore be of interest to all glass manufacturers.

The principal advantages resulting from the use of the continuous-melting furnaces are claimed to be:

1. Increased power of production, as the full melting heat may be employed without interruption, while with the old method of melting nearly one-half of the time is lost by cooling and settling the metal, the working out of the glass, and the reheating of the furnace.

2. Economy in working, as only one-half the number of men are required for the melting operations.

3. Durability of the furnaces, owing to the uniform temperature to which they are subjected.

4. Regularity of working and improved quality of the glass made.

5. Convenience to the men and advantage to the manufacturers, as owing to the continuous action the metal is always ready for the blowers, and the gatherers can draw the metal from a practically constant level.

6. For the manufacture of window-glass the working-out end of the furnace may be so arranged that the blowers can work without interfering with the gatherers. This would do away with the separate blowing furnace now in use.

The greater durability of the tank is not only due to the uniform temperature maintained, but also to the circumstance that the batch is charged in such quantities at a time as not to come into contact with either the sides or the bottom of the tank, which, consequently, are not suddenly cooled or eaten away by the mixture. Furnaces containing as few as four gathering-holes, while others of greater capacity—up to thirty-two gathering-holes—are now in operation, the latter being worked with a consumption of one ton of lignite per ton of glass bottles produced, which, having regard to the calorific power of that fuel, is equivalent to the small consumption of 10 hundred-weight of coal to the ton of glass melted, molded into bottles, and annealed. As showing the results obtained with the second style of tank we give the following statement from one of Mr. Siemens' pamphlets, showing the work done during five consecutive weeks in a continuous tank furnace by one of the extensive glass manufacturing companies of England. It should be noted that at the time this statement was taken the furnace was working but two shifts out of the twenty-four hours, whereas it can be as readily worked continuously three shifts in twenty-four hours:

Week ending—	COAL USED.			Batch.	BOTTLES DECLARED.		Number of chairs used on all shifts during the week.	Declared bottles per chair per shift.	BOTTLES DRAWN.		PER TON (2,240 POUNDS) OF BOTTLES DRAWN.		
	Producers.	Kilns.	Total.		Dozen.	Weight.			Dozen.	Weight.	Coal in gas-producers, exclusive of kilns.	Total coal, including kilns.	Batch.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*		*Pounds.*				*Pounds.*			
February 19, 1875	90,720	26,880	117,600	70,000	3,873	55,272	40	96.8	3,698	51,828	3,942	5,017	3,146
February 26, 1875	84,000	26,880	110,880	101,360	4,124	58,408	40	103.1	3,867	54,600	3,449	4,547	4,144
March 5, 1875	80,640	26,880	107,520	84,000	4,057	57,008	40	101.4	3,733	52,416	3,427	4,592	3,584
March 12, 1875	73,920	26,880	100,800	88,480	4,450	66,276	45	98.9	4,070	56,364	2,912	3,987	3,516
March 19, 1875	78,400	33,600	112,000	112,000	4,960	67,872	49	* 101.2	4,609	62,608	2,800	3,987	3,987

* One chair missed a journey.

The accompanying diagrams, from drawings kindly furnished me by Messrs. Richmond & Potts, of Philadelphia, give an idea of this furnace, Figs. 1 and 2 showing a four- or six-hole window-glass furnace, which at any time

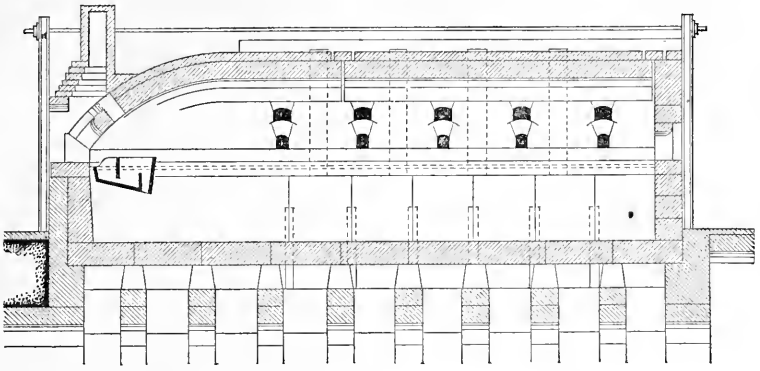


Fig. 1.

may be doubled in capacity by adding the same number of blowing- and gathering-holes at the other end and charging at the center.

These double-end furnaces are in use in Europe with the best satisfaction. No Siemens' tank furnaces were in operation in this country in the census year. One was building at Poughkeepsie, and has since been started, but

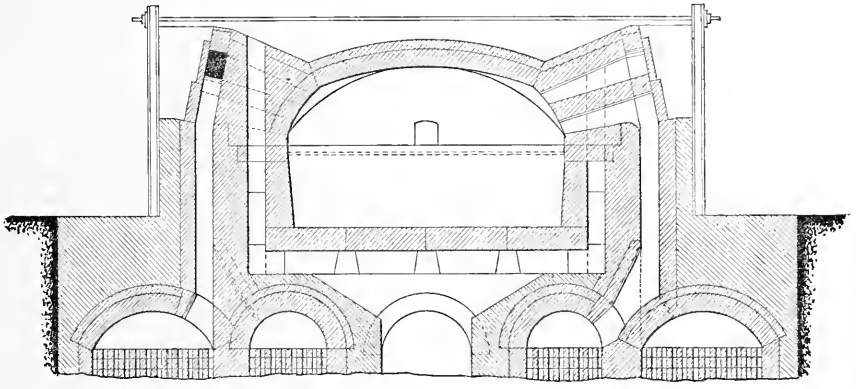


Fig. 2.

not with very good results. One has since been built in Illinois, and its operation has been attended with good success. A number of tank furnaces of various designs were in operation or building during the census year, however. These furnaces were generally oblong, resembling an iron-puddling furnace in construction and operation, or were simply a large round pot. I have no specific details of their construction or operation, but they seem to have been quite successful and economical.

POT-CLAY.—The pots used in melting are made from certain varieties of fire-clay, termed pot-clay, from its use for this purpose. The clay adapted to the manufacture of pots should be as pure as possible, and be very refractory, breaking with a clear, smooth, bright fracture, unctuous to the touch, free from lime and sulphide of iron, and the less oxide of iron the better. The shale or slate-clay from Stourbridge, England, which is brown in color, has a wide reputation, and is largely used in British glass houses, but the foreign clays most generally employed in this country are German, though American clays are, to a large extent, taking the place of the foreign. The clays most largely used in the European glass houses are those from Forges-les-Eaux, in France; Andennes and Namur, in Belgium; Stourbridge, in England; Glen-borg, in Scotland; Sargenau, in Switzerland; Schwarzenfell, in Bavaria, and Klingenthal, in Germany. In this country there are large deposits of excellent pot clays in many localities. Those that are used, however, are chiefly drawn from western Pennsylvania, Missouri, and New Jersey, though the clays of Maryland, Ohio, and Indiana are to some extent used. When American clay was first used it did not give the satisfaction that its analysis would indicate. This was owing to lack of skill in its

preparation, but as this has been acquired American clay is rapidly gaining in favor. Mr. Thomas Coffin, of Pittsburgh, one of the oldest pot-makers of this country, writes me regarding the use and relative value of German and American clays, as follows:

About three-fifths of the clay used in this country is foreign clay, principally German. Window-, bottle-, and plate-glass houses use the largest proportion of German clay, some making their pots entirely of German, others of a mixture of German and American. Nearly all the flint houses use pots made entirely of American clay, although a few mix some foreign. It is found by experience that the American (Missouri) clay will stand a more intense heat than any other, but that the German clay resists the action of the flux better; hence the mixture of the two to overcome as nearly as possible the two difficulties. American clay is fast superseding German clay because of the hotter-running furnaces that are now being used.

Our American clay is much purer than the German, and is more refractory, but not as dense. It is much less costly, however, and must eventually supersede the German.

COMPOSITION OF POT-CLAY.—The composition of pot-clay from different localities is given in the following table:

Localities and kinds of clay.	Chemist or authority.	Silica, including sand.	Alumina.	Oxide of iron.	Lime.	Magnesia.	Carbonate of magnesia.	Potassa.	Soda.	Sulphur.	Water.	Total.
Stourbridge, England:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Homer's Best	Willis	67.34	21.03	2.03	.....	.....	.....	.....	.....	.....	8.24	100.00
Best Pot	Richardson	64.05	23.15	1.85	.....	.....	0.10	.....	.....	.....	10.00	100.00
Chance's	Percy	65.10	22.22	1.92	0.14	0.18	.....	0.18	.....	.....	9.86	99.60
Do	C. Tookey	63.30	23.30	1.80	0.73	.....	.....	.....	.....	.....	10.30	99.43
Scotch Glen-borg	Professor Cook	61.45	24.68	1.67	.....	0.10	.....	0.20	.....	.....	10.90	.....
Belgium:												
Andennes	Bischof	46.64	34.78	1.80	0.68	0.41	.....	0.41	.....	.....	1.27	96.72
German:												
German	D. Tal Aran	46.44	36.95	1.64	.....	0.69	.....	.....	0.48	.....	.....	.....
Do	.....	70.60	23.60	.....	0.36	0.45	.....	.....	1.10	.....	3.89	.....
Coblentz	Professor Cook	71.31	15.66	1.19	.....	0.28	.....	0.63	Trace.	.....	9.70	.....
Ebernhahm	Kerl	46.97	37.95	0.95	0.04	0.11	.....	3.00	.....	.....	10.02	.....
Grunstadt	Bischof	47.33	35.05	2.30	0.16	1.11	.....	3.18	.....	.....	10.51	.....
French:												
La Bonchade	Percy	55.40	26.40	4.20	.....	.....	.....	.....	.....	.....	12.00	.....
American:												
Cheltenham, Missouri:												
Crude	Litton	61.02	25.64	1.70	0.70	0.08	.....	0.48	0.05	0.45	9.68	100.00
Washed	do	59.60	26.41	1.61	1.00	0.07	.....	0.29	0.16	0.38	10.48	100.00
Dixon, Missouri:												
Crude	Chauvenet and Blair	56.02	28.86	1.67	1.76	0.34	.....	.....	.....	.....	11.12	.....
Washed	do	55.06	30.02	1.57	2.20	0.41	.....	.....	.....	.....	10.54	.....
Blue Ridge, Missouri	Weiss	63.75	26.60	0.75	Trace.	0.85	.....	0.40	.....	2.25	7.40	100.00
Oak Hill, Missouri	Chauvenet and Blair	64.32	22.82	1.75	0.45	0.12	.....	0.23	0.54	0.12	10.26	100.58
Christy's, Missouri	.....	63.10	23.70	2.20	0.09	0.06	.....	0.04	0.08	.....	10.73	.....
Thomas, Pennsylvania	McKeown	43.88	40.96	0.82	Traces.	Traces.	.....	.....	.....	.....	13.99	99.65
Blair county, Pa	.....	70.18	20.99	.....	0.65	0.13	.....	.....	0.08	.....	7.75	.....
Dixon's, New Jersey	Professor Cook	59.93	26.95	1.24	.....	0.07	.....	Trace.	Trace.	.....	10.20	.....
Near Newcastle, Delaware.	Salvétat	72.33	16.75	1.29	2.00	0.07	.....	.....	.....	.....	7.98	.....

MANUFACTURE OF POTS.—The manufacture of the melting-pots for a glass furnace is one of the most important, careful, and tedious of the operations about a glass works. From the digging of the clay till it is refined, mixed, kneaded, and built into pots, and these are thoroughly dried, heated, and set in the furnace, two or three years often pass. The pots themselves are costly, the setting difficult and expensive, and if they are improperly made or spoiled in drying, heating, or setting, and break, the entire batch frequently is lost, and in many instances consequential damages ensue from the delays and loss of output. The importance of having good pots is so great that many manufacturers are not willing to depend upon outside makers to supply them, though this opposition to outside pot-makers is not so great as it was a few years since. It is estimated now that about one-half of the pots used in the country are not made at the glass works. The clay, having been allowed to ripen or putrefy a sufficient time, is mixed into a thick paste with water and from one-fifth to one-fourth its weight of finely-ground old pots or "potsherds", and is thoroughly kneaded by tramping until it is of the toughness of putty. This mixture dries more rapidly, contracts less when drying, and better resists the action of the fire and materials of the glass than the pure clay. The kneaded clay is then made into long rolls and built up by hand, little by little, into the solid compact pot, no machinery being used, and care being taken to keep it free from air cavities. The pots are not built up at once, but after placing a layer, each pot is permitted to stand and set, being kept carefully covered. A good pot maker and his assistants can furnish one pot a day. After the pots are made, great care is taken to

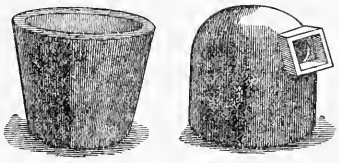
dry them thoroughly. In summer the natural temperature is sufficient, but in winter they are kept at from 60° to 70° F., care being taken not to allow them to freeze. The pots are allowed to dry from four to eight months, and when they are ready for use their temperature is very gradually and cautiously increased, first in a warmer room and then in the annealing arch, until they reach the temperature of the working furnace, when they are immediately placed in the furnace or "set". The soundness of the pots is tested by throwing a small lump of coal against the side. If it rings well, it is regarded as a good pot; but if dull, it will probably be short-lived, though this test is not always conclusive.

THE SETTING OF THE POTS is one of the most difficult and laborious of the operations at a glass works. Mr. Henry Chance remarks:

> The terrible task of setting these pots in the furnace falls upon the glass-house crew, and the nicety with which these enormous vessels are adjusted in their place, in the teeth of a consuming fire, is, perhaps, that operation which, in the many marvels of glass-making, would most astonish a stranger to such scenes.

LIFE OF POTS.—The average duration of open pots when thus fixed is about seven weeks; but some attain the age of ten or twelve weeks, while others, as every manufacturer well knows, terminate their existence prematurely, either from the naturally defective constitution of the pot, or from bad treatment in the pot arch, or, more frequently, from its having been "starved"; that is, exposed to a current of cold air in the furnace through the neglect of the attendant. Flint pots have a much longer life, averaging perhaps three months, single pots sometimes lasting ten months. In a ten-pot lime-flint furnace at Pittsburgh but 21 pots were set in a year. "Misfortunes never come singly" is an adage applicable to the catastrophes of pots, and it was truly remarked to a manufacturer, at a period when such calamities were frequent, "Your pots break because they break." The breakage of a pot often disturbs the furnace to such an extent that the breakage of others frequently follows, and many weeks will sometimes elapse before the disorganization thus produced can be rectified. The loss of a pot and the "metal" contained is nothing as compared with the injury which the glass in the surviving pots, and the pots themselves, are apt to sustain.

SIZE OF POTS.—The size of pots, not only in different countries but in the different works of the same country and in the manufacture of different kinds of glass, varies. The pots for the plate-glass houses of this country range from 30 to 35 inches in diameter; window-glass, from 40 to 44 inches; bottle-glass, 44 to 60 inches, and flint from 38 inches in diameter at the bottom to an oval 52 inches wide by 63 inches long at the bottom and 54 inches high. The English pots for blown window-glass are from 42 to 65 inches outside diameter; the French 1.10 meters (43.41 inches) at top, 0.92 meter (36.223 inches) at bottom, and 1.12 meters (44.09 inches) inside height; the Belgian about 48 inches (say 1.10 by 1.30 meters); the German contain from 140 to 180 cubic feet; and the Austrian from 500 to 600 millimeters. Flint-glass pots are generally smaller, say from 36 to 40 inches, while those used in the Bohemian glass houses are stated by Mr. Colné to hold only 160 pounds of batch. Pots for colored glass are also very small.



SHAPE OF POTS.—Pots for all glass but flint are open truncated cones, the smallest diameter being at the bottom. Even some flint-glass pots are used uncovered in the gas furnaces, but usually they are covered as represented in the accompanying cuts.

CHAPTER VI.—MIXING, MELTING, FINING, AND FAULTS.

INFLUENCES THAT DETERMINE THE CHARACTER OF GLASS.—The materials for the manufacture of glass when properly mixed and ready for melting are technically known as the "batch" or "mix", but it is impossible to lay down any standard and invariable proportion of these materials for the several kinds of glass. As has already been shown, glass is by no means a definite compound when made, and the proportions of materials are subject to even greater variations than the product. The batch not only differs for the several kinds of glass, but makers of the same kind use the materials in widely varying proportions, and even the same maker is often compelled to vary his mixture from day to day, either by reason of the varying character of his materials or the melting power of his furnace. A variation in the sand or alkali will change the color and call for a change of the amount of the decolorizer used. When the furnace draught is good, or the furnace works "hot", as it does on a cold, clear day, the melting is more perfect and less alkali need be used; but when it works "cold", from insufficient draft or heavy atmosphere, more alkali is needed, and the glass is inferior. To properly manipulate the melting, in view of these varying circumstances, is the work of the teaser, and his success in thus manipulating them indicates his skill.

CONSTITUENTS OF THE BATCH.—As indicating the general composition of the batch for the different kinds of glass in different countries we have selected the following receipts, which are given in tabular form. These must, however, be regarded as only approximate, for the reason already given, and for the further reason that manufacturers guard with the utmost jealousy the special composition they use to obtain the best results in their furnaces.

PROPORTION OF MATERIALS USED FOR PLATE-GLASS.

Constituents.	FRENCH.		ENGLISH.	
	Saint-Gobain.*	Saint-Gobain.†	No. 1.‡	No. 2.§
	Pounds.	*Pounds.*	*Parts.*	*Parts.*
Sand	100	100.0	400	720
Sulphate of soda				
Carbonate of soda	35	60.0	250	450
Niter				25
Lime	5			80
Carbonate of lime		13.0		
Chalk			30	
Charcoal				
Arsenic				
Manganese		1.0		
Smolt		0.5		

*Authority: Knapp. †Authority: Bastinaire. ‡Authority: Pellatt. §Authority: Lippincott's Cyclopædia.

PROPORTION OF MATERIALS USED IN WINDOW-GLASS.

Constituents.	Pittsburgh.*	FRENCH.			ENGLISH.†		
		No. 1.†	No. 2.‡	No. 3.‡	No. 1.	No. 2.	No. 3.
	Pounds.	*Parts.*	*Parts.*	*Parts.*	*Pounds.*	*Pounds.*	*Cwt.*
Sand	8,000	100	100	100	560	448	16
Sulphate of soda	2,200		44	58 to 75	63	17	1.25
Carbonate of soda		28 to 35			119	103	5
Lime	§2,500		6	13 to 15			
Chalk		35 to 40			154	146	5
Powdered coal or coke	40		4	4.5 to 5.5			
Arsenic	50	0.20			2	2	
Manganese		0.25					

*Authority: Pittsburgh manufacturers. †Lippincott's Cyclopædia. ‡Authority: Dumas.

PROPORTION OF MATERIALS USED FOR FLINT (LEAD) GLASS.

[The usual rule for flint glass is expressed 3:2:1 or 3 of sand, 2 of lead, and 1 of potash.]

Constituents.	Pittsburgh.*	English.†	FRENCH.		
			Optical.‡	No. 1.§	No. 2.‖
	Pounds.	*Parts*	*Parts.*	*Parts.*	*Parts.*
Sand	1,500	336	43.5	100.0	300
Lead	600	224	43.5	80 to 85.0	215
Carbonate of potash	500	112	10.0	35 to 40.0	110
Niter				2 to 3.0	
Saltpeter	150	14 to 28	3.0		10
Manganese	½	4 to 12 oz.		0.5	
Borax					12
Arsenic	½				

*Authority: Pittsburgh manufacturers. †Authority: Pellatt. ‡Authority: Bontemps. §Authority: Loysel. ‖Authority: Dumas.

PROPORTIONS OF MATERIALS USED FOR FLINT (LIME) GLASS.

[Sometimes a few hundredths of saltpeter, borax, and red lead are added.]

Constituents.	Pittsburgh.*	Bohemian.†	French.‡	Lime-white.†	Clear white.†	Chemical.†
	Pounds. 1,500	*Parts.*	*Parts.* 300	*Parts.* 100	*Parts.* 100.0	*Parts.* 100.0
Sand						
Quartz		100.00				
Carbonate of potash		60.00		30	65.0	41.4
Carbonate of soda	500		170			
Lime	150		75	18	6.0	17.5
Chalk		8.00				
Manganese		0.75			0.5	
Charcoal			10			
Arsenic						
Nitrate of soda	200					

*Authority: Pittsburgh manufacturers. †Authority: Lippincott's Cyclopædia. ‡Authority: Colné.

PROPORTION OF MATERIALS USED FOR BOTTLE GLASS.

Constituents.	Pittsburgh.*	French.†	English.‡	Belgian.†
	Pounds.	*Parts.*	*Parts.*	*Parts.*
Sand	8,000	100	100	10
Sulphate of soda		8		15
Carbonate of soda	2,200			
Peat-ashes				20
Lime, slacked		24	80	
Limestone	2,400			5
Salt	250		3	
Soapers' waste			80	
Clay			5	

* Authority: Pittsburgh manufacturers. † Authority: Colné. The sand contains about 20 per cent. of calcareous matter. ‡ Authority: Pellatt.

MIXING THE BATCH.—Upon the thorough mixing of the materials depends in some degree the homogeneity, and, consequently, the structure and value of the glass. These materials differ so much in their specific gravities that the thorough mixing, as well as the melting, is a work of some difficulty. In this country, with the aid of a coarse sieve and shovel, the mixing is generally done by hand. Many attempts have been made to introduce mechanical mixers, but, though some are used, they have been discarded in many works, and the older method is employed. Where manual labor is as high-priced as in this country, the introduction of a satisfactory mixer would seem very desirable. In England several machines are used, that of Mr. Chance being a very simple machine, consisting of a wooden cylinder with a number of revolving oblique beaters; but Cooper's mixer is a revolving barrel, similar to those used in powder works.

FRITTING.—At the present time the materials thus mixed are charged directly into the pot or tank, as the case may be. When the impure alkalies obtained from sea-weed or wood-ashes were used the batch was submitted to a preliminary refining process termed "fritting". This consisted in stirring the materials together under the heat of a reverberatory furnace, called a "calcar arch", which effected a partial decomposition and the burning of any carbonaceous matter that might be present, and the "frit" thus obtained was remelted in the pots. With the use of the purer alkalies made from salt this fritting is not necessary, though heating the batch in the arch may be desirable.

CHARGING.—The pots having been heated to a white heat, the materials, mixed with a proportion, generally one-third, of cullet of the same kind as the glass to be made, are shoveled into them. Mechanical chargers have been used to some extent in this country, but not very successfully. As the melted glass is less in bulk than the materials, the entire batch is not charged at one time. The pots are filled as full as possible at first, about two-thirds of the whole batch being charged, and the remainder is shoveled in as the melting and sinking of materials permit. Two or three shovelings or fillings are sufficient. During the melting the grate-bars are kept well supplied with coal, to prevent a rush of cold air into the furnaces, which might split the pots.

MELTING.—As the melting progresses the teaser (*a*) watches it most carefully, urging the furnaces to their utmost intensity and determining the fitness or unfitness of the metal for working, as there are signs which indicate to the practiced eye when the metal is ready, such as the color of the flame or the appearance of proof specimens taken from the pots with a short rod flattened at one end. The escape of the carbonic-acid gas answers the purpose of stirring the materials. When the disengagement of this gas ceases, especially in the manufacture of window-glass, the mass is stirred with a pole of green wood, or a piece of arsenious acid is thrust into the bottom of the pot, thus causing a forcible expulsion of gas and consequent stirring of the materials. When impure materials were used, the close of the period of melting found the surface of the molten glass covered with a thick scum of unvolatilized salts, called "glass-gall", or "sandiver", which was skimmed off. The relative proportions and the purer materials of modern glass houses render this skimming unnecessary; indeed, the appearance of "sandiver" in any quantity is regarded as an indication of impure materials or wrong proportions.

FUSION AND FINING.—The melting may be divided into two periods, fusion and fining or refining, the first ending when the materials are thoroughly melted, and the second including the after process of freeing the glass from bubbles, lime, and earthy impurities that do not fuse. For this purpose the glass must be brought to the most fluid state possible, and the heat is therefore raised to the highest point. This process of fining, refining, or "hot-stoking", as it is called in this country and in England, or *heiss-schüren*, as it is termed in Germany, involves a very high temperature, which is estimated in certain cases to reach from 10,000° to 12,000° F. (*b*) Though the authority for this statement is very good, it is doubtless too high, about 3,200° to 3,600 F. being the average. The time of fusion and refining should be as short as possible, the shorter the better, as long-continued melting or fining detracts from the brilliancy of the glass and favors the formation of threads. The time occupied in melting varies greatly, depending upon the construction and character of the furnace, the proportion and the character of the materials, and the size of

a The word appears to be derived from the French "*tiseur*". *b* *Encyclopædia Britannica*, 9th ed., article, "Glass."

the pots. Gas furnaces will, as a rule, make a "melt" in less time than the old style, and those of the old style that use coal as a fuel will melt in less time than those using wood. The larger the proportion of sand the longer will be the time, while lead will hasten the melting. Very large pots, holding, as some English ones do, 5,000 pounds of material, will consume 48 to 50 hours in melting, while the French pots, of from 1,000 to 1,200 pounds, will melt the batch in 12 hours. This is not uniformly true, however, as the pots in the Bohemian furnaces are stated to hold but 160 pounds, and yet the melting occupies 18 hours. This is due to the construction of the furnaces, the use of wood, and the materials used.

TIME REQUIRED TO MELT AND FINE.—In England the time of melting in the plate, crown, and sheet window-glass houses is stated to be from 16 to 20 hours, and the time of fining from 4 to 8 hours. In France and Belgium it is somewhat less. In this country the time of melting is about 12 hours, and of fining from 3 to 4 hours. In green-glass houses the time occupied is about one-third less. This glass is inferior to window-glass, and the perfect fusion and fining is not as necessary for the purposes for which it is used as it is for sheet-glass. The time required to make a melt of flint-glass is much longer than that for either of the other kinds; the pots being covered, the heat is kept out and the melting is retarded. The time is shorter with lead as a flux than with lime, but, as a rule, twice as much time is occupied as in the melting of window-glass. In England the time is from 48 to 60 hours, the batch being very large, the melting consuming about five-sixths of the time; but in France, where pots holding but 1,600 pounds are used, the time of melting is from 8 to 9 hours, and of fining from 1 to 2 more; and, as already stated, the Bohemian houses require 18 hours for a melt of a 160-pound batch. In this country, in lime-glass houses, the melting of a 3,200-pound batch consumes from 20 to 24 hours, the fining from 2 to 4, and the cooling one-half an hour to an hour, the latter process being hastened by opening the mouth of the pot and blowing the blast into it. In France thin pots, with a small amount of batch, have been used to hasten the melting.

COLD STOKING.—When the fining is completed the molten glass is very fluid, and in this condition could not be worked, as it must by cooling be brought to a viscid or plastic condition necessary for working. To accomplish this the draught is stopped and the grate-bars are plastered or the fire is covered with "braize" or fine coke. In some cases the blast is turned into the pots. This is called "cold stoking" or "standing off", or by the Germans "*kalt-schüren*", cold covering. In window-glass works this process requires from one and one-half to three hours; in flint works, from one to two hours.

LOSS IN MELTING.—As already indicated, the process of melting results in the disengagement of the gases that are contained in the materials, as the weight of the glass is considerably less than that of the batch. This loss, however, is chiefly in the gases other than oxygen, though this is expelled to some extent. Mr. Henry Chance (*a*) states "that very little alkali is lost by volatilization during the intense heat to which it is subjected. I do not find in any case a difference of more than 1 per cent. between the alkali in the mixture and that in the glass produced, and this includes the waste that must necessarily arise in mixing, in carrying the materials to the furnace, and throwing them into the pots". By alkali Mr. Chance evidently means the available alkali in the material charged, and not the entire amount of carbonate or sulphate, as the case may be. Some manufacturers think a larger proportion is lost. I am indebted to Mr. Julius Fahdt for the following very interesting and complete table, showing the practice of the Austria-Hungarian glass houses:

DIMENSIONS OF POTS AND TIME OF MELTING AND WORKING.

	EXTERIOR DIMENSIONS.			CONTENTS IN—			DURATION IN HOURS OF—				
	Height.	Diameter.		Weight.	Proportion.		Heating.	Melting.	Fining.	Cooling.	Working.
					Batch.	Cullet.					
	Millimeters.	*Millimeters.*	*Millimeters.*	*Kilograms.*							
Plate-glass (only one factory)*	550	600	500	150	120	30	1	8	6	2	.....
Sheet-glass (few exceptions with pots, as in Germany).	550	600	500	150	100	50	1	8	6	1	12.00
Flint with lime†	450	450	400	75	50	25	½	8	6	½	10.12
Bottles‡	550	600	500	150	120	30	1	10	6	1	10.00

* Small plate of from 50 to 60 square feet.

† According to articles.

‡ Bottles are nearly all made in two large establishments with Siemens' tank furnaces. Lead glass is only manufactured in some works for false jewelry in flint and colors, in very small pots, not exceeding 50 to 60 kilograms, which are worked out in lumps, cut and ground. About one-third of the Austrian glass-melting establishments produce raw glass, which is pressed or worked out in heavy pieces for prisms, chandeliers, and heavy ground articles. These are finished by the so-called refiners, who buy the raw glass and finish and sell it. A good many sheet-glass works only make a very thin sheet-glass, which is used in looking-glass manufacture. The Austrian window-glass, with a very few exceptions, is also very thin, generally not much above one millimeter. This is the reason why the small pots require a much longer time to melt and work out. Austrian factories in general blow their articles much lighter than in Germany. They require a longer time for melting, because their metal is very hard.

FAULTS IN THE METAL.—The faults in glass that occur in connection with its melting are chiefly those from air or gas bubbles, imperfect fusion, and foreign substances. When the fining has been obstructed by too great

a On the Manufacture of Glass, a lecture delivered before the Chemical Society, March 19, 1868, page 8.

difficulty of fusion the mass becomes thick or viscid and the bubbles are retained, giving rise to what are known as "seed", "blibe," or "blister". When the fusion is imperfect, and the glass is not uniform throughout, the density of various parts of the glass varies and refraction of light is not equal, and consequently images of objects seen through the glass are distorted or out of place. These faults are termed "striæ", and when they show on the surface they are termed "waves". "Threads" or "strings" are produced by cold glass dropping into the metal and not undergoing fusion. "Tears" are vitrified portions of the side or roofs of the furnace that drop into the pot. Mr. Henry Chance's *résumé* of the defects of crown glass and their cause is so indicative of the many difficulties in the way of producing perfect glass that I copy it: (*a*)

Perhaps the glass has been badly melted and is seedy, that is, full of little vesicles, to which the rotary motion has given a circular shape; or the gatherer may have inclosed air within his "metal", and a gatherer's blister is the result—or a pipe blister, or pipe scales, or dust from the pipe-nose, or dust from the marver, or dust from the bottoming-hole, or dust from the nose-hole, or dust from the flashing furnace, or bad bullions, or scratches, or music lines, may disfigure the table, or the glass may be crizzled, or curved, or bent, or hard, or smoky, or small and light, defects to explain which would be a long and dreary task.

Chapter VII.—GLASS-WORKING.

Methods of glass-working.—It is not the intention of this report to enter into the minute details of the various methods of glass-working, as it is not intended that this work shall be a perfect hand-book for beginners or for skilled glass-makers. I have only endeavored, while giving full and correct statistics of the trade in the United States, to glance at the history of glass-making at home and abroad, and to give some general idea of the processes employed and of the materials which enter into the composition of glass. For these reasons I shall here only describe in a general way the most important processes used in the manipulation of the melted glass. The chief methods of working glass are three: (1), casting; (2), pressing; (3), blowing. Casting and pressing are closely related processes, and blowing and pressing are often combined to produce certain forms of glass, but the processes are generally so distinct as to justify the classification adopted. Glass is also manipulated in many ways that do not properly fall under either of these classes, but they are of minor importance, and either are subsidiary to one or more of these three methods, or are, strictly speaking, reworking glass.

Plate-glass.—The most important form of cast glass, and the one most largely produced, is plate-glass, or, as it might more properly be called, cast plate-glass. This is the well-known cast, ground, and polished plate used for windows, mirrors, etc., and should not be confounded with the blown plate and Chance's patent plate, which are blown glass. In the manufacture of cast plate furnaces and pots of the ordinary construction are used, the melting-pots, however, sometimes holding as much as 2 or 2½ tons of batch. In French works, and in some others, two forms of pots are used, which are placed side by side in the furnace: the ordinary melting-pot, and an auxiliary pot, called a "cuvette", large enough to hold sufficient glass to cast a sheet of a given size. The molten glass is ladled from the pot into the cuvette, allowed to clear, if necessary, and is then cast. In most works, however, the practice now is to pour or cast directly from the pot in which the glass is melted, and in other cases it is ladled from the pots to the casting table.

Casting and annealing.—The casting table, formerly made of bronze, is now made of one piece of cast-iron, (*b*) heavy and thick, and in width and length exceeding the dimensions of the largest sheet of glass. It is commonly mounted on wheels, running on a track laid down the center of the casting hall or room, on each side of which are the annealing ovens. A heavy cast-iron roller the full breadth of the table is arranged to roll its whole length by means of a spur-wheel on the roller working in gearing on the side of the table. The height from the table at which it rolls, and consequently the thickness of the glass, is regulated by narrow strips of metal placed along the edge of the table, while the width is determined by what is known as the "gun", two plates of cast metal bolted together, adjustable to the breadth desired and moving with the roller and before it. All being ready for casting, a pot filled with the molten glass is removed from the melting furnace, placed on a truck, and run to the casting table. The pot is lifted from the truck by a crane, is suspended over one end of the table and tilted, and the viscid, semi-fluid mass being poured out, the roller is moved forward, flattening the glass and rolling it to a uniform thickness, while the "gun" prevents it from spreading to a greater width than is desired. As soon as the plate has solidified sufficiently to bear moving, it is laid in the annealing oven on the "flat" to slowly cool. All the operations are performed with the greatest rapidity, that the plate may be as hot as possible when laid in the oven. The number of plates that can be put in an oven varies with the size of the plates. But one layer of those

a Mr. Henry Chance *On the Manufacture of Crown and Sheet Glass.*

b In some cases, in order to overcome the "bowing" of the plate, it is made in a number of pieces.

designed for polishing can be placed in it; consequently a large number of ovens is needed where large plates are made. These ovens are large, shallow, brick reverberatory furnaces, with floors as smooth and as level as possible, as the semi-plastic mass molds itself into the unevenness, and any bending of the plates would make them valueless. As soon as the plate is placed in the oven, all the openings are carefully closed and the oven is allowed to cool gradually to a point where the glass may be safely removed, generally requiring from three to five days.

ROUGH PLATE.—The cast plate as it comes from the oven is rough and irregular on its surface, constituting the rough plate of commerce, and in this form it is used for roofs and floors, and even for windows where light without transparency is desired.

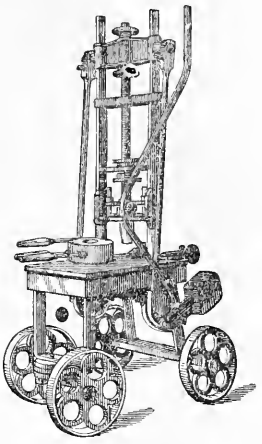
GRINDING, SMOOTHING, AND POLISHING.—The plates having been examined for defects, such as spots, air-bubbles, etc., and, if necessary, cut into such sizes as these defects require, the selected pieces are then polished, which operation consists of three processes: (1), grinding; (2), smoothing; (3), polishing; but it is exceedingly difficult to describe these operations without the aid of drawings. Various machines have been invented for these purposes. The machine originally used for grinding was known as the "fly-frame" machine, the design of which is attributed to James Watt, and in one form of this machine commonly two or more plates, according to their size, are imbedded in plaster of paris, spread upon a table. Other plates are imbedded in the under side of two runner-frames or swing-tables, which by a strong fixed bar are caused to move with a transverse motion backward and forward, a circular motion being at the same time imparted by means of a vertical crank-shift, pivoted to the central and upper part of the table and actuated by bevel gearing. Four other cranks, one at each corner of the frame, serve to guide and limit its motion, causing its central point to describe a circle about 4 feet in diameter, so that different portions of the faces of the upper and lower glass plates are continually applied to each other. Sharp river sand, sifted into two different sizes, is used as an abradant. When the surface of the lower plate has been ground quite flat by the coarser sand it is removed, and after careful washing finer sand is substituted. To this succeeds emery powder, a coarser and then a finer quality being applied, the glass being thoroughly washed previous to each change of material, so that none of the coarser particles previously used may remain to cause scratches on its surface. The plates are then turned over, and the same process is repeated on the other side. The smoothing process is carried on with similar machines, the only difference being that emery powder of increasing degrees of fineness is employed. The polishing is done with reciprocating rubbers covered with fine felt and supplied with rouge. The table on which the glass lies also is given a backward-and-forward transverse movement, so that all parts of the plate are brought under the polishing operation. About 40 per cent. of the weight is removed in these three operations. Ordinary plate-glass varies in thickness from one-fourth to three-eighths of an inch. The largest plate ever made was exhibited by the Saint-Gobain Company at the Paris exposition of 1878, and measured 21 feet 2 inches by 13 feet 6 inches.

ROLLED PLATE.—A form of unpolished plate-glass, known as rolled plate, has been manufactured largely in England for some time, and has latterly begun to be manufactured in France and Belgium. This is used for coverings for hot-houses, for door-panels, for windows, for partitions, and for other places where obscure light is required. The glass is not poured from the pots, but is dipped from them with a large ladle or dipper and poured upon the casting table, which, instead of being smooth and plain, is engraved or indented in fine lines or flutes or in small squares, lozenges, or even ornamental patterns, the glass, of course, taking on its lower surface the impression of the pattern or lines engraved on the table. The roller is passed over the molten glass as in the ordinary cast plate. These plates are usually cast one-eighth of an inch thick, and in annealing a large number are piled on their edges in the annealing oven, instead of a few laid flatwise, as is done with plate-glass which is to be polished. By this ladling process numerous "air-bells" and imperfections are inclosed in the glass, but as it is obscured by its roughness they do not affect its usefulness.

OPTICAL GLASS.—The flint-glass used in the manufacture of optical instruments is also in a certain sense a cast glass, or at least a massive glass, not manipulated by blowing or pressing. For this purpose a glass of the utmost purity, transparency, freedom from color, striæ, and imperfections is of the highest importance. As has been already stated, this glass has a large proportion of lead. It is melted in the furnace in a single pot, and Guinand's secret, by which it was first made successfully, consisted in constantly stirring the mass while in a molten condition to prevent the heavier lead silicate from falling to the bottom. After the glass is thoroughly melted the stirring is continued until the contents are cooled down to little more than a red heat, when the furnace is closed and the metal is allowed to cool and anneal gradually in the pot within. When withdrawn, the pot is broken and the mass of glass removed. Optical glass is also blown into thick cylinders, and sometimes is cast in slabs from one-fourth to one inch in thickness. The crown optical glass is made with as great care as the flint, but it contains no lead, and has about the same composition as window-glass.

STRASS.—This is the glass used in the manufacture of the remarkably faithful imitation of precious stones, which have been and are still so common, and is manufactured somewhat in the same way as optical glass, special precaution being adopted in the melting of the materials. Formerly it was believed that only rock crystal could be used in its manufacture. This belief, however, is wholly without foundation, sand which is pure making equally good Strass.

PRESSED GLASS is, strictly speaking, one form of cast glass, the molten metal being gathered and cast in a mold which would correspond with the table of the plate-glass works, the plunger of the press answering to the roller. There are, however, so many and important variations in the methods of pressing as to justify its classification as a separate process. Pressing by mechanical means in metal molds, which is an American invention, is a most important and valuable improvement in glass-making, and by its adoption comparatively unskilled labor can be substituted for the highly trained workmen demanded by the blowing process, and cheaper materials can be used. Labor as highly skilled as that required in glass-blowing is not necessary, as intelligent men can be trained in a short time to perform the work, and a glass rivaling lead flint in whiteness and clearness, but not in brilliancy, can be made with lime. In the pressing process as usually practiced a metallic plunger is driven into a metallic mold, into which molten glass has been placed by mechanical means, the glass taking the form of the mold upon its outer surface, while the inner is modeled by the plunger itself. The simplest form of mold is a flat slab of iron or other metal with slightly raised sides. For articles of some complexity molds are made in two or more divisions, hinged together (joint molds), and opening outward. The chief parts of the mold are termed the "collar" and the "base". The ordinary form of press used is shown in the accompanying cut, the mold, with its handles, being shown on the table of the press. The molten glass having been gathered and dropped into the mold, a sufficient quantity is cut off, the mold is pushed under the plunger, and the long lever at the right of the press is pulled down. The plunger enters the mold, the glass is pressed into all parts of the same, the plastic mass solidifies, the plunger is withdrawn, the mold opened, and the glass in the required form is withdrawn, to be fire-polished and annealed. If too much glass is cut off, the article is too thick; if too little, it fails to fill the mold, and the article is spoiled. Though this is quite a simple operation, and though as great skill as in the old method of glass-blowing is not required, considerable practice is still necessary to gather the right amount of metal and to cut it off so as not to waste glass, and also to keep the mold at the right temperature. If it is too hot, the glass will adhere to the die and plunger; if too cold, the surface will not be clear and transparent.



IMPROVEMENTS IN THE PRESSING PROCESS. (*a*)—Since pressing was first introduced many improvements have been made; indeed, the improvements in glass-making during the past ten years in connection with the manufacture of pressed glass have been most marked, one very important one having been what is known as fire-polishing. By this process the outer film of glass is roughened by contact with the mold, and the film is repolished by a slight reheating. Some of the recently invented mechanical devices for this reheating are most ingenious, and have made the production of certain articles possible which it was believed could not be produced by pressing. One of the chief difficulties in pressing glass is the production of sharp angles, which are so easily obtained in cut glass. If these are secured in pressing, they are apt to lose their sharpness in fire-polishing and reheating. This defect has been obviated in some degree by making the angles longer in the molds, so that when they are softened by the heat they still stand enough in relief to give marked and distinct outlines. To obviate the uneven surface of flat or fluted articles the molds have been constructed so as to make the flutes deeper in the middle, and with angles slanting toward this point. It will readily be seen that a flute composed of two angles tending to the center is not as likely to show defects as if it was of a flat surface. Another important improvement in connection with pressing glass is the process of cooling the molds by the use of air, an invention which has doubled their durability.

MOLD-MARKS.—A common defect of pressed ware is the marks left on the glass at points where the different pieces of the mold are joined together. However skillfully the molds may be made, in course of time the joints will work loose through the expansion and contraction of the metal, and the glass will gradually be pressed in the loose spaces of the joints, thereby imprinting on the surface of the articles ribs or sharp threads, marring the beauty of the work. To obviate this molds are made to open at such places and parts of the design that the marks left can scarcely be seen; for instance, in goblets the marks are left on the edges of angles. The parts of the molds are also combined so as to leave the marks on the edge of the scallop made by the top of flutes in a goblet or tumbler. Tumblers, however, are rarely made in "joint molds", but in solid ones.

MOLDING ARTICLES WITH LATERAL DESIGNS.—Various mechanical devices have been adopted that have permitted of the production of forms that at first seemed beyond the skill or ability of the glass-presser. Pieces requiring to have designs pressed in the side, which would prevent them from coming out of a mold made in one piece, have been made by having sliding lateral pieces. These pieces are moved forward and withdrawn by suitable means, leaving them free to come out of the mold. Improvements in the same order have also been made for molding handles, forming holes in handles by means of sliding pieces, which are pushed through the side of the mold and withdrawn to take the pieces out. When articles are so shaped on the outside as to present a few protuberances, and it is not thought advisable to open the mold, in order to avoid mold-marks the

a Many of the following facts about pressing are condensed from Charles Colné's report on glass and glassware.

molds are so combined that the protuberances are made by sliding lateral pieces, which, when withdrawn, allow the object to be taken out. Letters, monograms, and ornaments have been made by introducing lateral pieces in molds containing the proper designs. These pieces are changeable, and the same shaped article may be made having different lettering, etc.

Molding curved hollow articles, lamps, goblets, and taper articles.—Curved tubes and glass slippers are made by giving the plunger a descending curvilinear instead of a vertical motion, and lamps, goblets, and similar articles are frequently made by first pressing the foot, then blowing the head or body upon it, placing the foot in suitable bearings to connect the two together. The upper part may be either blown in a mold or previously shaped with tools and made to adhere while the glass is hot. Bowls are also made by first pressing, then inverting them, and then pressing the foot and stem upon them. Pieces which are wider at the top than at the bottom, as a decanter, cannot be pressed in the usual way, since the plunger is always a cone, which must be pushed into the mold and withdrawn. These pieces are pressed bottom up, and lips or projections sufficient to form the bottom are formed in the mold. The piece, after being pressed, is withdrawn from the mold, the bottom is heated, and with a tool the lips are brought together to close it up.

Molding mouths, necks, etc.—In shaping tools for the mouths of bottles, jars, etc., there are several combinations to produce effects not to be obtained by hand. The ordinary neck-shaped tool for making bottle necks is made of a central pivoted piece to form the inside of the neck and two stationary pieces to form the outside. Sometimes the necks of certain jars require to have a screw shape molded in the inside, and to accomplish this the central piece of the shaping tool is made screw-like, the two outside rubbing pieces of the desired shape, according to the style of jar. It is sometimes desired to form cavities or projections in or on the necks of jars, and this is usually done by having laterally-moving pieces attached to the inside former or the outside jaws, as the case may be. These sliding pieces are operated when the tool is at rest after shaping the neck. In the same order of tools may be classed the formers for making pouring-lips on the necks of cruets. These tools have suitably shaped jaws, which are pressed against the neck to give it the proper slant. It is also desirable sometimes to make holes in the side of a jar or jar-cover. This is done by having metallic pegs placed on the outside jaws, which are pushed in through the metal to pierce it. The middle piece fitting the inside of the bottle-neck in some of the forming tools is so made that at the time of entering it is very narrow, but is gradually widened by forcing apart the two sections of which it is made. Molasses-cans are now made with a glass pouring-lip at top and slanting channel to run the dripped molasses into the can again, the whole being closed by a metallic cover. To form the glass lip the piece is molded upside down, with bottom flaps to close up the can. In this position the can forms a cone, and the plunger can therefore be pushed in and withdrawn with facility. The bottom of the mold is made of a suitable shape, and the plunger is so combined with the bottom piece that the opening in the mouth of the can is made at the same time as the body is pressed, the film of metal at the mouth being so thin as to be readily removed by a sharp blow. By this device clock frames, decanters, pipes open at both ends, etc., can be made.

Handles.—Handles can be pressed in one mold, and the body of the object subsequently blown upon them in another mold, the operation cementing the parts together while the metal is hot. Small hand-lamps have been blown in ordinary iron molds, and the handle for each formed by allowing hot plastic glass to descend in a channel at the side until the two ends meet the bowl of the lamp and become cemented to it while hot.

Lamp bodies with feet and screw coupling.—Lamps are sometimes made with the foot and bowl fastened together by means of a metallic casing screwed over the two parts. In order to obtain the screw-pegs at the bottom of the lamp bowl and the top of the foot molds have been devised so as to give to the bottom piece a rotary motion, to withdraw it from the formed peg. This style of forming screws is to avoid the mold-marks which are made when the mold opens.

Lamps with metallic pegs or collars.—Lamps are blown with metallic pegs or collars imbedded in the glass. The pegs are previously heated, set in recesses in the molds, and the lamp blown over it.

Insulators.—In telegraph insulators, however, requiring a hollow screw, a rotating retreating bottom piece becomes a necessity, as the plunger cannot be pushed and withdrawn, owing to the projecting screw-threads.

Balls.—Round glass balls, used for castors or for shooting at, are now made by using molds containing several sections, which leave only a small connection of glass between the balls. A rod of hot glass is prepared, then rolled lengthwise over the different sections of the mold, and is gradually shaped into several balls, slightly attached together by thin connections. These balls are easily severed, and are then perfectly round.

Movable-bottom molds.—Molds have been made with movable bottoms, to allow the surplus glass, when in excess, to force the latter down, thereby increasing the thickness of the bottom piece. In order to equalize the distribution of heat in iron molds, they have been so made that by varying the thickness of the different parts the cooling and heating become equalized.

Battery jars.—To manufacture battery jars having tubular formations running from top to bottom a ring-plate is used having two mandrels attached to it and falling into suitable recesses in the bottom of the mold. This ring-plate being adjusted in the mold, the plunger is made to come down, and by its pressure the hot glass is made to run round the mandrels while the jar itself is being formed. The plunger having been withdrawn, the mandrel plate is pulled out, and the tubular cavities now appear properly formed.

MOLDS FOR FLARING ARTICLES.—Articles wider at the bottom than at the top on the outside may be pressed by introducing between the outer shell of the mold and the plunger a cylinder tapering wider from top to bottom; but the inside of the article must, of course, be made tapering downward toward the center, so that the plunger may be withdrawn. It will be understood that the plunger having been withdrawn, the article being wider at the bottom than at the top, it cannot yet be taken out of the mold. To do this the intermediate cylinder is withdrawn, and the article is now left free to come out.

MOLDING ARTICLES WITH BULGING BODIES.—A combination mold has been made to press molasses-cans and such articles which are wider in the middle than at both ends, and it is plain to be seen that to make such cans no plunger can be used to press the article all the way down, on account of the belly of the can. To obviate this inconvenience molds have been made of several pieces, as follows: The upper part, consisting of the neck and handle, is pressed in a mold having a movable bottom piece, which is run up past the belly of the can, but only to a proper distance, so that the bottom may be left thick enough to furnish sufficient material to form the body. The plunger is provided with air-passages, to admit of the bodies being blown, and the lower part of the mold, through which the bottom piece ascends, is made of the proper shape to form the body and the bottom. The operation is as follows: The mold bottom piece is run up to its proper height, glass is introduced in the mold, the plunger is brought down, thereby forming the neck and the handle of the can and a thick glass bottom. The mold bottom piece is now lowered, and the thick glass bottom is dilated and made to fit the lower mold by the pressure of the air sent through the plunger, thereby finishing the piece.

MOLDING ARTICLES WITH OPENINGS.—It is sometimes desirable to make certain articles with openings, such as on the top of a lamp head to leave an opening for filling the lamp. These holes or openings are produced as follows: After the lamp head has been properly shaped, a small quantity of hot glass is dropped upon the lamp top, which has been previously reheated. The hot glass and top of the lamp being now sufficiently plastic, a tool somewhat in the style of those for forming bottle necks is used. This tool consists of an annular piece, which is brought over the hot lump of glass and shapes the outside. While this annular piece is in contact a central pin is pushed forward and pierces the glass, thus producing the opening. Should it be required to cement a cap over the opening, the shaping tool is provided with two levers, having ends properly shaped for the purpose. These ends are pressed on the outside of the tube and form recesses.

SPRING SNAPS FOR FIRE-POLISHING.—Many articles, after being molded, pressed, or blown, require to be held by the foot for fire-polishing or for giving them a final shape. It has been customary, heretofore, to fix the foot to a piece of hot glass on the end of an iron rod, and then to put on the finishing. To detach the pieces it is necessary to part the two by giving a sharp blow on the iron rod. The foot frequently retains pieces of broken glass, which must be removed by grinding, and to avoid this spring "snaps" are used. These consist of a couple of jaws mounted on springs, so that they can open and shut. These jaws are fastened at the end of an iron rod like a blow-pipe. If a goblet is to be finished the process is as follows: The jaws are made to open, and, by the action of the springs, they immediately close upon the foot and hold the goblet ready to be finished. Sometimes these jaws are so arranged that they can be set forward and back and fastened by screws.

COOLING HEATED MOLDS BY AIR-BLAST.—When pressing glass continuously for a long time the molds often become too highly heated, and in this state glass is very apt to stick to them; but this inconvenience is now done away with by a system of blowing air into the molds. By means of a revolving fan or other device and tin pipes arranged around the furnace a continuous stream of air is furnished. India-rubber pipes are attached to the tin pipes at suitable places, and by this means, after each pressing, or as often as necessary, a stream of air is sent inside of the mold, thereby cooling it. The air circulating in the pipes may also be used for the ventilation and cooling of the glass house.

APPLICATION OF STEAM TO GLASS-PRESSING.—Attempts have been made of late to use presses for pressing glass by steam or compressed air. One of these presses has a set of molds carried on a revolving bed, and is operated by a presser like a hand-press. The power, however, is applied to the presser by means of an auxiliary steam-engine, which is continually at work. Whenever an article is to be pressed, by suitable leverage the presser is forced down, then released, the bed-plate revolves far enough to bring another mold under the presser, and the operation is repeated as often as desired. Mechanism is attached and operated also by steam, so as to push the pieces out of the mold after they are pressed. These are the principal features of the invention.

APPLICATION OF COMPRESSED AIR.—In the other press steam is replaced by compressed air contained in a reservoir, which may be filled by means of an air-compressing engine. The bed-plate carrying the molds has a rectilinear motion. When an article is to be pressed, the mold is brought under the presser, and by means of suitable valves and pipes air is sent to a cylinder piston carrying the plunger, the pressure of the air forcing the presser down into the mold and reversing the valves, and the piston and presser flying back. A new mold is now under the plunger. This operation may be repeated as often as desired by simply opening and closing the air-valves. In this press, as in the other, the pieces are forced out of the molds by rising plugs or bottoms. The different motions are entirely automatic, with the exception of operating the air-valves. Though steam and air have been used, the success reached has not been great.

INCLOSED AIR-BUBBLES.—In order to form the bubbles which are often seen inside of solid pieces of glass these have been pressed with cavities on the outside, and, after being reheated, the cavities are closed by pressing the outside down with suitable tools, thus inclosing the air.

BLOWING is used in the production of cylinder or sheet glass, of table and similar ware, with or without the use of molds and of bottles.

WINDOW-GLASS.—In the production of window-glass a square or an oblong furnace is used. Radiating from the work-holes, and so arranged as to be on the edge of a pit some 7 to 10 feet deep, are long stages, separated by spaces sufficiently wide to allow the workman to swing about his long tube to form his elongated cylinder. When the glass is ready for blowing the workmen take their stations, each having his own pot and stage, and also assistants, and commence gathering the glass, which is done by dipping the end or nose of the pipe or hollow rod of iron into the pot of molten glass, twirling it around to equalize the thickness of the gathering, and collecting a lump of glass at the end. After gathering the amount of metal required, generally about 20 pounds, the workman rolls the gathered glass on a block of wood so hollowed out as to allow the lump when placed upon it to be extended by the blower to the diameter ultimately required. Here it is shaped into a solid cylindrical mass, water in the mean time being applied to the block to keep it from burning and to give brilliancy to the surface of the glass. When the mass of metal is sufficiently formed and cooled, it now being of a pear shape, the blower raises the pipe to his mouth at an angle of about 75°, blowing into the glass and turning it in the wood block until the requisite diameter is reached. It now has the appearance of a hollow flattened globe. This mass is then reheated, and when it is sufficiently softened the workman begins swinging it over his head, reheating and swinging in the pit until it has reached the desired length, which is about 45 inches. This is the most difficult part of the operation, uniformity of substance and diameter being chiefly the result of the skill of the workman, who, when he finds the metal running out too freely, holds the cylinder vertically above his head, still keeping it filled with air, and then by dropping elongates and thins it. The cylinder is now, say, 45 inches long by 12 inches in diameter, one end being closed and the other having the pipe attached to it. The thinner cylinders are opened by the workman blowing into the pipe and then stopping it with his finger, and at the same time applying the lower end to the fire, when the air inside is expanded and the point of the cylinder bursts open, this being the hottest and most yielding part. The aperture thus made is widened out to the diameter of the cylinder by subsequently turning the cylinder to and fro with the opening downward. The thicker cylinders are sometimes opened by attaching a lump of hot glass to the end, which thus becomes the hottest and weakest part. The blower forces it open, as in the case of thin glass. The opening is enlarged by cutting it round with scissors. This method is used in preference to opening it in the furnaces, as it occasions less waste. The other end, which is attached to the pipe, is now cut off by the workman, who, having gathered a small quantity of metal on his pontil, draws it out into a thread and wraps it around the pipe end of the cylinder, letting it remain for an instant, withdrawing it suddenly, and immediately applying a cold iron to the heated part, when it cracks where the hot string of glass had been placed. The weight of the cylinder, as finished, is about two-thirds that of the lump of glass which the gatherer collected. The finished cylinder is now split open either by a red-hot iron or by diamond, which, attached to a long handle and guided by a wooden rule, is drawn along the inside of the cylinder, the edge of the glass being rubbed with a cold iron, as in the case of disengaging the pipe.

FLATTENING.—The cylinder is now ready for the flattening oven, which is generally a circular oven with a revolving bottom, composed of a number of stones as smooth as possible. The cylinder is laid in the oven with the split side uppermost, and is soon opened by the flame passing over it, and falls back in a wavy sheet. The flattener now applies another instrument, called the *polissoir*, which is a rod of iron furnished at the end with a block of wood, and rubs down the waviness into a flat surface, often using considerable force. The flattening-stone is now moved to the coolest portion of the furnace, the sheet is delivered by means of the flattening fork to the cooling-stone, and from this, when sufficiently rigid, it is lifted and is piled on its edge and annealed in an annealing kiln or laid flatwise on iron carriages, which are conveyed through a long annealing chamber, called a leer. When annealed they are examined, cut into a size that the defect will permit, and packed.

DEFECTS OF WINDOW-GLASS.—Mr. Chance thus describes the many vicissitudes through which window-glass passes in the processes of manufacture:

> The manner in which a sheet spared by one process is disfigured by another is sometimes curiously provoking. Standing before the table of the "assorter", your eye lights upon a piece which, blown under an evil star, has imbibed in the glass house every possible defect. The founder, skimmer, gatherer, and blower have all stamped their brand upon it. It is seedy—the vesicles, which were in the crown tables rounded by the rotary motion of the piece, here elongated by the extension of the cylinder; it is stony, disfigured with stony droppings from the furnace; stringy, thin threads of glass meandering over its surface; "ambitty," covered with stony speckles, symptoms of incipient devitrification; conspicuous with gatherers' blisters and blisters from the pipe; badly gathered; badly blown—thin here, thick there, and grooved with a row of scratches; and on this abortion the flattener chances to have exerted his most exquisite skill; it has passed through his hands unscathed, flat as a polished mirror, yet, from its previous defects, entirely worthless. Next comes before you a piece whose beginning was miraculous—no seeds, no blisters; it prospered under the hands of the gatherer and blower, and left the glass house a perfect cylinder. But the croppie of the flattener marked it; the fire scalded it; dust fell upon the lagre and dirtied it; scraps from the edges of the preceding cylinder staid upon the lagre and stuck to it; the stone scratched it; and the heat of the annealing chamber bent it. Such are the difficulties to which every cylinder is subject—those of the glass house and those of the flattening kiln. Not all, however, are such as these; there are good as well as bad, but the good are generally in the minority.

SIZE OF WINDOW-GLASS.—When the manufacture of glass was new in England the size usually blown was 36 by 20 inches. This is now somewhat increased, and cylinders 85 by 49 inches have been blown, and in some cases blown cylinders 158 inches long by 26 inches in circumference and 70 inches long by 60 inches in circumference have been made, but such large sizes, and indeed any over 60 by 40 inches, are exceedingly difficult to make. The thickness is computed by the number of ounces to the square foot. The average size of 15- and 21-ounce glass is 48 inches by 34 or 36 inches.

BLOWN AND PATENT PLATE.—In various parts of England thick blown glass is often ground and polished in a manner somewhat similar to the cast plate of commerce, and is known as blown and patent plate. The cheap production of this glass was made possible by the remarkable invention of Mr. James Chance, who conceived the ingenious idea of laying every sheet of glass intended to be ground and polished upon a flat surface covered with damp pieces of soft leather. Two sheets thus placed are turned one against the other in a horizontal position, sand and water being constantly supplied between them by means of a most ingenious machine. The two surfaces are rapidly rubbed one against the other in all directions and ground and afterward polished.

BLOWING FLINT WARE.—All glass when in the plastic condition can be blown with greater or less facility. This statement applies not only to the lead flint of England, but to the lime and half crystal of other countries. In blowing and working the various glasses of these countries into the many forms of blown wares the process is essentially the same. The metal is gathered in a manner similar to that described under window-glass. The metal, so gathered, is rolled on the marver (a corruption of the French word *marbre*, marble being formerly employed), which is a slab of cast-iron with a polished surface. Upon this slab the lump of glass is rolled to give it a regular exterior, so that the blowing may give a uniform thickness of the metal. This lump of glass is then expanded by blowing and lengthened by swinging. A pontil, puntee, or ponty, a solid iron rod, tapering and varying greatly in length and strength, is attached to the blown globe of glass, when the blowing rod is removed by wetting the glass near where the tube enters. The workman now takes the pontil from his assistant and lays it on the chair, which is a flat seat of timber about 10 inches wide, each end being fixed to a frame connected with four legs and two arms, the latter being inclined. This pontil is rolled backward and forward by the workman with his left hand, thus forming a throwing-wheel of great delicacy, while with his right he molds the glass into the various shapes required by means of a very few simple tools. By one of these, called pucellas, the blades of which are attached by an elastic bow, like a pair of sugar-tongs, the dimensions of the vessel can be enlarged or contracted at pleasure. Any surplus matter is cut away by a pair of scissors. For smoothing the sides of the vessel a piece of wood is used, and for flattening the bottom of tumblers or similar purposes the battledore, a flat square of polished iron with a wooden handle, is used. In these operations the article operated upon may be reheated several times. After it is finished it is detached from the pontil by a sharp blow and carried on a pronged stick to the annealing oven or leer, which is a low arched furnace, generally of considerable length. In this oven small tracks are laid, on which wagons mounted on four wheels are placed, the articles to be annealed being filled into such wagons. These are slowly pushed through the ovens, and are removed at the opposite end.

FLINT-GLASS CUTTING, ENGRAVING, AND ETCHING.—The sparkle and brilliancy of flint-glass are developed by the process of grinding and polishing, technically called glass-cutting. Motion is communicated to the glass-cutter's mill, which is of wrought- or cast-iron, by a pulley and band. Over it is suspended a wooden trough or cistern, containing a mixture of sand and water, which, for the operation of grinding, is fed on the wheel as required. Smoothing is done on a wheel of fine sandstone, to which water alone is applied, and for polishing a wooden wheel, supplied with emery, and finally with putty powder (oxide of tin), is employed. The trough under the wheel receives the detritus of the grinding and other operations. The articles are held in the hand, and are applied to the mill while rotating. The punty marks on tumblers, wine-glasses, and the like are ground off by boys holding them on small stone-mills. Ground or obscured glass is made by grinding the surface on a wheel with sand and water. In some works in this country the article is placed on a lathe, and while it is revolving sand and water is applied by a wire brush. Iron tools, fixed on a lathe and moistened with sand and water, are used to rough out the stoppers and necks of bottles, which are completed by hand polishing with emery and water. Engraving is the production of ornamental surfaces by a fine kind of grinding, mostly done with copper disks revolving in a lathe. Etching is variously done by submitting the portions to be etched or bitten to the influence of hydrofluoric acid, the remainder of the glass being stopped off or protected by a coating of wax or some pitchy compound. (*a*)

BLOWING IN MOLDS.—In blowing bottles or other articles the same method is pursued in gathering the glass as is described above. When sufficient glass has been gathered by the assistant, it is handed to the blower, who rolls it upon a marver, blowing into the metal and forming the rough outline of the article. This is then put into a press or cast-iron mold, which is divided into two or more pieces, and which the workman operates by his foot, opening or shutting at pleasure. As the glass is dropped into this mold, and the mold is shut, the workman blows into the glass to cause it to fill all parts. The glass immediately solidifies, the blowing-iron is broken off, and the article carried to the annealing furnace, the mouth, if it is a bottle, having previously been fashioned.

a See *Encyclopædia Britannica*.

The great objection to molds is the injurious effect on the surface of the glass. This objection has been overcome by the use of wooden or carbon molds fitted in metal frames, the use of which is quite common in France and Belgium.

FASHIONING ART-GLASS.—To describe the various methods employed for manipulating art-glass, and to enter further into details regarding methods of fashioning the higher grades of glass for table use, hardly fall within the scope of this report. Those interested in these matters, however, are referred to various works on this subject, especially that of Mr. Apsley Pellatt on the *Curiosities of Glass Making*, Mr. Alexander Nesbitt's *Hand-book on Glass*, and the recent publication, *Glass in the Old World*, by M. A. Wallace-Dunlop.

THE PORTLAND VASE.—Though I have not deemed it advisable to enter into any extended description of the different processes employed in the manufacture of what I have termed art-glass, this account would be incomplete without some reference to the Portland vase. This vase was found in a marble sarcophagus of a sepulchral chamber under the Monte del Grano, about 3 miles from Rome, on the road to Laurentium. The inscriptions on the sarcophagus showed it to have been dedicated to the memory of the Emperor Alexander Severus, killed A. D. 325, and his mother, Julia Mammoea. The vase measures 10 inches in height by 7 in width, and is ornamented with white opaque figures in bas-relief upon a dark-blue transparent ground. This blue ground was originally covered with white enamel, out of which the figures have been sculptured in the style of a cameo with astonishing skill and labor. For a long time this vase was supposed to be of stone, but now there is no doubt that it is of glass, and is supposed to date about two centuries before Christ.

Immediately after its discovery this vase was placed in the library of the Barberini family, who sold it to Sir William Hamilton, by whom it was brought to England and disposed of to the Duchess of Portland, from whom it received the name by which it is now known (the Portland vase), having previously been called the Barberini. At the sale of the museum of the Duchess, in 1786, the vase was purchased for £1,029 by her son, who permitted Wedgwood to copy it. Fifty copies were made in jasper ware, which were sold at 50 guineas apiece, but the sum received did not pay for the reproduction. The vase is now in the British museum, where it is carefully guarded. (*a*)

It was for a long time believed that modern skill was inadequate to the reproduction of this vase, or indeed to the production of work similar in character; but the intelligence and remarkable artistic skill of Mr. John Northwood, of Wordsley, near Stourbridge, England, has not only succeeded in reproducing this vase, but in producing similar vases fully equal, if not superior, to the Portland. The reproduction of the Portland vase by Mr. Northwood was undertaken with the assistance of Mr. Philip Pargeter, who manufactured the vase used, and after a large number of trials succeeded in imitating the full rich blue of the original. He coated the copy a sufficient thickness with a layer of white, soft, opal glass, and succeeded in welding them together with the utmost thoroughness. The vase was now ready for Mr. Northwood to operate upon. His mode of proceeding was to cut away the opal by hand with chisels and gravers and carve upon it the entire design of the original in the same manner as the finest cameo engraving. For the entire ground of the design the opal has been literally chiseled away and the surface of the blue glass polished. The figures, trees, etc., composing the design are left in relief in the opal, and are carved with consummate skill and unapproachable delicacy. Mr. Northwood devoted three entire years to the work. In addition to the skill required on the artistic part of the work the artist met with unexpected difficulties in contending with a flaw in the metal. The character of the work was such, also, that the ordinary glass-engravers' tools would not answer, and new ones had to be invented. The result has been, however, that again it has been shown that modern art, in many respects, is equal to ancient. This copy is valued by Mr. Pargeter at £1,000.

Since reproducing the Portland vase, which was finished in 1877, Mr. Northwood has produced others of a similar character that are regarded by some critics as even superior to that work. At the Paris exposition of 1878 a vase was shown in the exhibit of Thomas Webb & Sons, representing the triumph of Galatea and Aurora. This vase at the time was unfinished, but its value was estimated at $15,000. Mr. Northwood has also produced a vase called the Milton vase, which in beauty of conception and in exquisite and delicate execution is believed to surpass the Portland vase.

TEMPERED, HARDENED, OR TOUGHENED GLASS.—In 1875 M. Alfred de la Bastie, a French gentleman, announced that as the result of a series of experiments he had discovered a method of so tempering or hardening glass that the strength of the material would be greatly increased. His experiments were based upon the assumption that the fragility of glass is due to the weakness of the cohesion of its molecules, and that if the molecules could be forced closer together, thus rendering the mass more compact, the strength of the material would be increased. In his first experiments he endeavored to produce this result by mechanical compression while the glass was in a fluid or viscid state. Being unsuccessful in this, he was led to make use of a modification of the method by which the well-known Prince Rupert's drops have so long been produced. In the manufacture of these drops a piece of very fluid glass is dropped into water, assuming, as it falls, the shape of a tear or drop. The outside of the glass cools at once, the inside remaining partly fluid for some time, but ultimately the mass becomes

a After being placed in the British museum it was left uncovered, and was dashed into a thousand pieces by the cane of a madman. The pieces, however, have been so skillfully joined as to leave no trace of the accident.

perfectly solid. This indicates that the outside layer is at once condensed by cooling, while the inside remains fluid, and is consequently more distended. Though the outside of the drop is very hard, and a severe blow may be struck upon the thick part without any perceptible effect, if the tail or thin end is broken the whole mass instantly flies to pieces with a slight detonation. Dumas explains these phenomena by stating that when at last the central and dilated parts of the drop become cooled they must have retained points of adherence to the surface, and consequently occupy a larger volume than that which agrees with the temperature to which they are reduced. The central molecules, therefore, must be much distended and exert a more powerful contracting influence on the surrounding parts; are, in a word, "on a strain," as a workman would term it. At the instant when a part of the envelope or outer portion is broken the molecules held by it briskly contract, draw in with them all the others, and thus determine a multitude of points of rupture; and as this effect is instantaneous, the particles move very rapidly and drive out the air before them, producing a sudden dilation and contraction of the latter.

BASTIE'S TEMPERED GLASS.—In view of these well-known phenomena, M. de la Bastie endeavored to find a method by which the hard surface produced by immersion in water could be retained and thickened while the objectionable tendency to flying in pieces would be lessened or removed. In his experiments he found that two conditions were necessary: first, the glass must be brought to just that degree of heat where softness or malleability begins, the molecules then being capable of closing suddenly together and condensing the material when immersed in a liquid at a considerably lower temperature; second, the liquid employed must be capable of being heated much higher than water without boiling. He therefore adopted an oleaginous mixture, into which he plunged the glass, reheating the latter, which had previously been annealed in a kiln.

DIFFICULTIES OF THE PROCESS.—This process was admittedly a success as far as flat or solid glass was concerned, although the necessity of heating the glass to the point of softening rendered it extremely difficult to handle, and the liability of the bath to catch fire had to be lessened in some manner; but both these difficulties were overcome by M. de la Bastie's apparatus for reheating and plunging the glass. The process, however, was found to be defective as regards any other forms of glass, such as hollow flint vessels, as such glass, while being reheated, is almost certain to collapse before reaching the required temperature. In M. de la Bastie's experiments at Whitefriars glass works, England, therefore, a new plan was adopted, by which the bath was placed as near the mouth of the working pot as possible, and the workmen dropped the finished vessels directly into it. This process was found to answer well in the manufacture of all vessels made in one piece, and the somewhat complicated apparatus for reheating was done away with. As regards the character of the glass obtained by the process, Mr. Powell, of the Whitefriars works, disposes of some popular fallacies in this wise:

> Hardened glass is not unbreakable; it is only harder than ordinary glass, and, though it undoubtedly stands rough usage better, it has the disadvantage of being utterly disintegrated as soon as it receives the slightest fracture, and up to the present, until broken, of being undistinguishable from ordinary glass. This glass is known as "toughened" glass, and we have seen the terms "malleable" and "annealed" applied to it. Nothing can be more misleading than these unfortunate epithets. The glass is hard, and not tough or malleable, and is the very opposite to annealed glass. Annealed glass is that glass the molecules of which have been allowed to settle themselves; the molecules of hardened glass have been tortured into their position, and until the glass is broken are subject to an extreme tension. It is the sudden change of temperature that "hardens"; glass heated up together with the oil may be annealed, but decidedly is not hardened. A piece of hardened glass is only a modified Rupert's drop, *i. e.*, it is case-hardened; the fracture of both is identical; both resist the diamond and both can be annealed. * * * In our experiments we found that while the glass could be marked with the diamond or smoothed and engraved in the ordinary way, still an endeavor to cut it with the diamond, or even the disturbance caused by the smoothing-wheel, when penetrating to any appreciable depth, tended to weaken or even to cause the destruction of the entire mass.

For practical utility the value of glass tempered by M. de la Bastie's process is of course impaired by its inability to be cut, and also its utter destruction by the slightest fracture. It will stand sudden changes of temperature without breaking, but if reheated slowly to a high temperature its temper is destroyed and it becomes as common glass. The great anticipations which were at first formed as to the extended use of the glass have not been realized. M. de la Bastie has made some improvements in his process, and two eminent London firms adopted it and manufactured the glass for a time, but finally gave it up. In this country Messrs. E. de la Chapelle et C^ie^., of Brooklyn, manufacture on the Bastie system, but the process is not a complete success, the glass not being uniform in temper or producing the best results.

SIEMENS' TEMPERED GLASS.—While M. de la Bastie was introducing his discovery to public notice in Europe Mr. Frederich Siemens, who is owner of the most considerable glass-bottle works in Germany and Bohemia, and perhaps in the world, was studying the question of tempering glass by following a different course from that selected by the former. Instead of plunging hot glass objects into liquids, Mr. Siemens, fearing distortion of the articles to be treated, conceived the idea of subjecting them to tempering by placing them in molds between cooled surfaces, whereby not only would their shape be maintained intact, but force could also be applied, if necessary, to press the molecules of glass firmly together. By these means glass of any shape could be tempered, and the process was considered to be particularly well suited for the production of strong window-glass, which had not previously been attempted. Mr. Siemens, however, soon found that the glass so prepared was liable to the defect of breaking suddenly, and he had to undertake further researches, with a view of perfecting his process, by the removal

of that defect. When a cube of tempered glass is considered, it will at once be seen that, all its surfaces having been subjected to the same cooling influence, the edges, and particularly the corners, will be much more cooled than the broad surfaces. At each edge the cooling will take place from two surfaces, and at each corner from three surfaces, from which circumstance Mr. Siemens inferred that glass so treated could not be homogeneous in character, and that sudden breakages were due to that cause. To overcome this defect Mr. Siemens modified his process so as to limit the cooling influence of his apparatus to two surfaces of the glass under treatment. From these surfaces the cooling and tempering action is transmitted to the center of the mass in a uniform manner, whereby homogeneous glass is produced which is found to give entire satisfaction. By Mr. Siemens' process glass may be tempered to various degrees of hardness, according to the use for which it is intended. For the production of window and other flat or molded glass presses, cooled by the circulation of water, are employed, but in dealing with large castings of glass, such as railway sleepers, for example, the castings are packed in rectangular boxes, or trucks, heated internally for their reception, and all interstices between them are filled up with a material having the same conductivity for heat as glass. These boxes or trucks are constructed so as to prevent dispersion of heat at their sides, and as each is filled with glass articles it is withdrawn from the kiln to cool from two parallel surfaces only By this means ideal plates are formed, which are treated like the solid plates for the production of homogeneous tempered glass in bulk. Glass railway sleepers, tempered on Mr. Siemens' plan, have been introduced in England, and have been put in actual use on one or two railway lines.

TESTS OF THE SIEMENS' GLASS.—A number of tests were made of these sleepers, at one of which it was shown that their average breaking weight, when resting on supports 30 inches apart, was 5 tons. At another time a plate of Mr. Siemens' toughened glass, 9 inches square by 1⅛ inches thick, imbedded in gravel ballast 9 inches deep, and having on its top a wood packing one-eighth of an inch thick and a piece of rail, was subjected to the action of a falling weight, the blows being delivered on the rail. The weight was 9 hundred-weight, and blows were successively delivered by letting this weight fall from heights of 3 feet, 5 feet 6 inches, 7 feet, 10 feet, 12 feet 6 inches, 15 feet, 17 feet 6 inches, and 20 feet. Under the last-mentioned blow the rail broke, the glass, however, being uninjured. A higher fall could not be obtained, and a greater weight was not available. A smaller section of rail was substituted for that previously employed, and the glass was broken by the second blow of the 9 hundred-weight falling 20 feet, the plate being driven through the ballast into the hard ground. A cast-iron plate, 9 inches square and one-half an inch thick, tested in a similar way, broke with a blow from the 9 hundred-weight weight dropped 10 feet.

USES OF SIEMENS' GLASS.—Mr. Siemens writes me, under date of January 29, 1881:

Extensive works are about to be established in England for carrying out my process and for producing the glass to be tempered. These works will at the start comprise furnaces capable of producing 50 tons of glass per day, and will be arranged in view of being doubled and trebled in a short time, it being confidently expected that a large demand will arise for strong glass as a substitute for wood, brass, cast-iron, stone, and other substances, in the condition of railway and tramway sleepers, gas-, water-, and drain-pipes, eave troughs and gutters, millstones and crushers, tiles for roofing, facing walls and flooring, plates for floors of bridges, tanks, and cisterns, ship lights, telegraph insulators, etc., for which applications tempered glass will offer the advantages of economy in first cost and greater durability over the materials now usually employed.

COST OF SIEMENS' GLASS.—The cost of glass toughened on Mr. Siemens' plan is stated to be about the same per ton as that of cast-iron; but as its specific gravity is only about one-third that of iron, the cost of any article of given dimensions is, of course, materially less. The material has as yet been too recently introduced, and too little is known of its characteristics, to enable any very decided opinion to be formed as to its future capabilities; but the results of the experiments so far made are certainly of a very promising character, and the further development of its application will be watched with much interest.

GLASS FROM BLAST-FURNACE SLAG.—The process of manufacturing glass from the waste cinder or slag of iron blast-furnaces is simply the utilization of a substance which already contains many of the ingredients of glass by adding to it those materials necessary to complete the composition. The idea is not a new one. In England, and also on the continent, a sand prepared by pulverizing slag has long been used as an ingredient in glass-making with much success. It is possible that much of the early glass was metallurgical slags remelted.

RELATIVE COMPOSITION OF GLASS AND SLAG.—Recent comparative investigation into the composition of glass and of slag shows that the use of the latter in this manner is not without reason, the two substances being very similar, as is shown by the following table:

Constituents.	Composition of iron slag (Welsh or South Staffordshire).	Composition of bottle-glass (quantities variable).
	Per cent.	*Per cent.*
Silica	40	45 to 60
Lime	35	18 to 28
Alumina	16	6 to 12
Magnesia	6	0 to 7
Alkali	½ to 2	2 to 7
Oxide of iron	½ to 2	2 to 6

A trace of sulphur is also found in slag associated with the lime, but this readily passes away with heat, and is insignificant. The iron, which would seem to be the most objectionable element, while present in too great quantity for the manufacture of perfectly clear glass, is still less than is often required by the glass-maker. The chief points of difference between the slag and the glass are in the silica, alkali, and iron, the slag being too deficient in sand to make a hard glass.

ADDITIONS TO SLAG IN THE MANUFACTURE OF GLASS.—To make glass of slag of the composition given the additions indicated in the following table should be made:

Slag.		Additions.		Glass.	
Silica	40	Ferruginous sand	60	100	or 57.14 per cent.
Lime	35			35	or 20.00 per cent.
Alumina	16			16	or 9.14 per cent.
Magnesia	6			6	or 3.43 per cent.
Alkali	1	Soda	10	11	or 6.29 per cent.
Oxide of iron	2	From the sand	5	7	or 4.00 per cent.
	100			175	100.00

Thus by combining with 100 parts of slag 10 parts of soda and 65 of sand the proportions of the lime, alumina, and other constituents are severally altered, and a compound formed of the precise nature required. It is to be noted that the figures come well within the limits of difference found in the analyses of glass given in the previous table. It would seem that the variation in the purity of the slag would interfere with certainty in its use; but daily analyses of slag at a furnace in Great Britain have shown that its composition is measurably regular, enough so for all practical purposes.

USE OF HOT SLAG.—To take slag, however, which has cooled, and remelt it in connection with the additions named, would require so intense a heat as to counterbalance all benefit to be derived from its cheapness. A plan was brought to public notice in England in 1876 by which the slag is taken as it comes from the blast-furnace and converted into glass without cooling. Mr. Bashley Britten, the originator of this plan, has established glass works at Finedon, in Northamptonshire, at which the slag from the Finedon furnaces is used. The molten slag is conveyed (presumably in covered iron vessels mounted on wheels) to the glass furnace in the immediate vicinity, and is poured, after the addition of the necessary ingredients, directly into the melting furnace, where, after proper fusion, it is run into another chamber, from which it is drawn by the workmen and fashioned into shapes. The products of these works comprise chiefly such articles as wine and beer bottles, which do not require a colorless glass. This process might be much improved by locating the glass house immediately adjacent to the blast-furnace, from which the slag could be run directly into the melting furnace. In regard to the great economy of the process, Mr. Britten says, (*a*) referring to the table given above:

> The above 175 parts or tons of glass would, consequently, be produced with the following economy: One hundred tons of it would cost an iron-master nothing. Instead of the labor of mixing and handling in the usual way the whole quantity of the material, only 75 tons would have to be lifted into the furnace. The only ingredients to be bought are 65 tons of common yellow or red sand, to be had anywhere at a mere nominal price, and 10 tons of common sulphate of soda, which may be bought or made for about 20*s.* per ton. The necessary fuel would be limited to what is needed beyond the surplus heat of the slag to raise only three-sevenths of the glass to the required heat; and it is a question whether the greater part of even this might not be saved by bringing down some of the spare gases from the blast-furnace and employing them with regenerators; if needed, they could easily be enriched with a little added carbon. Against these items there would be a set-off from the cost of removing the 100 tons of slag, which must otherwise be thrown away. Beside this, another and considerable saving would arise from the wear and tear of the glass furnace being lessened, in consequence of four-sevenths of the materials going into them being already fused. Under such circumstances the total cost of the glass in a melted state ready for working is seen to be so extremely small that it is hardly safe to venture to express it in figures; it scarcely amounts to the value of the commonest bricks per ton.

COLOR OF SLAG GLASS.—The natural tint of the glass thus produced is greenish, but it can be colored to any required tint, and by careful fining and bleaching it can be produced almost as colorless as common window-glass. A cheaper glass can be made by using more slag and less sand, and with some ores the slag is said to be sufficiently siliceous in itself to be converted into a black or dark green or amber glass. With the simple addition of soda and a little arsenic it becomes transparent and perfectly workable, and may be used for many purposes. Acid, however, corrodes this glass, on account of its want of silica. Glass of superior quality to the first mentioned can also be produced. The constituents of slag, as has been seen, are common to all kinds of green glass, and by diluting them with the usual pure materials to a greater or less extent the compound may be brought up to any standard short of the purity of color inconsistent with the iron and sometimes manganese in the slag. Should the manufacture of glass in this manner ever be deemed of sufficient importance to warrant the taking of steps to purify the slag, much more might be accomplished. The working qualities of the glass thus produced are excellent, admitting of its being blown, cast, or pressed with great ease, and Mr. Britten's company propose to enter into the manufacture of other articles beside bottle from a material so cheaply produced.

---

a See his paper in *Journal of British Iron and Steel Institute*, 1876, pages 453–467.

Chapter VIII.—HISTORY OF SOME PROCESSES OF GLASS-MAKING.

For many years the question as to whether window-glass was known to the ancients was a matter of doubt and discussion, and it has only been recently that the evidence of its use prior to the beginning of the Christian era has been conclusive. Winckelman, the author of the remarkable *History of Art*, who was assassinated in 1768, pleaded its antiquity, but by far the greater number of scientific men considered it a modern invention, their view being strengthened by the almost utter absence of any allusion by ancient writers to window-glass and the utter lack of fragments of this glass, though large quantities of pieces of vases and other vessels had been found. This want of allusion and absence of remains shows that at least it was of rare occurrence and use.

The first positive evidence of the antiquity of window-glass was its discovery, in the year 1763, in a small chamber attached to the bathing-room of a private dwelling, the House of the Faun, unearthed at Pompeii, "in a window closed by a movable frame of wood, which, though converted into charcoal, still held when it was found four panes of glass about 6 inches square." In 1824, in a room connected with the public baths, "a window 2 feet 6 inches high and 3 feet wide, in a bronze frame, in which were found set four beautiful panes of glass fastened by small nuts and screws, very ingeniously contrived with a view to being able to remove the glass at pleasure," was discovered. Remains of what is supposed to be window-glass of the Roman period are now occasionally found in the ruins of Roman houses built in England and Italy. Dr. Bruce, in his work on the Roman wall, states that "fragments of window-glass are frequently found at some of the stations", and in 1855 he exhibited at Newcastle samples found in the course of his excavations at Bremenium. It is also certain now that glass was used by the Romans for green-houses and for the frames used over plants. The glass found at Pompeii shows by chemical analysis a very close resemblance to the glass of modern days, containing about 69½ per cent. of silica, 7¼ per cent. of lime, and 17⅓ per cent. of soda, with 3½ per cent. of alumina. This glass also contained 1.15 per cent. of oxide of iron and 0.39 per cent. of oxide of manganese, the latter being used probably to correct the color due to the iron.

It must not, however, be supposed that glass was used to any great extent in the windows of dwelling-houses at this time. The glass was not blown, but probably cast on a stone, as it is very uneven and full of defects.

Before the close of the third century, however, window-glass begins to be mentioned in the writings chiefly of the monks and priests of the time, and mainly in connection with the glazing of churches. About this time reference is made to window-glass by Lactantius, A. D. 290, who says that "our soul sees and distinguishes objects by the eyes of the body as through windows filled with glass". Jerome, A. D. 331, speaks of sheets or plates of glass obtained by casting, the casting-table being a large flat stone, and the ordinance of Constantine II, A. D. 337, mentions *specularii*, who were probably glaziers working in other materials as well as in glass.

From this time the evidences of the use of window-glass multiply. It is reasonably certain that it was employed in the church at Treves early in 420. During the fifth and sixth centuries many large churches were built at Rome and Ravenna which were filled with numerous windows, and in the sixth century the glazed windows in the church of Saint Sophia, at Constantinople, with panes from 7 to 8 inches wide by 9 to 10 inches high, were among the wonders of the East. Indeed, it was the building of churches, or the conversion of pagan temples into houses for Christian worship, that extended the use of window-glass at that time. The Roman priests kept the windows and sometimes the roof of the buildings open to read the auguries, but these the Christian priests closed.

Window-glass was used in France as early as the third century, but became more common in the sixth. Late in the seventh century "Abbot Benedict", so saith the venerable Bede, "sent for artists from beyond the seas to glaze the church and monastery at Wearmouth," and York cathedral was glazed about the same time. In the eleventh and twelfth centuries glass was generally employed in the windows of the religious edifices, and it is reported that somewhere about the end of the first thousand years of the Christian era a window-glass works was established at Newcastle-on-Tyne, which proved a failure. From the close of the twelfth century the use of glass for windows became more and more common.

The earliest glass used for windows was undoubtedly cast, that used at Pompeii having evidently been cast on a stone, on the same principle as plate-glass is made at the present time, only it was not polished. It thus appears that, though rough cast plate-glass was for a long time believed to be a modern invention, it really is the oldest method of making glass for windows. This was, however, probably in the twelfth or thirteenth century, or perhaps earlier, abandoned for blown window-glass, and was revived and virtually rediscovered in France in 1688 by Abram Thevart. He obtained a patent for thirty years for the invention, and erected works in Paris, where plates were cast of the then extraordinary dimensions of 84 inches long by 50 inches wide. This works was transferred to Saint-Gobain, which has since become celebrated for its plate-glass. Disputes arose between Thevart's company and a company of Venetian workmen who were manufacturing blown plates near Cherbourg, and Thevart's company was bound not to cast any plates whose dimensions should be less than 60 inches in length and 40 in breadth. To end the rivalry the two companies were consolidated. Two years, however, from the consolidation

the company was in a state of insolvency, and many of its furnaces were abandoned. Blancourt gives a different account of the invention of plate-glass, and ascribes it to the accidental spilling of some liquid glass from a crucible upon the ground. The metal having ran under one of the large flat stones with which the place was paved, upon taking up the stone a piece of plate-glass was found under it. This is stated to have been two hundred years before Blancourt wrote in 1699. The first English establishment of any magnitude for the manufacture of glass was begun in 1772 or 1773 at Ravenshead, at which date "the Governor and Company" "of the British Plate-Glass Manufacturers" were incorporated for the purpose of manufacturing plate-glass in England, and as late as 1832 this was the only establishment in that country. Since that time, however, a number of works have been established. The oldest plate-glass works in Belgium, we believe, dates from near the beginning of the present century, while that of Germany has been in existence but a few years.

As noted, it is very difficult to say when blown window-glass was first made; but one of the earliest notices of it is by the monk Theophilus, in the thirteenth century, who, in his *Essay on Divers Arts*, gives an account of a method then employed of blowing glass, which is a perfect description of that used at the present time. For many years the factories at Venice were renowned for their blown window-glass, and in the seventeenth century workmen from its houses were scattered in various parts of Europe and taught many of the glass-workers of the different countries the method of making cylinder-glass. Nesbitt also states that window-glass was made in Germany at a very early period, and it also seems, from a statement quoted elsewhere regarding the windows of Beauchamp chapel at Warwick, that window-glass was made in England, probably blown, in the fifteenth century. Mr. Chance states that the manufacture of blown window-glass in England existed in the fifteenth century, and perhaps even prior to that period; but the glass then produced was of a very inferior description, and the first works of note established in England were those of Sir Matthew White Ridley & Co., on the river Tyne, at Newcastle, about the middle of the seventeenth century.

Vases, cups, and other hollow ware.—As has already been noted, the earliest records of glass-making (those on the tombs of Beni-Hassan and at Memphis) show unmistakably that the art of glass-blowing was well known at the early period at which these tombs were built. One of these figures illustrates two glass-blowers, with their blowing irons or rods in their hands, heating the glass, which has evidently been gathered, in a small U-shaped furnace. Another drawing represents two men blowing a vase.

From that day to this the production of various kinds of hollow ware has not ceased. An immense number of articles of this character, including vases and cups of all sizes and almost all shapes, from those of the most common description to others showing the most exquisite art, as instanced in the Portland and the Naples vases, and bottles of all forms and decanters, have been found. Indeed, so common and persistent has been the manufacture of these various articles, that the history of ancient and modern glass is chiefly the history of the manufacture of hollow ware, and, as we have entered so fully into the statement, nothing more need be said here.

Lead glass.—The invention of what was so long known as flint-glass, and now generally termed lead flint, to distinguish it from the lime flint of the glass houses of to-day, is an English invention. Its production was a necessity arising out of the use of coal in the place of wood in the furnace. This substitution of coal for wood affected injuriously the color of the glass, and to overcome the pernicious effects of the smoke the melting-pot was covered with a clay cap, which gave it the shape of a short-necked retort. It was found, however, that though the metal was protected from the action of the smoke, it was also protected from the action of the heat, and it became evident that either the time of melting, as well as the consumption of fuel, must be very much greater, or some flux or alkali must be used which would not deteriorate the glass, but hasten its melting. The flux used was lead, which had to a slight extent been employed on the continent of Europe for some time previous in the manufacture of artificial gems: a use which may probably have suggested its employment for the making of flint-glass. The use of lead, however, in the manufacture of glass was not entirely unknown before, as lead is found in many specimens of ancient glass, and Heraclius gives a recipe for making glass with lead. There was also a glass, known as the Jewish, made with lead in the Middle Ages. M. Peligot, however, reviewing these facts, comes to the conclusion that there is no proof that the true flint-glass was known to the ancients, and that to the English should really be attributed the honor of having created in their flint-glass a new product, which, by the progress made in the quality and selection of the materials used in its fabrication, has become without dispute the most beautiful glassy substance which we know, and which it may be possible to produce.

The date of the introduction of the manufacture of flint-glass with lead is placed by M. Bontemps about 1635; Nesbitt suggests that it may have been 1615.

The use of molds is generally believed to have been a comparatively modern invention; but, as is shown in the chapter on ancient glass, it is evident that some of the vases used in very remote times were not blown, but were cast or molded over a sand or clay core, which was afterward broken up. It also seems that the so-called Roman molded glass, which was supposed to be a modern invention, was well known to the Romans, as specimens exhumed in the city of London prove. At what time, however, the modern method of using molds in the production of various forms of hollow glass was first introduced is not known, though it is evident that the use of these has largely increased within the years since the introduction of the use of the lever-press for molding or pressing glass.

PRESSED GLASS.—One of the most important inventions of recent times, especially in the line of cheapening glassware, has been the production of what is generally known as pressed glass. This is an American invention, and the right of this country to the honor of its production has not been called in question until recently. Lardner, in his *Cabinet Cyelopœdia*, published in 1832, which has a very complete *résumé* of the methods of making glass in use at that time, has not even a suggestion of the pressing process. Pellatt, in his *Curiosities of Glass-making*, published in 1849, says:

> The invention of pressing glass by machinery has been introduced into England from the United States of America. It has not, however, realized the anticipations of manufacturers; for, by the contact of the metal-plunger with the glass, the latter loses much of the brilliant transparency so admired in cut-glass; hence it is now chiefly used for common and cheap articles. The process of rewarming or fire-polishing after the pressure has somewhat remedied this defect.

Recently, however, an attempt has been made to deprive the American glass manufacturers of the credit of this invention. The *London Pottery Gazette*, in a recent issue, says:

> There seems to be a general impression that pressed glass was first made in the United States. This is an error. The addition of the ring to give the thickness was undoubtedly an American invention; and this discovery, trifling in itself, opened up the pressed trade in a remarkable way by enabling the lever used in modern pressing to force up the metal sharply, so as to give it the appearance of cut-glass, as well as to closely imitate cut-glass patterns.
>
> Many in the English glass trade are living who remember the pressed square-footed ales and goblets. These are as old as the end of the last century, and were very fashionable with our ancestors. At first they were cut over, but they perfected the make so that they were simply cut at the bottom to take off the overplus.

ANCIENT PRESSED GLASS.—It is undoubtedly true that glass was pressed before the invention of the American lever-press, and one of the earliest specimens, bearing an inscription from which its date may be ascertained, is the lion's head, now in the Slade collection in the British museum, which was found many years ago at Thebes. This is evidently a piece of pressed glass, or glass pressed in a mold. In the British museum are also many pieces of glass found at Ialyssos, in Rhodes, chiefly disks, all of which have evidently been produced by pressure with a mold or die. There is no doubt that the Venetians were acquainted with pressed glass; but, notwithstanding this, the invention of what is now known as pressed glass is undoubtedly American. The same line of reasoning that is adopted to prove that this is not an American invention would also prove that lead-flint glass was not an English invention. Lead was used to make glass centuries before the invention of lead-flint in England, but the English are none the less entitled to the credit of the discovery of that beautiful, brilliant ware that we know to-day as lead-flint glass. Glass was no doubt made by pressing many centuries ago, but the invention of pressed glass, as it is understood to-day, the use of a mechanical press with mold, plunger, lever, etc., is due to American ingenuity. Pellatt, when referring to specimens of the embossed and pressed glass of the ancients, says: (*a*) "No machinery was used by them in producing any completely pressed hollow vessel or utensil at one operation." It occurs to me that if Mr. Pellatt, with all of his knowledge and information regarding ancient glass-making and his years of practical connection with the business in England, ascribes the invention of modern pressed glass to Americans, his testimony cannot be impeached.

HISTORY OF THE INVENTION.—The invention of the American press is ascribed to a Massachusetts carpenter in the town of Sandwich, about 1827, who, wanting an article of glassware made for some purpose, went to Mr. Deming Jarves and asked him if he could make the article desired. Mr. Jarves told him that it would be impossible for the glass-blowers to make such an article. The carpenter, who was of a mechanical turn of mind, asked if a machine could not be made to press glass into any shape. This idea was scouted at first, but upon second thought Mr. Jarves and the carpenter fashioned a rude press and made their first experiment. This machine was intended to make tumblers, and when the hot molten glass was poured into the mold, which was to determine whether glass could be pressed, the experiment was witnessed by many glass-makers of that time. They were nearly all of the opinion that the experiment would come to naught, and were greatly amazed when the result demonstrated that it was possible to press glass. From that time the manufacture of articles of glass by the use of pressing machines gradually developed, until to-day the bulk of the glassware produced in this country is made with presses. The first tumbler manufactured in the rough improvised press, alluded to above, remained in Mr. Jarves' possession for many years, and then passed into the hands of John A. Dobson, a well-known glass dealer in Baltimore, and was exhibited at the Centennial Exhibition by Hobbs, Brocknnier & Co., when it was accidentally broken by Mr. John H. Hobbs.

The *London Pottery Gazette*, to which we have referred above, in an article claiming the invention of pressed ware for England, says: "The first pressed tumbler was undoubtedly English, and was made about 1836." As Mr. Jarves made his pressed tumbler in 1827, as described above, we think that the evidence is conclusive that the first pressed tumbler was not English, but American.

The result of this American invention in cheapening glass has been most marked. By the use of iron or other metal molds immense quantities of the same article can be produced at a very low rate. This invention has in fact revolutionized the whole system of flint-glass manufacture, and has made it possible for all to possess for common use glass that in gracefulness of form and beauty of design and material was formerly within the reach of only the most wealthy.

---

a See Pellatt's *Curiosities of Glass-making*, page 122, note.

Chapter IX.—ANCIENT GLASS.

Discovery of glass.—But little is known of the early history of glass-making, and absolutely nothing of the method and date of its discovery. The story told by Pliny, (*a*) and repeated substantially by Tacitus (*b*) and by Strabo, (*c*) of its accidental discovery by some storm-driven Phœnician mariners while cooking their food on the banks of the river Belus, (*d*) is not entitled to the least credence. It is impossible that the high temperature necessary to the production of glass could have been obtained in the manner described in these fables. It is true, however, that a small spot at the mouth of this river supplied a most excellent sand, which was used not only by the Phœnicians, but by many other ancient glass-workers, and even by the Venetians in latter times. This fact, coupled with the excellence of the Phœnician glass and the commercial enterprise of the people, which carried the products of their manufactories to all lands, may have given rise to the story related by Pliny, and thus for a time robbed the Egyptians of the credit of a discovery which is undoubtedly theirs.

Probable method of discovery.—While nothing positive is known of the method of the discovery of glass, it is not improbable that it was in connection with the older art of metallurgy. (*e*) Many metallurgical operations produce in their vitreous slag a coarse colored glass that may have led to the manufacture of glass as a direct product. All of the oldest specimens of glass are colored, and, so far as these have been analyzed, the coloring matter is metallic. The extreme variability in the composition of this antique colored glass led Klaproth to the conclusion that many of the specimens are merely metallurgical slags remelted. It is also true that much of the ancient glass is "cast." These facts certainly indicate, if its discovery was not due to this older art, that metallurgy had an important influence on early glass-making.

Egyptian glass.—The earliest evidences of the existence of the art of glass-making are found in Egypt. It is impossible, however, to surmise even at what time it began to be made in that country, aside from the certainty that the art antedates by many centuries the time of its earliest inscriptions and specimens. Egyptian chronology is so uncertain, that the same events are assigned by different Egyptologists to periods thousands of years apart. Inscriptions, paintings, and the glass itself, however, indicate its manufacture at least from 4,000 to 6,000 years ago. (*f*) Rawlinson, (*g*) a most conservative authority, states that "glass was known in Egypt as early as the Pyramid Period", which he places at 2450 B. C. (*h*) That at this early date the art of glass-making had reached a high degree of perfection and development seems beyond question. The art of blowing glass into bottles, fashioning it into vases and drinking-cups, pressing it into various shapes, especially figures of deities, sacred emblems and coins, forming it into huge masses for pillars, adapting it for mosaic art, coloring it to imitate precious stones, the color being of surpassing brilliancy, working it into beads or necklaces, these and similar processes were well known and practiced with great skill. It would seem impossible that the processes necessary to the production of these forms of glass could have been developed without centuries of practice. The invention of the art of blowing glass, which is unmistakably figured on the tombs of Mastaba of Tih, at Memphis, and on the tombs at Beni-Hassan, (*i*) is as remarkable as the discovery of glass itself, and would indicate an advance in the art that, in that day of slow development, must have required many centuries to evolve. The manufacture thus early begun was continued by Egypt far into the Christian era, and under the various dynasties and rulers, both native and foreign, it continued to flourish. When Egypt passed under the dominion of Rome, its glass houses found in the palaces and villas of the the imperial city a larger and more profitable market for their wares, and even as late as the third century its glass works were still in operation, an ordinance of Aurelian providing that glass should form a part of the

a See Pliny's *History*, book xxxvi, chap. xxvii.

b *Histories*, book vi.

c *Geography*, book xvi.

d This river runs along the base of Mount Carmel, and empties into the Mediterranean near the modern city of Saint Jean d'Acre.

e Metallurgy is one of the arts the invention of which is ascribed by the Egyptians to Osiris, and while the first man was living copper and iron were melted and worked (Gen., iv: 22). Some writers incline to the opinion that the discovery of glass was in connection with the art of pottery in making the glassy glaze.

f Among the earliest traces of glass are those found in the ruins of Memphis, built by Menes, first king of Egypt, whose reign Manetho places at 5004 B. C. The mummies in the tombs of this city wear necklaces of paste-glass beads. Glass-blowing is unmistakably figured on the walls of the tomb of Mastaba of Tih, belonging to the fifth dynasty, or, say, 3900 B. C. This is the earliest representation of glass yet discovered.

g See *Origin of Nations*, p. 56. For further account of glass and glass-making in ancient Egypt, see Wilkinson's *Manners and Customs of the Ancient Egyptians*, vol. iii, p. 58, and Rawlinson's *Herodotus*, 2d ed., vol. ii, p. 292. Pellatt, in his *Curiosities of Glass-making*, gives beautifully colored lithographs of some of the glass found in Theban tombs. See also *Glass in the Old World*, London, 1882.

h The enumeration of articles put into the west pyramid mention "glass which might be bended and not broken".

i The tomb is supposed to be of the time of Osirtasan I, some 2500 to 3000 B. C. A late number of the *Saturday Review*, discussing the antiquity of glass, says of the Beni-Hassan inscription: "A much older picture, which probably represented the same manufacture, is among the half-obliterated scenes in a chamber of a tomb of Tih, at Sakkara, and dates from the time of the fifth dynasty, a time so remote that it is not possible, in spite of the assiduous researches of many Egyptologists, to give it a date in years."

Egyptian tribute. Coins and tokens of as late a date as the eleventh century are in the Museum of Paris, and a basin of the same century, and lamps of the fourteenth, all the products of Egyptian glass houses, are still in existence. This long-continued practice of the art of glass-making in Egypt was probably due to the possession by the Egyptians of a great abundance of the essential materials, sand and soda, the latter, which was of excellent quality, being found native on the shores of its lakes. In a valley abounding in these lakes extending northwest from Memphis the Egyptian expedition of Napoleon I found remains of ancient glass furnaces. In this locality, at the "very gates of the lakes of Nitre", the priests of P'tah or Vulcan, who were constantly engaged in experimenting, placed their glass factories, and Rawlinson states that their ruins may still be found. These glass works, however, were not confined to this valley, but were situated also in the Delta and along the Nile valley. Those of Alexandria, however, were the most famous, especially for the production of colored hollow glass and mosaics.

Processes of Egyptian glass houses and character of the glass.—The processes used by these early glass-makers were, in many respects, similar to those of the present day. The "batch" was melted in crucibles, and the glass-blower's tool pictured on the Beni-Hassan tomb might well be taken as a representative of those in use at Pittsburgh to-day. Cast glass appears to have been a common product both of the Egyptian and the Phœnician glass houses, and molds were also used both for blowing and for pressing. Some of the hollow ware gives evidence of having been made on wire molds, and other specimens indicate that the glass was molded around a core or "former" of sand. Pressed glass, however, was not made as American pressed glass is formed, a die being used, into which the glass was pressed, or the die was pressed into a mass of pasty glass. The perfection to which these processes were carried, however, will not compare with that attained to-day. Egypt in the days of its best glass-making could not produce a cast plate approaching in size, purity of the glass, or brilliancy of surface those of Saint-Gobain, nor would her blown and pressed ware approach that of the United States; but it must be conceded, that some of the specimens of ancient glass that have been preserved, (*a*) especially such as are evidently the result of careful, patient manipulation, are unsurpassed by the products of our modern glass-houses, as they not only display a high degree of art, but give such evidence of exquisite skill and a knowledge of the most refined and delicate processes that even now they excite unbounded admiration. Among these products may be mentioned embossed and molded reticulated vases, glass mosaics, imitation pearls, glass pastes in several colors, precious stones, glass eyes, the "ut'a" of mummies, bottles, etc. This perfection, however, is only seen in articles of luxury, and indicates a degree of skill on the part of the workman that justly entitles him to the title of an artist in the highest sense of the word, and the product to be termed a work of art. While all this may be said of the skill displayed in working the glass when made, the "metal", as glass itself is technically termed, was decidedly inferior to that of the present day. White glass, as we understand whiteness, was unknown, and the clear, white, brilliant flint-glass of our works of to-day would have excited astonishment in the Egyptian and Phœnician glass houses. Most of the specimens that have come down to us from these ancient glass works are articles of luxury, and therefore might give rise to the belief that most ancient glass was of this character; but such is not the fact. Glass of an inferior quality, for common use, was largely produced, and it is probable that it was much more extensively employed by the ancients than it is in our time. (*b*) They had no porcelain, and were forced to use metal vessels or those of glass for many of the uses for which porcelain is now employed.

Composition of Egyptian glass.—The early Egyptian, as well as other early glasses, appears from its analysis to be a soda-lime glass, the Egyptian containing from 70 to 72 per cent. of silica, 17 to 20 per cent. of soda, and 5 to 8½ per cent. of lime, with some iron and alumina. Its composition is very similar to plate-glass made without potash, containing, however, more impurities.

Phœnician glass.—Second to Egypt in the antiquity, extent, and character of its manufactures of glass, if indeed it did not for a time surpass it in the excellence of its products, was Phœnicia, that wonderful country which gave us letters, and whose nautical skill and commercial enterprise made the Mediterranean, even in Homer's time, a "Phœnician lake". The renown of the workmen of Phœnicia at an early date is evidenced in the selection of Hiram of Tyre, the artificer, whom Hiram the king loaned to Solomon for the ornamentation of the Temple. Both Tyre and Sidon were famous for their glass, and the beautiful hollow ware made by them was universally celebrated in the ancient world. As already noted, the river Belus, which was near the northern boundary of Phœnicia, furnished a sand of excellent quality, which added largely to the renown of Phœnician glass. Mr. Nesbitt (*c*) thinks that among the earliest products of Phœnicia in the art of glass-making are the colored beads of opaque glass in great variety of color and pattern, called by the Ashantees "Aggry" beads. These beads have been found in all parts of Europe, in India, and in many parts of Asia and Africa, (*d*) their wide dispersion, as well as the abundance of other forms of glass that are probably of Phœnician origin, bearing evidence to the extent of this industry,

a These are chiefly articles of luxury or personal ornament, and have been largely preserved through the custom of burying with the dead articles which the deceased regarded highly, or which were used constantly.

b See Winckleman's *Origin de l'art.*

c South Kensington Museum of Art Hand-books: Glass, by Alex. Nesbitt, F. S. A., page 13.

d These are the "Glain neidr" (adders' eggs) and the "Gleini na Droedh" (Druids' beads) of Wales and Ireland, which are regarded with superstitious veneration by the peasantry.

and there is good reason to think that many of the glass vases found in tombs in the countries washed by the Mediterranean are the products of Phœnician work-shops, rather than of those of the country in which they are found.

CHARACTER OF PHŒNICIAN GLASS AND PROCESSES EMPLOYED.—Speaking of the character of Phœnician glass and the processes known and practiced, Kenrick says:

> They knew the effect of an addition of manganese to the frit of sand and soda in making glass clearer. They used the blow-pipe, the lathe, and the graver, and cast mirrors of glass. They must also have been acquainted with the art of imitating precious stones and coloring glass by means of metallic oxides. The "pillar of emerald" which Herodotus speaks of (ii, 44) in the Temple of Hercules at Tyre, "shining brightly in the night," can hardly have been anything else than a hollow cylinder of green glass, in which, as at Gades, a lamp burnt perpetually. (*a*)

Rawlinson says regarding Phœnician glass-makers:

> What was the amount of excellence which they attained is uncertain; but the fame of the Sidonian glass in early times would seem to imply that they surpassed the artists both of Assyria and Egypt. (*b*)

LATE PHŒNICIAN GLASS MANUFACTURE.—As in Egypt, the manufacture of glass was continued in Phœnicia, especially at Sidon, far into the Christian era, even as late as the twelfth century, at which time it appears to have retained some of its ancient reputation. The art also seems to have found a place in the industries of the other Syrian cities. In the twelfth century some Jews of Antioch were known as glass-makers. In the fourteenth century Damascus was the chief seat of glass-making in the East, and as late as the seventeenth century glass-making is mentioned among the industries of Smyrna.

GLASS-MAKING IN THE OTHER ANCIENT MONARCHIES.—In following the history of glass-making, there is little to note after leaving the glass houses of Egypt and Phœnicia until we reach those of Rome. The other great monarchies do not appear to have become celebrated in this art, as the specimens found in their buried cities do not furnish sufficient data to enable the formation of any judgment as to the extent to which glass-making was practiced, and but little as to the character of the glass.

ASSYRIAN GLASS.—Layard found in the ruins of Nineveh, which was destroyed 625 B. C., a number of specimens of glass, among which were a glass lens and a small vase or bowl of a transparent green glass with the name and title of the Assyrian monarch Sargon (719 or 722 B. C.) This was blown in one piece, and was then shaped or hollowed by a turning machine, and is regarded as the earliest specimen of transparent glass. An earlier vase, with the name of a Khorsabad king, which Layard found, was stolen or lost. Many glass vases and bottles of elegant shape were unearthed in the same mound, some of which were colored, some ribbed, and others otherwise ornamented. In the palace of Babylon, at Kars, vases and bottles of gilt glass of Assyrian origin have lately been discovered, and M. Botta found among the ruins of Nineveh a round glass bottle or vial with oblong black spots melted into the glass, the earliest specimen of the tear-sown bottles known, the "*gafres de Venise*". The discoveries at Babylon, while they show the use of glass by its inhabitants, indicate the possession of but little skill, the vessels found being of small size, and the bottles very frequently misshapen. Egypt, however, exported immense quantities of small glass articles to Babylon, and some of the glass found may have been of Egyptian origin.

GREEK GLASS.—But little is known of the history of glass in Greece. Homer does not mention it, Aristophanes being the earliest writer who refers to it, and the excavations by Dr. Schliemann throw but little light on the subject. At Mycenæ and Troy he found but few pieces of glass, and these only beads, disks, and pieces of vitreous paste. General De Cesnola brought to light at Dali, in the island of Cyprus, a remarkable collection of Greek glass, containing 1,700 pieces, some of which show great skill; but these are by no means of the earliest Greek period, and are placed by him at later than 100 B. C. Greek art, however, had considerable influence upon Roman glass. The Portland vase, for example, shows marks of Greek rather than of Roman art, though it is not certain that it is of Grecian workmanship. However, it is certain that some glass was made in Greece, and many of the lovely Greek vases of the tombs of the countries of the Mediterranean are undoubtedly of this kind of glass. The Greeks appear also to have used glass occasionally for purposes of architectural decoration during the best period of Grecian art, but not to the extent that it was afterward used at Rome.

CARTHAGINIAN GLASS.—There is some evidence that Carthage was the seat of glass-making. As is well known, this city was thoroughly Tyrian, and the relations between it and the mother city were very close. It is probable that most of the glass used in the African colony was procured in Phœnicia. At the same time M. Deville, whose contributions to the history of glass have been so valuable, found on a tomb at Lyons the name of "Jules Alexander Africanus, citizen of Carthage, artist in glass". If this artist was from old Carthage, he must have gone to Lyons at least as early as the sack of that city, 146 B. C. Mr. G. Rawlinson attributes to Carthage work-shops many of the glass objects found in the northwest of Africa. The only glass yet found in the ruins of Carthage was in the tomb of Thapsus, but the tomb is probably of the Roman-Carthage period.

ETRUSCAN GLASS.—But little is known of the state of the glass-makers' art in Italy prior to the Christian era; but there is evidence from Etruscan tombs that this people, who are noted for their massive engineering works, were acquainted with the use of glass, and some very fine specimens have been brought to light. These specimens, however, are believed not to be of Etruscan origin, and as yet no distinct evidence of glass manufacture among this people has been found.

---

a Kenrick: *Phœnicia*, p. 249. *b* Rawlinson's *Origin of Nations*, p. 57.

INTRODUCTION OF GLASS-MAKING INTO ROME.—It is uncertain when glass-making began to be practiced in Rome. By some it is assigned to 536 B. C., but others place its introduction as late as the time of Cicero, 106 B. C., and state that the first works were near the Flaminian circus. This latter statement is probably not correct. Though Cicero is the first Latin author who refers to glass, it was not, however, until the days of imperial Rome that glass-making in that city attained any importance, either by reason of the character or the extent of its products. It is probable that a cheap glass had been made in Rome before the time of the Cæsars, but the Romans had been dependent upon Egypt for the bulk of their glass, and with the wealth and luxury of the empire came a demand that stimulated its manufacture and use to a degree of development that has, in some respects, never been excelled, and perhaps never equaled. The beginning of the better period of Roman glass dates probably from Augustus. The secrets of the Egyptian glass houses were secured by purchase or by threats, and the long fusion, remelting the frit, and the slow cooling, that had given much of its reputation to Egypt, became the property of Rome. With this knowledge came perfection, and gold and silver cups gave place to those of glass. Strabo says "that in Rome such improvement had been made in the coloring and process of working, especially in making glass of a crystalline appearance, that you might buy there a cup and dish for half an as". The degree of skill in manipulation shown by the Roman glass-makers, as well as the taste exhibited in designing, is evident, not only in the stories of the fabulous sums paid for samples of their work, but in the exquisite specimens of their skill that have been preserved, such as the Portland and the Auldjo vases and the Naples amphora. These are as beautiful objects of the glass-makers' art as have been produced in any age of the world, and though at some of the late expositions our modern glass-makers have shown most elegant work in similar style the work of the Romans has rarely been excelled. (*a*)

AMOUNT AND VARIETY OF THE PRODUCTION OF ROMAN GLASS HOUSES.—If these vases and other similar works show the skill attained and the elegance and variety of the products of the Roman glass houses, the prodigious quantity made is evidenced by the wonderful abundance of the fragments of glass found even now, not only in and around the ancient city, but in all parts of the world where the Roman legions penetrated. Nesbitt states that in the winter of 1858–'59, during a residence of four months at Rome, he saw in the hands of dealers fragments of at least 1,000 to 1,200 vessels of colored glass, for the most part the crop of that season's discoveries. (*b*)

The number of specimens of Roman glass that have been found in Germany, France, Spain, and especially in England, is very great, the museums of those countries abounding in examples, and even now in some of them it is no uncommon occurrence to bring to light glass of the Roman period. The use of glass in Rome was not only very extensive, but entered into use for some purposes to a much greater extent than in modern times. For domestic purposes, for architectural decoration, and for personal ornaments, it was used far more extensively than with us, and so common was its use, and so largely and cheaply was it produced, that, as stated by Strabo in the passage above quoted, a cup and a dish were sold for a coin worth a little less than a cent.

LATER GLASS-MAKING.—As stated, it is uncertain when the art was introduced into Rome. It was probably derived from Egypt, but it did not reach perfection until after the beginning of the Christian era. A company of glass-makers established themselves in the city in the reign of Tiberius, and were assigned a street near the Porta Capena. In the succeeding reigns marked improvement was made, and in A. D. 220 glass-making had become of so much importance that Alexander Severus levied a tax upon its manufacture in common with other industries, which lasted until the time of Aurelian, if not later. Pellatt thinks that this tax was one of the causes of the transfer of the art to Venice, (*c*) but the transfer is more correctly ascribed to the incursions of the barbarians, and the dispersion of glass-makers attendant upon them.

BYZANTINE GLASS.—With the decline and fall of the city of Rome under the torrent of the German and Hunnish hordes the manufactories fell into comparative neglect and were confined to articles of every-day use. When Constantine the Great, about A. D. 330, made Byzantium his capital, he attracted to the city, with other tradesmen, the glass-makers of the world. In the first half of the fifth century the Emperor Theodosius exempted the glass-makers from all taxation. In the commencement of the eighth century Justinian II furnished the Caliph Walid with glass mosaics for a new mosque at Damascus, and in the middle of the tenth century Romanus II sent presents of glass to Cordova; indeed, so extensive was its manufacture at Byzantium that one of the gates leading to the port took its name from the adjacent quarter in which the glass houses were situated. As has been noted, many of the Byzantine artisans came originally from Rome, and brought with them the traditions and customs of the art as it had been practiced there. These, as was customary in this early period, were handed down from father to son. In the new Rome of the East glass-making for a while assumed a front rank among the arts, but from the specimens that have come to us it is evident the skill and splendor of the Roman period was not reached, though for five hundred years at least Byzantium secured and held the markets of the world. This art, with others, however, fell under the adverse influence of the bigoted emperors of the East, and the ancient

a The reproductions of the Portland vase in jasper ware by Wedgwood are well known, but its reproduction in glass by Mr. John Northwood, of Wordsley, England, is not so noted.

b South Kensington Museum Art Hand-book: Glass, by Alex. Nesbitt, F. S. A., page 19. Those interested in the character of Roman glass and its manufacture will find in this work a very complete description.

c See *Curiosities of Glass-making*, page 8, note.

traditions were wholly lost. The glass that belongs probably to the later period shows but little of the elegance of form and the skill in manipulation of the early Byzantine and later Roman, and the weakness of the later days of the empire of the East had impressed itself upon its art, and with its fall its artisans were scattered, many seeking the shores of the Upper Adriatic to renew their art and restore some of its lost glory in the rising city of the refugees, Venice.

EARLY GLASS-MAKING IN OTHER COUNTRIES.—The details of the manufacture of glass in other countries prior to the Middle Ages are imperfectly known. Pliny states that the glass works of Gaul and Spain were established before those of Rome, and it may be possible that this is true, as in the days of the later republic and early empire Rome was too intent on extending its conquests to give that attention to the arts, other than those connected with war, which it afterward bestowed upon them. Wherever the Romans extended their conquests, however, in the western part of Europe, glass is found to a considerable extent in the ruins of their occupation.

GLASS IN FRANCE.—M. Fillon considers that the manufacture of glass in France began at Poitiers (*a*) in the second century. (*b*) These factories were active in the Roman and Frankish periods, survived the Norman invasion, and were left a legacy to the gentleman workers of the Middle Ages. In many tombs of the Gallo-Roman period in the neighborhood of Poitiers large quantities of vases of varied form, and sometimes of delicate and careful workmanship, are found; but the amount found in these and other tombs of France can only be described as immense. Abbé Cochet states that 20,000 vases were found buried in the cemeteries at Terre-Nigre, Bordeaux, and in many of the tombs glass vials, children's glass toys, beads, twisted sticks, and tiny glass vases, some not exceeding half an inch high, were very common, all indicating the extensive scale upon which the industry was operated. In the Boulogne museum are preserved some curious barrel-shaped jars of a low-grade glass quite green in color, bearing the mark of the imperial factory at Frontinceunes, at Forêt Eu, which is supposed to have been started in the second century, and was the school shop of all the Norman factories of later times. It is still a great factory, and must surely be about the oldest in the world.

It is impossible to give a suggestion even of the styles and character of early glass found in France. As Christianity advanced and spread over Gaul the character of the glass changed, and in this way its history can be, in a measure, traced. Its use for church purposes also became established, a pope in the year 197 having ordered that wine should not be consecrated, as heretofore, in a wooden, but in a glass vessel. Glass chalices were used in the fifth century, but at last glass became so common that it was not deemed costly enough to celebrate this mystery, and the church found it best to interdict its use, though glass vessels were still used as late as the tenth century.

M. Fillon says that the written documents connected with glass works begin in the ninth century. Normandy was the first country where special privileges were given to glass-workers, and in the tenth and eleventh centuries the first dukes of Normandy bestowed special glass-making privileges on four families attached to their persons, these families continuing the manufacture of glass and enjoyed their privileges up to the last century; and to this day descendants of one of these families, the Brussards, are to be found as glass-makers.

SPAIN.—If Pliny's statement quoted in connection with France be true, glass was made in Spain before it was in Rome. As to the localities of these early works, Mr. Nesbitt quotes Sinobas as authority that in the Ibero-Roman period "glass was made chiefly in the valleys which run from the Pyrenees to the cost of Catalonia near the Ebro, also in Valencia and Murcia. Ruins of furnaces still met with in these parts are small in diameter". It is believed that the manufacture continued to exist under the Gothic kings, though others are of the opinion that the art did not survive the invasion of the barbarians. There is evidence that in the seventh, tenth, twelfth, thirteenth, and fourteenth centuries glass was made in various parts of Spain. An edict of 1324 banishes all glass ovens from inside the city of Barcelona, and after this date large quantities of glass seem to have been manufactured in Spain, both for home use and exportation.

GERMANY.—In Germany also the influence of Rome on the early glass is marked, and it is probable that glass was made in the vicinity of Cologne, Treves, and other places near the Rhine during the Roman occupation, but many questions in connection therewith are as yet unsolved. As to the glass of later times there is similar uncertainty. The drinking glasses found in the Saxon graves of Germany are similar to those found in France and England, but it is undetermined whether these were made in the countries in which they were found, or are all the product of one of these countries, and if so, which one. It seems probable, however, that the art of glass-making was not wholly allowed to die out after the Roman dominion had passed away. The early glass of Germany was inferior in color and ornamentation to that of its more southern and artistic rivals, but it was superior to them in hardness. The first notice of glass-making in Germany in any document yet published is that to the Bishop of Mainz, elsewhere referred to, in which the Abbot of Wearmouth, England, wrote about the middle of the eighth century, asking him to send him workmen who "can make vessels of glass well". Window-glass was also made in Germany at a very early period, and mirrors were made as early as the twelfth century. The use of the tin amalgam is claimed as a German invention of the fourteenth century, and German authors claim the invention of painted glass for their workmen.

---

a See *Glass in the Old World* (page 126), to which I am indebted for much of the information about early French glass.

b This can hardly be so if Pliny's statement is true.

British Islands.—Though the evidence seems to indicate that glass was made in England by the Romans, it is not as yet quite fully determined that such was the fact. Beads and glass vessels of various kinds are found in tombs of the Roman period, and fragments of ornamented glass, and even of window-glass, are often met with in the ruins of towns and villas; but the similarity in most instances of these to Roman glass lead to the belief that they were imported. The probabilities are that, if glass was made in England by the Romans, it was of the coarser kind, the finer articles being the product of other countries. The remains of a glass furnace found at Buckholt in 1860, however, if it was of Roman origin, which is doubtful, would prove that colored and ornamented glass was made in England in the days of the Roman occupancy. It is worthy of note that some authors claim that glass was made in Britain in pre-Roman times; but if it was, it must have been of the coarsest and most common kinds. In Kentish graves, dating from about the time of the conversion of the Saxons to Christianity, many vessels of glass, mostly the peculiar elongated tumblers, are found, which Nesbitt thinks there is some reason to believe were made in England, though they resemble greatly French and German drinking vessels. At what time the manufacture of glass became firmly established in Britain is not known. In A. D. 670 an attempt was made to establish a glass factory at Newcastle-on-Tyne, but it was a failure, and eight hundred years passed before the attempt was renewed but in A. D. 675, when Benedict made glass for his monastery at Wearmouth, he imported workmen from France, who were probably skilled in making cast, not blown, glass for the windows, and eighty years later the Abbot of Wearmouth asked the Bishop of Mainz, in Germany, to send him a maker of glass vessels. For some centuries from this glass-making seemed to languish in England.

Little ancient glass is found in Scotland. Rome had but little foothold on its shores, and but few fragments of Roman glass have been found. Even the Druids left but few of their paste beads to be preserved in tombs. No record of glass-making in this country exists until 1620.

In Ireland there are more evidences of early glass-making than in Scotland. The art seems to have been practiced at an early period, and mosaic glass dating as early as 1112 exists. Some chalices are also in the museum of the Irish Academy that are supposed to date from the ninth and tenth centuries.

Persia, that ruled Egypt so long, carried away captive its most skilled workmen and artists and employed them in building and decorating their famous cities, Persepolis and Susa, and among the ruins of these cities to this day are found fragments of mosaics and other glass, evidently the work of these Egyptian captives. At least 400 B. C. the Persians made glass, as the Athenian ambassadors to Ecbatana drank "wine out of glass and golden cups", and the remarkable cup of Chosroes I (A. D. 532) proves that the art was practiced long into the Christian era; and even to the present glass works are in operation.

China.—The same mistiness that surrounds everything in connection with the arts of this mysterious empire attaches to glass-making. There seems some reason to believe that glass was made in this country before the Christian era, though it does not appear to have attained much importance. The ancient books state that mirrors were made from pebbles and materials obtained from the sea and reduced to ashes, which is a fair description of glass-making. A factory still in existence in Shan-tung is believed to date as far back as the third century.

India.—There are few traces of the manufacture of glass in India. The remark of Pliny that Indian glass was the finest, being made from crystal, is now believed to refer to Chinese glass, as no examples of early glass of undoubtedly Indian origin have yet been found.

Chapter X.—MODERN GLASS.

Modern glass-making dates from Venice.—We have dated the history of glass-making from the workshops of Venice and its island of Murano. It was in the glass-houses of that "gentile island",(a) as Howell terms it, that the art that produced the beautiful and exquisite forms of Roman glass was revived, and from its "whole street of glass furnaces" came the knowledge and inspiration as well as many of the workmen who carried its manufacture into many of the countries of Europe, and laid in these countries the foundations of the glass industry that has continued until the present time.

Venetian glass did not, however, at once attain the full measure of its reputation. For many years after the establishment of the industry in that city Egyptian, Phœnician, Roman, and Byzantine glass were those of most repute in the markets of the world, while the earlier products of the Venetian glass houses were of a greatly different character from those that in the sixteenth century gave Venice such renown.

a See *Howell's Familiar Letters*. First letter dated Venice, May 20, 1621.

INFLUENCE OF BARBARIANS UPON GLASS-MAKING.—Glass-making, with all other arts, felt the influence of the barbarian deluge and that strange stupor that marks the centuries from the close of the fifth to the close of the eleventh. The demand for glass for other than the most common uses quite ceased when the barbarians conquered Rome and appropriated its wealth. The glass works of the imperial city were broken up and the workmen, for the most part, slain or scattered, while those that continued the art, from lack of opportunity, soon lost their cunning. Only in one branch did any of the former glory remain: the manufacture of mosaics and painted glass for windows. Here, as in so many of the arts, the church saved glass-making from perishing from the earth.

REVIVAL OF ART INFLUENCED GLASS-MAKING.—Such was the condition of glass manufacture when the works of Venice began to assume importance; but as the eleventh century drew to a close the great cities of Germany and Italy, with their opportunities for commerce and the arts, arose, and among them the republic city of Venice, and the artisans in glass of reputation were attracted to this rising city and shared in the great art revival of the Italian Renaissance. The false and debasing canons of the art of the dark ages were cast aside, and from the study of the pure and simple antique came those great works in modern glass that are regarded as masterpieces in form and color.

EARLY VENETIAN GLASS-MAKING.—It is not known when glass began to be manufactured in Venice. The Venetians place the date as early as the fifth century, but there is no evidence of its existence earlier than the eleventh, with the exception of certain mosaics that may be of Byzantine origin. In the thirteenth century the art had grown to considerable magnitude, and about the middle of this century codes of rules for regulating glass-workers were drawn up. In 1291 the Council of Ten, to guard against fire, ordered that the glass furnaces in the city should be demolished, but that they must be reconstructed in the district of Venice. This led to the establishment of works at Murano. This edict was afterward modified so as to allow the manufactories of small wares to remain, provided there were fifteen paces left between the works. In 1275 the council prohibited the exportation of glass-making material, and in 1295 renewed it; in addition, it levied a heavy fine upon all glass-makers who should leave Venice to practice their art in other cities, and in 1474 death was made the penalty. At this time the fame of Venetian glass had become so great that extraordinary efforts were made to induce workmen to leave Venice and establish its manufacture in other countries, and England, Spain, and Flanders all endeavored to secure workmen to build up their glass works. This was the occasion of the edicts of the great council to which we have referred. (*a*) In the sixteenth and seventeenth centuries glass-making reached its highest development in Venice, from which time it began to decline, and in the eighteenth century England, France, and Bohemia began to compete successfully with Murano, interrupting its trade, and the works became idle, the glory of Venetian glass departed, and only beads and common ware came from the shops that for five centuries had given an incontestable superiority to Murano. This lethargy remained until the art was recently revived through the efforts of Dr. Salviati.

EXTENT OF THE INDUSTRY AT VENICE.—The extent to which this art was practiced in Venice can be inferred from the fact that in the time of its prosperity 8,000 men were regularly employed, and the glass houses extended in an unbroken line for a mile along one of the streets of Murano. The manufacture was not carried on, as now, in large establishments, but by artisans working on a small scale, which may account for the great variety of form. For the most part, the glass, with the aid of the pincette, was shaped before the blow-pipe, and the forms of the product were vessels, window-glass and mosaics, optical glass, mirrors, and beads.

CONDITION AND RESTRICTION OF WORKMEN.—Mr. Jarves, in his admirable paper in *Harper's Magazine* on Venetian glass, in speaking of the causes that produced such a body of workmen and maintained the superiority of its glass through so many centuries, says:

> As early as 1500 there were twenty-four glass houses at work at Murano, each having more or less its specialty. The furnaces in general were small. During the period of its greatest prosperity (the fifteenth, sixteenth, and seventeenth centuries) Murano counted 30,000 inhabitants, now reduced to about 5,000. Each owner of a factory was obliged to contribute annually a certain sum into a common fund for the succor of the unfortunate of their own class, poor and infirm artisans, or those out of employment, and for the maintenance of the schools of inventive design. No apprentice could be admitted as a master-workman before passing a strict examination in his art and proving his skill in the manufacture of certain objects. The candidate was elected into the body of masters by their secret ballots. Each factory was subject to inspection, night or day, by certain officers, whose duty was to see that the work was regular according to the statutes, to note the quantity and quality of the objects, and that no glass in fragments or cullet be exported. Proprietors and master-workmen of ten years' experience, if they honorably failed and had no other means of subsistence, were entitled to pensions of 70 ducats annually. When there were more master-workmen than could be profitably employed, it was forbidden to increase their number from the apprentices until there was a real call for new hands. Whoever became a member of the guild was obliged to take an oath of fidelity. No one who had not a regular discharge from his employer could be received into the service of another, and every proprietor was obliged to seal his cases with his own trade-mark. It was forbidden to employ strangers under any pretense. If there were not enough of the Muranese at times for labor, or to exercise the art, Venetians only might have the privilege, but they must be duly qualified. No employer could hire a master-workman who was in debt to another of the guild. Such were some of the regulations to keep the art in a high state of efficiency, and which for more than five centuries gave it an incontestable superiority in its special aim over other establishments in Europe. In fine, Murano became as artistically famous for its glass as Urbino, Pesaro, Gubbio, or Chaffagiola at the same time for majolica, but with far greater commercial development.

---

a It is impossible to follow the history of glass-making at Venice. An admirable account will be found in Nesbitt's "Glass" in the *South Kensington Art Hand-book.*

GLASS IN THE DARK AGES.—As has already been stated, the barbarian invasions and the destruction or decadence of the Roman power brought with it a decline in the art of making glass. The conquerors of Rome had but little in common with the taste and refinement that have sought and preserved as precious treasures the dainty and exquisite gems of the glass-maker's art of which so many evidences remain, and under their early dominion it seems probable that only the commoner and more useful forms of glass were produced. Thus it would appear that while glass-making in most of its higher and artistic processes was a lost art for some centuries, it was not wholly forgotten, but in all countries where Roman enterprise had established glass houses the art was preserved. It seems certain that France, Germany, Spain, and possibly England, made glass during the period of its decadence, and thus kept alive the practice of the art that was afterward, under the influence and example of Venice and by the art of its workmen, to grow in most of these countries into the glass works of to-day.

FRANCE.—It is reasonably certain that the manufacture of glass has not been wholly lost in France at any time since the days of Pliny and the Romans. The glass works at Poitiers, which were of so much importance, and which, if the evidence of the tombs in its neighborhood is to be taken, produced such enormous amounts of glass during the Roman period, seem to have maintained a continued existence and to have been of no little account even into the eighteenth century, when the industry declined under the competition of the glass houses of La Rochelle and Nantes. There is no doubt, however, that the works of Poitiers felt the same adverse influences as fell upon those of all Europe, and also that the new skill and the advance in its art that marked the close of the sixteenth century came from Venice. In 1572 one Salviati, "gentilhomme de Murano," came to Poitiers to practice his art, and was undoubtedly accompanied or followed by others. Their presence is evidenced in the efforts to produce fine and ornamented wares, and enameled glass, pretty drinking-cups, vases, and bottles, both white and colored, were some of the products of the period that followed the coming of these gentlemen of Murano. Glass-making, however, was by no means confined to the neighborhood of Poitiers, as works were erected at Provence as early as the thirteenth century, and attained considerable skill in the sixteenth. Large quantities of glass were made in Normandy in the twelfth century, and the le Valliant family, upon whose ancestors Charles VIII, in 1490, conferred the "privileges de verrerie", have continued its manufacture up to the present century. In the Boulogne museum are some barrel-shaped jars from the imperial factory of Frontinecnnes, which is supposed to date to the second century, and is still a great factory. In 1598 Henry IV permitted two "gentilshomme verriers", natives of Mantua, to establish themselves at Rouen, in order to make "verres de cristal, verres dorés, emaulx, et autres ouvrages qui se font à Venise", and in 1603 the same king established works at Paris and Nevers. Colbert, the great finance minister of France, who did so much for French industry, wrote to his ambassador at Venice in 1664 requesting him to procure workmen for a glass house; but the story runs that the ambassador replied if he did so he ran the risk of being thrown into the sea. In 1665, however, eighteen Venetian glass-makers were obtained, and the manufacture of mirrors was begun at Paris. Colbert united this with another existing at Tour-la-ville, near Cherbourg, and in 1693 the united works were transferred to Saint-Gobain, where the manufacture is still carried on upon a very large scale. It was about this date also that Thevart rediscovered the method of casting plate-glass, and succeeded in making plates 84 by 50 inches.

For a time in the eighteenth century France seems to have lost the art of making "vases de verre", as in 1759 the Academy of Sciences offered a prize for the best essay on the means by which the art could be revived. If this was true, France has abundantly recovered its prestige, and Baccarat wares are to-day the rival of any. France seems also for a while to have been behind its neighbors in the manufacture of blown window-glass. Even in the beginning of the eighteenth century the French imported from Germany and Bohemia whatever window-glass of the better sort they used. In 1740 an association for the making of French cylindrical or broad window-glass was formed by Drolinvaux, workmen being drawn from Germany, and a manufactory was established at Lettenbach (Saint-Quirin), which attained good repute, and became later the parent factory of the modern French, Belgian, and some English plate-glass works.

A late German writer, from whom the above statement is derived, states also regarding the influence of Germany on French glass-making:

> By holding closely together, and by steadily and firmly repelling French apprentices, the workmen who had been attracted from Germany kept off the competition of the natives of the country during a long time, and, as a consequence, even at the present day, among the French artisans in glass a very great majority bear German names, while German words and phrases are very numerous among the technical terms of the art.

The first lead-flint glass melted in France was by Lambert, at Saint-Cloud, in 1784. In 1790 the crystal manufactory of Muensthal, or Saint-Louis, was founded. In 1823 d'Artigues bought the glass manufactory of Saint-Anne, and changed it into the world-famous "Crystallerie de Baccarat".

SPAIN.—In this country, as in France and Germany, glass was made in the Roman period, and it is probable that its manufacture did not wholly cease in the dark ages, though this is not as well settled as in the case of France. Señor Juan F. Riano (I quote from Nesbitt), in the introduction to the catalogue of art objects of Spanish production in the South Kensington museum, has supplied much information with regard to the later history of Spanish glass making. He commences the modern history of the art in Spain by stating that an Arab author of

the thirteenth century says that Mercia was renowned for the fabrication of glass and pottery, of both which materials large vases of the most exquisite and elegant shapes were made by the Moors; and that "Almeria was also famous for the fabrication of all sorts of vases and utensils, whether of iron, copper, or glass". The making of glass at Barcelona was probably of equal, if not of greater antiquity.

In a municipal edict of 1324 is a prohibition that the glass ovens should be inside the city. In 1455 permission was granted to the "vidrieros" to form a corporation under the patronage of Saint-Bernardino, and from this period some of the members figure as holding municipal charges. Jeronimo Paulo, who wrote in 1491 a description in Latin of the most remarkable things at Barcelona, says "they also send to Rome and other places many glass vessels of different sorts and kinds, which may well compete with those of Venice". Marineus Siculus, who writes at the beginning of the sixteenth century, says "that the best glass made in Spain is that of Barcelona"; and Gaspar Baneiros, in his *Chronographia*, published at Coimbra in 1562, mentions that excellent glass was made at Barcelona, almost equal to the Venetian. From the beginning of the seventeenth century there are several allusions to the merit of the Barcelona glass, and to the vast quantity which was exported.

Glass was also made at Cadalso, in the province of Toledo, as early as the beginning of the sixteenth century; other works were at Torre de Esteban, Hambroz, in 1680, which gave the most brilliant results, and at Recuenco, in the province of Cuenca, in the beginning of the sixteenth century, and in 1722; also in the seventeenth century at Valdemaquada, in the province of Avilo. In a royal schedule, dated 1680, stating the prices at which things were to be sold in Madrid, glass made at Barcelona, Valdemaquada, and Villafranca in imitation of the Venetian is mentioned; and the glass of Valdemaquada was sold for a higher price than that made at the other places. There was also an important manufactory at La Granja, famous for fine chandeliers, mirrors, and engraved glass.

What we have of the products of these factories scarcely seems to support the assertion that the glass rivaled Venetian, though several pieces in the collection formed by Señor Riano closely resemble the products of Murano. One reason of the success of so many factories making glass of the same character as Venetian, and of the failures of England, was, no doubt, that the Spanish, in the interior of a country ill provided with the means for the transport of such an article, did not sustain so severe a competition as the English factories.

Spain is not a country very productive of fuel, and doubtless when the glass houses had burned up the wood in their neighborhood the manufacture ceased to be profitable. It would seem that, except near the coast, the glass must have been made with potash obtained from the lees of wine or from burnt wood, as the transport of soda, either from Egypt or from the coast, on which it could be produced from seaweed, would have been extremely costly. At Barcelona and other places on or near the coast soda may, of course, have been used.

GERMANY.—Though the specimens found in the neighborhood of Cologne, Treves, and other places bordering on or near the Rhine indicate that glass was made during the Roman occupation, it is not clear that it continued to be manufactured after this time. From the tenth to the fourteenth century, however, it is certain that window-glass was made in considerable quantities, and the letter of Cuthbert, Abbot of Wearmouth, to Lullo, Bishop of Mainz, about the middle of the eighth century, would indicate that glass vessels were made as early as this. Vessels of the sixteenth century, however, are quite common, among them the "wiederkoms", some of which are twenty inches high, the oldest of which the date can be ascertained being 1553. From the wood-cuts in Agricola's *De Re Metallica*, published in 1556, we may gather some idea as to the products of German glass houses at that time, which seem to be vases, bottles, and retorts, but he does not indicate that any fine glassware was made in Germany. About the year 1600 glass was extensively made in Bohemia and other parts of Germany, and the fine crystal glass of Bohemia may date from this time. In 1609 glass-cutting was practiced, and some of the work in this century was said to be of remarkable fineness and delicacy. The invention of etching with fluoric acid is ascribed to Henry Schwanhard in 1670. The Electoral glass works, on the Isle of Peacocks, near Potsdam, was established in the eighteenth century, and, under Kunckel's management, gained great celebrity for its gold ruby. Then, under the ministry of Danckelmann, French workmen were drawn into the country, and under Moor's management the manufacture for blown plate-glass was established in 1695 at Neustadt-on-the-Dosse, whose workmen, when, after Danckelmann's overthrow, Neustadt for a time fell into stagnation, founded, at the instigation of the elector, Lothar Franz, the mirror manufacture at Lohr-on-the-Mayn, which in course of time attained to great distinction. Similar manufactures were soon afterward established at Schleichach, near Wurtzburg; at Fahrafeld, near Vienna; at Gruenplan, near Hanoverian Minden; at Senftenberg, in the electorate of Saxony; and at Alten-Kronau, in Hesse. Finally, in 1710, through the influence of Count Rechtskron, mirror or plate-glass casting was introduced from France, and a mirror foundery was established after the model of Saint-Gobain at Neuhaus with French workmen, which, though protected in every way and defended by prohibitive regulations, in 1728 passed over to the Austrian state. In fact, plate-glass casting did not prosper in the beginning any better in Germany than in France. As little successful, too, were the attempts in various places made to obtain useful flint-glass for optical purposes, and it was not until 1806 that Utzschneider, at Benedictbeuren, produced such an article of the kind as answered the ends for which it was required.

BOHEMIA.—It was in Bohemia that Venetian glass first found a successful rival, this rivalry being at first manifest in the quality of the glass itself. Venetian glass had never been noted for the purity of the metal, and

with their purer materials the Bohemians were able to produce a much whiter glass than the Venetians could with their somewhat impure sand and soda from seaweed. The Bohemian crystal, therefore, soon became noted, and for centuries was held in high estimation, and only lost its pre-eminence with the invention of English flint. But it was not alone in the purity of its glass that Bohemia became the successful rival of Venice, for in the beginning of the seventeenth century the decoration of glass by engraving, probably a Bohemian invention, which soon became the fashion, sadly interfered with the products of the Italian city. The cut-glass was especially noted, and so sharp and injurious did the competition become that one Briati, a glass-maker of Murano, determined to go to Bohemia and learn the secret, and accordingly worked for three years in a Bohemian glass house as a porter, returning to Venice in 1739 to obtain a patent for ten years for the production of glass after the fashion of Bohemia. The excellent character of Bohemian glass is noticeable to this day, and the skill of the workmen who robbed Venice of its glory has not departed from the forests of Bohemia.

THE LOW COUNTRIES.—But little is known of the glass industry in the Low Countries until a very recent period, though it is positive that glass was made in Flanders as early as the fourteenth century. "Crystal of Antwerp" is mentioned in 1509, and in 1563 glass is mentioned as among the articles of export from Antwerp to England. In the first half of the seventeenth century several Muranese glass-workers obtained privileges for making glass, and in 1642 John Savonetti was permitted to establish glass-making at Brussels with an absolute prohibition of all imports. In the sixteenth or beginning of the seventeenth century were produced the glasses on which are to be seen the paintings of John Steen, Zerburg, and others. In comparatively modern times the works of Belgium have been quite noted, at one time the product of vases and such ware surpassing the French. It is stated that the celebrated Baccarat works were established by Belgian workmen.

BRITISH ISLANDS.—As has already been noted, there is considerable doubt as to the continued existence of the English glass works after the period of Roman occupancy, and it was not until the beginning of the fifteenth century that they awoke from their period of actual or comparative idleness. In 1447 John Prudde, of Westminster, covenanted to "use no glasse of England" in executing the windows of the Beauchamp chapel at Warwick, which would indicate that glass was made in England at that time. The vast palace of Henry VIII that formed one of the attractions of the Field of the Cloth of Gold in 1520 was built of wood and glass. The glass-maker's art, however, did not advance rapidly, for, in 1557, according to quaint Thomas Charnock:

> As for glass-makers, they be scant in the land;
> Yet one there is, as I do understand,
> And in Sussex is now his habitation;
> At Chiddingsfold he works of his occupation.

In 1589 George Longe petitioned for a patent, in which he stated that there were fifteen glass houses in England. These he proposed to reduce to two and rebuild the balance in Ireland, whereby the wood of England would be saved and that of Ireland wasted. In the reign of Queen Elizabeth some persecuted Protestants from France came to Newcastle and worked at their trade of glass-making at the Close Gate, and afterward went to Tyne. In 1662, Fuller states that "coarse glass-making was, in this county (Sussex), of great antiquity", and another, writing of the manufacture of glass in that county, says:

> Neither can we match the purity of Venice, and yet many green ones are blown in Sussex profitable to the makers and convenient to the users thereof.

INFLUENCE OF VENICE ON ENGLAND.—As the use of glass began to increase in England adventurers from Venice and other portions of the continent sought to advance their fortunes by bringing schemes for making glass of superior quality before the English government. In 1550 eight Muranese glass-makers, imprisoned in London, who had been induced to go there by offers of no small sums of money, and who had heard of the edicts of the Council of Ten, petitioned the council to be allowed to work out the money received. On June 13, 1550, the council, to gratify the king, decided to allow this. For the next few years evidences of the influence of Venetian workmen multiply, and the art began to assume importance. Early in the seventeenth century sea-coal began to be used. Mansel secured the patents for its use in 1616, and set to work making both window-glass and glass vessels of various kinds, having brought a Venetian to aid him. About this time one of the most important advances or discoveries in modern glass-making, and one of the very few real discoveries of modern time, was achieved (the manufacture of lead flint), and the English workman had this beautiful and brilliant glass to stimulate his exertions. In 1677 the Duke of Buckingham made at Lambeth "huge vases", "clear, ponderous, and thick as crystal," as well as looking-glass plates and windows for coaches. In 1673, at the "Italian glass house at Greenwich", "glass was blown of finer metal than that of Murano at Venice." The revocation of the edict at Nantes in 1685 drew a number of glass-workers to England, and the manufacture continued to improve, until, in 1736, Dr. Pococke considered English glass to be superior to that of Bohemia, and only inferior to that of the royal Prussian glass houses. From this time the manufacture of glass was of growing importance, and the details need not be given.

RUSSIA.—In Russia the glass industry first obtained a firm footing in the course of the seventeenth and eighteenth centuries, having been introduced by German and Bohemian workmen. As regards the details of its

introduction and establishment, slight information has ever reached the public. We have historical mention of a glass manufactory at Schabino, near Jamburg, in 1717, and in 1720 an establishment for the making of French mirrors and dishes and plates of crystal was opened at Kiew. In the last year of the last century we find mention of Lund's plate-glass manufactory at Wyborg, in Finland, and of Bolew's similar establishment in the Russian government (province) of Rajasan. At the same time the imperial mirror foundery at Saint Petersburg had already begun work; and the imperial crystal and hollow-glass manufactory, which exists at the present day, had been already established at the same place. In 1792, with the aid of workmen from Gruenenplan, the foundation was laid of the Amelung mirror manufactory at Dorpat, near which place, in 1780, a similar establishment had been set up by Major Lauw, but its existence had been brief.

Chapter XI.—THE PRESENT CONDITION OF GLASS-MAKING IN EUROPE.

Chief glass-making countries of Europe.—The countries of Europe most largely engaged in the manufacture of glass at the present time are England, France, Belgium, Germany, and Austria-Hungary. Each of these countries not only manufacture most of the kinds of glass needed for its own use, but the factories supply the non-glass-making countries of the world and supplement the production of each other and of such other states as manufacture to some extent. This is especially true of the finer grades of glassware (table and ornamental glass) and plate-glass.

Each country has a specialty.—While each of the countries named produces most, if not all, of the chief varieties of glass, each one has become especially skillful in the manufacture of some particular variety, and has secured and maintained a pre-eminence in its production that has enabled it to command the markets of the world.

England's specialties.—England is especially noted for the beauty, purity, and brilliancy of her flint ware, which is without doubt the purest and most brilliant made. Individual glass houses in other countries may produce flint that may be compared with some English flint, but none, as a commercial product, that can rival it, while in no other country does the bulk of the flint-glass made approach even the bulk of that made in England. These remarks apply to lead-flint only, as the American lime-flint is probably, so far as the metal is concerned, equal, if not superior, to any other. In the blowing, cutting, and engraving of the flint, the regularity and perfection of the work, as well as the beauty and brilliancy of the finished ware, England is unequaled. The exhibit of Thomas Webb & Sons at the Paris exposition of 1878 surpasses in these respects, and in the limpid whiteness, purity, and brilliancy of the metal, all other flint I have ever seen, and was justly entitled to the "grand prix" it received, while the vases engraved by Mr. Northwood in the style of the Portland vase equal in workmanship, if they do not surpass, that product of the glass-makers' and engravers' art. Certainly no modern work equals it.

France's specialties.—The artistic taste shown in the product of the French glass houses has given French glassware a world-wide reputation. The metal is not as white as that of Bohemia, nor has it the brilliancy and fire of the English flint; but for elegance of shape, lightness of design, and beauty of glass, all combined, it is unsurpassed. The products of the Baccarat works have been regarded for years as models of taste, and have been eagerly sought for and copied in cheaper wares by the glass houses of other countries. France is also unsurpassed in the manufacture of plate-glass, the product of the Saint-Gobain works being taken as the standard of color, quality, and perfection; and to say that the plate-glass of any works equals French plate is generally considered sufficient praise. (*a*) The same artistic taste that has given French glassware so enviable a reputation is displayed in the staining and decorating of window- and plate-glass. The stained-glass windows of French artists show remarkable ability in designing and execution. (*b*) The decoration of fancy ware by various methods, especially by enameling and etching, is also carried to a high state of perfection, both as to color and workmanship.

Belgium's specialty.—Belgium is pre-eminently the window-glass manufacturer of the world, and though the other countries mentioned above (England, France, Germany, and Austria-Hungary) all make window-glass to a considerable extent, there is not one of them in which Belgian window-glass does not find a market. A large amount, equaling a large proportion of their consumption, is also exported to other countries, and even the United States imported in the fiscal year ending June 30, 1880, 37,927,414 pounds of Belgian window-glass, valued at

a Our American works claim to have succeeded in making plate-glass fully equal to the French; indeed, some works claim to make better.

b Most marked advances in the art of staining windows have been made in the last ten years in this country, and the productions of Tiffany and La Farge rival those of the artists of any country.

$1,230,622. The excellent quality of this glass, as well as its remarkably low price, accounts for this import. The average value of the Belgian window-glass imported into this country in 1880 was about 3¼ cents per pound.

GERMANY'S SPECIALTY.—Germany is especially noted in the markets of the world for her silvered plate or looking-glass and for her cheap table ware and colored vases. The production of mirrors of various grades, largely of the cheaper kinds, in Germany is enormous, and their exportation constitute a large part of her foreign trade. Of the $2,897,747 in value of silvered plate imported into the United States in 1880, $2,746,636 was from Germany. The cheap colored-glass vases of this country were the first (about 1830) to supplant the decorated china vases, which until that time had undisputed sway as cheap mantel ornaments, and she still retains much of the trade in these articles, though other nations manufacture them in large quantities. Germany is also noted for a remarkable ruby glass, which was brought to perfection by Kunckel in 1679.

AUSTRIA-HUNGARY'S SPECIALTIES.—Austria, or Bohemia in Austria, rivals France in the graceful forms, the variety of shapes, and the beauty of the engraving and decoration of its glassware, and surpasses it in the color and purity of the glass itself. Bohemian glass has been renowned for many years, its workmen apparently inheriting the skill and some of the peculiar processes of manufacture of the Venetians when the cunning of glass-making left the city of the Doges, and it is this cunning in design and ornamentation that has given it its celebrity. It does not compare with the English flint in brilliancy, and is only equaled by the French in beauty of contour, but in purity, whiteness, and homogeneity of metal it is the best white glass made in Europe, while their success in making glass of intricate design and great difficulty of manipulation makes the Bohemian glass workers second only to those of Venice.

VENETIAN GLASS.—Though not a large producer of glass, Venice deserves most honorable mention in any statement of the specialities in glass manufacture of the different European nations, and the recent very successful revival of the manufacture of Venetian glass at Murano, that "gentile island which attends the cittie of Venice", promises to restore to that city the world-wide celebrity of its former days of glass-making. The wonderful color, intricacy of design, and execution of the mosaics; the pastes, gem-like in color and brilliancy; the murrhine of Pliny; the remarkable enameling of the famous tazze of St. Mark's; the aventurine or imitation gold-stone, with its difficulties in manufacture; vases in millefiori, others with metallic flakes and spun and twisted threads of filigree work; all of these products of the elder Venetian glass houses are reproduced with wonderful fidelity in the modern Venetian glass of the Venice and Murano Glass and Mosaic Company. The glass-bead manufacture of Venice is also a remarkable industry, 6,000,000 pounds a year being produced, the markets of the world being largely supplied from this country.

GLASS IN OTHER EUROPEAN COUNTRIES.—None of the other European countries are especially noted for their glass, nor is it made to any great extent in any of them. Sweden and Norway make glass of the commoner kinds, window, flint, and bottle, but no plate. Russia has largely increased its make of glass in the last ten years, but does not yet supply the demand of its own people even for the commoner kinds. Holland makes large quantities of a square black bottle. Of the glass works of Spain and Portugal but little is known.

PLATE-GLASS FACTORIES IN EUROPE.—The manufactories of plate-glass are located chiefly in England, France, Belgium, and Germany. (*a*) In England there are six or seven works, in France seven, in Belgium five, in Germany five, in Russia one, and in Austria-Hungary (Bohemia) one, possibly two, making a total of twenty-six or twenty-seven. These differ greatly as to production, most of the English, French, and Belgian works being very extensive, while most of those of Germany and of Russia and Bohemia are comparatively small. Some blown plate is made in Bohemia, Bavaria, and England, and patent plate in England.

PRODUCTION OF PLATE-GLASS.—Of these countries France is the largest producer of plate-glass, England the next, Belgium the third, and Germany the fourth. Mr. Charles Colné (*b*) estimated the production of Europe in 1877 at 1,800,000 square yards, or 16,200,000 square feet, valued at $12,000,000. (*c*) This production he distributes as follows:

	Square feet.
France	5,400,000
England	5,400,000
Belgium	2,250,000
Other countries	3,150,000
Total	16,200,000

This production has largely increased since the date named. Mr. Charles Palmer, on behalf of the plate-glass manufacturers of England, made the accompanying statement regarding the weekly production of polished plate-glass in England, France, and Belgium (*d*) to the commissioner to negotiate a new commercial treaty with France.

a Statistics of the European glass houses are exceedingly difficult to obtain, especially in England. The statistics given will therefore be regarded only as an approximation unless otherwise stated.

b See Mr. Charles Colné's *Report on Glass and Glassware at the Paris Exposition of* 1878, page 329. Washington, 1881.

c Mr. Colné places the production of 1860 at 992,000 square yards, and of 1867 at 1,100,000 square yards.

d See *English Blue Book*, Commercial, No. 38, 1881, pp. 121, 122.

PLATE-GLASS.

WORKS IN BELGIUM.		WORKS IN FRANCE.		
Companies.	Weekly production in English feet.	Companies.	Weekly production in English feet.	Total.
Belgian Plate-Glass Syndicate:	*Feet.*		*Feet.*	*Feet.*
Floreffe	25,000	Floreffe (Belgian company), at Jeumont, department du Nord	32,000	
Sainte Marie d'Oignies	25,000	Sainte Marie d'Oignies (Belgian company), at Recquignies, department du Nord.	32,000	
Roux	15,000			64,000
Courcelles	20,000	Saint-Gobain Company:		
Auvelais	10,000	Saint-Gobain, at Aisne	80,000	
	95,000	Chauny, at Aisne		
		Cirey, at Meurthe	50,000	
		Montluçon, at Allier	32,000	
		Aniche, department du Nord	16,000	
				178,000
				242,000
Quantity of polished plate-glass made in England				175,000

Assuming that these works would average forty weeks' running in a year, and adding to the production of these countries thus found the best estimates obtainable for Germany, Russia, and Austria-Hungary, the production of Europe would be as follows:

	Square feet.
France	9,680,000
England	5,000,000
Belgium	3,800,000
Germany	2,900,000
Russia	250,000
Austria-Hungary	400,000
Total	22,030,000

This estimate agrees substantially with that of Mr. N. T. De Pauw, who estimates the production of Europe at 500,000 square feet a week. (*a*)

PRICES OF PLATE-GLASS IN EUROPE.—Mr. Palmer, in his statement to the French treaty commissioner before referred to, gives the following as the prices of plate-glass at the date of his communication:

LONDON.		PARIS.		
PRICE OF FRENCH POLISHED PLATE.		PRICE OF FRENCH POLISHED GLASS.		
Saint-Gobain, English tariff, less 40, 5, and 2½ per cent.		French tariff, less 50 per cent., disconnt 3 per cent., and 10 per cent. premium annually, and supplementary discount.		
Size.	Price per foot.	Size.	Supplementary disconnt.	Price per foot, net.
	s. d.			*s. d.*
About 10 feet superficial	1 6	10 feet superficial		1 11½
About 22 feet superficial	1 6½	22 feet superficial	Subject to 5 per cent	2 0
About 33 feet superficial	1 6¾	33 feet superficial	Subject to 10 per cent	2 3½
About 45 feet superficial	1 7	45 feet superficial	Subject to 15 per cent	2 3½
About 65 feet superficial	1 7½	65 feet superficial	Subject to 15 per cent	2 7½

WINDOW-GLASS IN EUROPE.—It is impossible from the data at hand to even estimate the production of window-glass in Europe or the number of factories at work. No statistics, not even an estimate, has been obtained from England. In Belgium there are 61 window-glass factories, with 216 furnaces, of which but 138 were in operation recently. These works produce from 3,600,000 to 4,000,000 boxes of glass of 50 feet each annually. In France there are from 25 to 30 furnaces, producing from 800,000 to 900,000 boxes annually; and in Sweden, 4 factories, with an annual production of 40,000 boxes; in Norway, 1 factory, no product given; in Italy, 12 factories. In Austria-Hungary, 63 factories make window-glass; in Germany, 86, while from Switzerland, Spain, Portugal, and Russia I have no statistics, though window-glass is made in all of those countries.

(*a*) *Report of the Tariff Commission*, page 941. Washington, 1882.

FLINT- AND BOTTLE-GLASS.—The statistics of the manufacture of flint- and bottle-glass in Europe are even more meager than those of plate- and window-glass. All the information that has been obtained is included under the notes of the manufacture of each country which follow.

MANUFACTURE OF GLASS IN GREAT BRITAIN.—The glass manufacturers of Great Britain are, as a rule, extremely chary about giving statistical information concerning their works, and it is a question whether any late complete statement as to the number and production of their glass houses exists. A table published in the factory returns of 1871 shows the number, locality, and employés of the glass works of the United Kingdom at that time to be as follows:

Localities.	Number.	Children.	Males up to 18.	Males above 18.	Females.	Total.
Durham	24	10	1,113	2,153	401	3,677
Lancaster	37	6	1,530	3,602	927	6,065
Middlesex	16	4	134	319	30	487
Northumberland	9	7	117	277	23	424
Somerset	1	.....	70	243	6	319
Stafford	33	1	808	2,755	312	3,876
Surrey	9	.....	86	136	5	227
Warwick	47	3	274	874	167	1,318
Worcester	8	2	56	131	7	196
York	29	12	877	1,961	138	2,988
Scotland	19	1	464	1,037	91	1,593
Ireland	8	.....	63	192	9	264
Total	240	46	5,592	13,680	2,116	21,434

CHIEF LOCALITIES.—The chief locality for glass manufacture in Great Britain is in the north of England especially on the Tyne, plate, window, and flint, both blown and pressed, being made in large quantities. Plate is also made at Saint Helen's, in Lancashire, at and near Birmingham, and at London; flint in London, the Birmingham district, Warrington, etc.; window-glass very extensively in the Birmingham district, and bottles and window-glass near Liverpool.

DECLINE OF THE ENGLISH GLASS INDUSTRY.—If the statements that are constantly appearing in the English journals devoted to this industry are true, glass-making in Great Britain is not in a very prosperous condition. A correspondent of the *Pottery Gazette* says:

> It is a very significant fact that nearly every trade in this country has made gigantic strides in advance during the past thirty-five years, during which time the glass trade has been stationary, if it has not even retrograded in its productiveness. (*a*)

This condition of affairs is especially noticeable in the flint-glass business. The same journal gave recently a list of 30 flint-glass furnaces, containing 296 pots, located in various parts of the United Kingdom, that had become extinct. Commenting upon this that paper says:

> It is but just to say that some of these houses have removed to more convenient works, to the extent of about 6 or 8 furnaces and 48 or 60 pots; but still there is a great reduction in the number of works, during which period it must be borne in mind the population has nearly doubled.

The following table shows the value of the British imports and exports of glass for the years 1878, 1879, and 1880:

IMPORTS OF GLASS.

	1878.	1879.	1880.
Window and German sheet, including shades and cylinders	£452,202	£450,647	£476,338
Flint	489,518	174,113	179,503
Plate, silvered or not	233,602	163,064	214,917
Manufactures, unenumerated, and old broken	879,733	789,006	906,991

EXPORTS OF GLASS.

	1878.	1879.	1880.
Plate	£106,762	£133,635	£192,607
Flint	239,747	230,537	248,694
Common bottles	310,307	305,606	332,886
Other manufactures, unenumerated	99,068	113,255	147,321
Glass of all kinds not of English manufacture	149,275	190,635	186,980

It will be noted that the imports of 1878 and 1880 do not differ much except as to flint, which shows a decided decrease, while the exports show in all classes of glass an increase. Part of the decline in flint-glass is no doubt

a See the *Pottery Gazette*. London, September 1, 1881.

due to the competition of the cheaper lime-glass, which, for ordinary purposes, is fully as good, and is now made of a superior quality. At the same time it is true that for beauty and brilliancy no glass can compare with English lead-flint.

MANUFACTURE OF GLASS IN FRANCE.—For many years France, through the Saint-Gobain works, has virtually controlled the manufacture of plate-glass on the continent of Europe, and, to a large extent, its production and prices throughout the world. The Saint-Gobain Company not only own four of the seven French plate-glass works, producing fully 70 per cent. of the total make of France, but they also own the only two important plate-glass works of Germany. On the other hand, however, it is to be noted that two of the remaining three of the French plate-glass works are owned by a Belgian company. It thus appears that the plate-glass production of Europe is largely controlled by two companies, one French and the other Belgian. It is possible that the number of plate-glass works at present in France should be given as eight, as a factory was erected at Saint-Denis, near Paris, a few years since, though I am not advised whether it is running at present. The Saint-Gobain works have made the largest sheets of plate-glass that have ever been produced. At the exhibition of 1878 at Paris an unsilvered polished plate, measuring 21 feet 2 inches by 13 feet 6 inches, was exhibited. A special table had to be prepared on which to cast this enormous plate. The quality of the French plate is most excellent, and is the standard for comparison in all the countries of the world. A considerable amount of the production of this glass is used in the manufacture of mirrors, some 275,000 square yards being consumed annually in this way. The manufacture of window-glass in France is relatively of the least importance, the production of plate, flint (lime and lead), and of bottles being greater in value than that of window-glass. According to Mr. Colné, there were in France in 1878 (*a*) from 25 to 30 furnaces, with 8 pots each, producing from 40,000,000 to 45,000,000 square feet. These are found almost entirely in the north of France, near the coal-fields. Large quantities of round, oval, and square shades, for protecting clocks, artificial flowers, etc., are made in France, the process of manufacture being similar to that of window-glass, the sheets being blown in cylinders of a very even thickness all through. The coloring, staining, painting, and decorating of window-glass is carried on to a remarkable extent in that country, there being in the neighborhood of five hundred establishments in France for thus manipulating sheet-glass, and the French colored sheet-glass is especially notable both for its colors and for their manipulation. The so-called flashed or doubled glass is very common, both in sheet and flint, flint glassware being in some instances coated with as many as four different layers of different colored glass put on very thin and evenly. Most of the stained or colored glass used comes from the departments of the Nord and Pas-de-Calais. The work at many of the establishments has attained a high degree of perfection, and the French stained glass, by reason of its artistic excellence and cheapness, is in demand in all parts of the world. As has already been stated, the French glass houses are especially noted for the taste displayed in their flint ware, both lime and lead; but the quality is not as good as the English, though a marked improvement has recently been made in this respect, and the gracefulness of the forms and the beauty of the designs have given French crystal glass a reputation that is unrivaled. The decoration of window-glass with enamel colors in imitation of the antique is also quite an industry in France. Most of the work in the French flint houses is hand-work, the result depending largely upon the manual dexterity of the workman. Pressing on the American system is not employed to any great extent, while that which is made is decidedly inferior to the American.

Owing to her wine production, France is naturally a large manufacturer of bottles, producing annually from 125,000,000 to 150,000,000; indeed, the value of bottles made in this country exceeds that of any other form of glass. Some of the bottle works have been established for a long time, one, that of J. Tumbeuf Neveu et Neveu, in the Jura, being founded in 1506. It was at this place in 1630 that the first gentlemen glass-blowers (*gentilhommes verriers*) were made by decree of the king.

The following table published in the *Report on Glass and Glassware of the Paris Exposition* shows approximately the value of the annual production and exportation of glass of French manufacture in 1878:

Description.	Production.	Export.
Crystal	$2, 200, 000	$800, 000
Glassware	2, 800, 000	1, 600, 000
Plate-glass	5, 000, 000	1, 600, 000
Window-glass	3, 000, 000	600, 000
Bottles	8, 000, 000	2, 400, 000

MANUFACTURE OF GLASS IN BELGIUM.—Belgium possesses excellent facilities for the manufacture of glass, and in some lines, especially window-glass, these facilities have enabled her to produce so cheaply as to command a portion of the trade of the most important countries of the world. Fully two-thirds of the glass made in Belgium is exported. As is noted elsewhere, Belgium has five plate-glass factories, producing about 94,000 square feet polished plate a year. While some of the plate in Belgium equals the French, this is not true of all manufactured. The production, however, is increasing, and the quality is improving every year. This

a Report of Paris Exposition on Glass and Glassware, Charles Colné, page 345. Washington, 1881.

production is controlled by a syndicate, as is also the production of plate-glass in France. There are in Belgium 61 window-glass factories, with 216 furnaces, containing from 6 to 8 pots each, of which at a recent date 78 were idle, leaving but 138 in operation. These works are mostly situated in Charleroi. Most of the furnaces used are gas furnaces. These works produce from 180,000,000 to 200,000,000 square feet annually, or, say, from 3,600,000 to 4,000,000 boxes of fifty feet each. The Belgian window-glass is, as a rule, of a very good quality, free from bubbles or impurities, of a good color, and even surface. A large quantity of the colored glass is of a superior quality and very clear color. Their flashed glass is very good, and is admirably adapted for etching or engraving. They also make quantities of corrugated, depolished, and painted sheets. Some corrugated cylinders 7½ feet high have been made at Charleroy. Depolishing is done by the Tilghman sand-blast. Considerable glassware, both lead and flint, is made in Belgium, but it is not, as a rule, of a high standard of excellence, though the product of some of the works, especially that of Val Saint Lambert, is fully equal to the English and the French. The cheapness of this ware has made a great demand for it, especially when made into objects of utility. The exportation of this grade of glass amounts to one and a half million to two million dollars annually. The bottle industry of Belgium does not hold the same relative rank as this industry does in either Germany or France, and the production from 1875 to 1880 was only about 12,000,000 annually, not as many as the single works of Siemens at Dresden make. This industry has been much neglected in recent years. In 1872 12 furnaces were at work on bottles; in 1877 but 5. In 1872 Belgium exported 7,568,000 pounds of bottles, and imported only 1,377,000 pounds; in 1877, however, the exports amounted to only 1,775,000 pounds, and the importations had increased to 3,476,000 pounds.

Manufacture of glass in Germany.—In 1882 there were in Germany 317 establishments for the manufacture of glass, (*a*) a reduction from 329 in 1878, (*b*) and 348 in 1873. (*c*) Many of these, however, were of little importance, being either small works for the production of watch crystals, blown pearls, etc., or so-called "refineries" similar to those common in Bohemia, in which crude glass is produced, to be finished in other works. (*d*) These glass works are found in nearly all parts of the empire, being most numerous in Prussia, especially in Silesia. The production of the different kinds of glass, however, is not so widely distributed, certain districts being the centers of production of certain kinds. In Thuringia and the Bavarian forests large quantities of both blown and cast glass are made for the mirror works at Fürth. (*e*) Window-glass is made chiefly in the Rhine provinces, Silesia, and Westphalia; common table ware in the Rhine provinces and Lusatia; fine table ware in the forests of Bavaria and Lorraine; and chemical ware in the forests of Bavaria and Brandenburg. The glass works of Saxony make large quantities of lamp articles; and Saarbrück, Prussia, and Saxony produce bottles very extensively, one establishment, that of Fred. Siemens, at Dresden, producing 16,000,000 annually.

The statistics of the glass houses of Germany other than those given above are not only exceedingly meager, but very difficult of classification. The best information obtainable places the number of establishments at which plate-glass is made at five. Two of these, Stolberg and Mannheim, owned by the French company of Saint-Gobain, had for a long time the monopoly of the manufacture of plate-glass in Germany, but within a few years past at least three other works have been established. In Thuringia and the Bavarian forests, also, according to the *German Catalogue of the Centennial Exhibition*, glass is made by casting, the plates being ground by water-power with very primitive machinery. These plates are chiefly used at Fürth for the manufacture of looking-glass. There are in the neighborhood of 86 establishments, with 125 furnaces, averaging 7 pots each, at which window-glass and blown spiegel-glass are made, and about the same number make bottles, carboys, and demijohns. At the other works, and also at some of those making window-glass and bottles, various kinds of table ware, articles of luxury, chemical apparatus, etc., are made.

Furnaces and fuel.—A great deal of attention has been paid in Germany to the construction and method of firing furnaces, and some very important advances have been made. Direct firing has been abandoned in many works and systems of indirect firing adopted. The Siemens furnace, not only with pots, but of the tank variety, has been very successful. Other systems, as the Nehse and the Boetius, are in use. While coal is the chief fuel of the glass houses, the use of wood, peat, and turf is by no means uncommon. When wood is used, the works are located with reference to its supply, and as the wood is exhausted and transportation into certain districts is made easier and cheaper these works are abandoned. The development of the glass industry of Germany is now in the neighborhood of the deposits of mineral coal, the old glass-making districts gradually losing their prominence.

Manufacture of glass in Austria-Hungary.—The beauty, elegance, and perfection of the Austrian glassware, as well as the skill displayed in its manufacture, have given it a reputation that is second to none other. The Bohemian glassware is a lime glass, containing little or no lead but a large percentage of silica, and is consequently well adapted to decoration. The purity, whiteness, and homogeneity of the metal make it equal to the best white glass produced in Europe. Not only in form and metal does the Bohemian ware rank with the highest, but

a See *Deutschlands Glasindustrie*, Julius Fahdt. Dresden, 1882.

b See same for 1878.

c *Bulletin of the Society for the Encouragement of National Industry*, page 71. Paris, 1877.

d In 1873 it was stated that but 250 of the German glass houses were of much importance. It is true, however, that though, as stated, the number of works has declined, the output of many of them has largely increased.

e Very large quantities of little mirrors, called Judenmasspiegel, are made in Germany.

in its manipulation it has deservedly a great reputation, the variety and diversity, as well as the beauty, of its engraved and decorated articles, being beyond question. The conditions of manufacture of this Bohemian glass are also such that it can be very cheaply produced.

One of the specialties of Austrian glass-making is the manufacture of various fabrics for ladies' wear from spun glass. The glass is spun into threads, like ordinary silk or cotton, and woven into different-colored fabrics, sometimes entirely of glass and sometimes with a warp of silk or cotton. Collars, neckties, cords and tassels, fringes, pincushions, feathers, belts, etc., are all made of this material. At the Paris exposition in 1878 a bonnet made entirely of spun glass, with feather and ribbons lined with silk, was shown, as well as cloaks and other articles of wear. This spun glass is also used for watch-chains, brushes, etc. Glass flowers are also made to a considerable extent, but it is difficult for these to compete with those made from china. As is stated elsewhere, large quantities of what is known as "raw glass" are made in Bohemia. This glass furnishes the raw material of other establishments, and is in these establishments decorated, polished, and made into looking-glasses, beads, etc.

There is but one plate-glass works in Austria-Hungary, as the manufacture of plate-glass has not been a very successful enterprise in that country. The first works was established in 1700, and, after leading a peripatetic existence, was finally abandoned in 1840. The plate-glass works now in operation is at Stockau, in Bohemia. The glass is chiefly used for the manufacture of mirrors. Considerable window-glass is also made in Austria, much of it for the manufacture of looking-glasses, for which large sizes are blown, the workmen using levers, cranes, props, and other mechanical means in its production. The finishing of this glass is carried on in the Pilsen district, where there is a number of establishments for grinding and silvering. There are in Austria 63 glass factories making cylinder glass, 46 making what is called cast glass, mainly for mirrors, and 56 making both.

The chief seat of the Austrian manufacture is in Bohemia, 169 of the 360 furnaces reported below being in that district. The glass houses, however, are generally very primitive affairs, being in the midst of forests, the furnaces ordinarily very small, containing seven or eight small pots, and burning wood. These furnaces, being so rude and inexpensive, are placed in the midst of the timber. As the fuel around a factory is burned, it is found more economical to move the furnace than to bring the fuel to it. This state of affairs has resulted in the division of glass-making in Bohemia into two distinct branches, the manufacture or the production of the rough unfinished articles and the manipulation—the so-called refining, or the cutting, engraving, and decorating of this raw glass. In a few establishments both operations are carried on, but the larger number simply blow or mold the articles and sell them to the glass refiner. The result of this division has been the training of a body of excellent engravers, and the skill has been still further encouraged by a government museum; and drawing- and art-schools in connection with the glass industry have also been opened at various places. As is stated in the chapter on materials, sand is but seldom used in Bohemia, quartz, which is quite abundant, being substituted for it.

According to the last statistical reports published in 1880 there are in Austria-Hungary 230 firms, operating 255 glass houses, in which there are 360 furnaces. In these furnaces are 2,803 open pots, 37 covered pots, and 5 tanks. Of the 360 furnaces, 15, with 123 pots, are regarded as permanently idle; 7 furnaces, with 50 pots, as temporarily idle; 1 furnace, with 8 pots, and 1 Siemens tank-furnace were in course of construction. The location of these furnaces and the number of workmen engaged are as follows:

Location of furnaces.	Glass houses.	Furnaces.	Workmen.
Bohemia	122	169	18,012
Moravia	16	27	9,072
Silesia	3	3	94
Galicia	15	15	358
Buckowina	4	5	111
Lower Austria	8	14	495
Upper Austria	3	4	179
Salzburg	1	2	300
Styria	20	27	1,142
Kaernten	2	2	60
Krain	2	4	109
Tyrol	4	5	169
Dalmatia	1	1	24
Hungary	40	66	2,850
Croatia	4	6	170
Slavonia	3	4	155
Transylvania	6	6	200

Helpers are not included in this estimate. If we add to this number 21,500 workmen engaged in glass refineries and other factories of a kindred character, we may put the number of workmen engaged in the glass industry of Austria-Hungary at 60,000.

Of these 360 works, 1 manufactures plate-glass, 1 cathedral glass, 63 window-glass, including blown looking-glass and colored glass, 71 table ware, 131 hollow glass, including crystal and fine glasses, 20 lamps, 50

green glass and bottles, 15 colored raw glass (9 of these are window-glass, and are included in window-glass manufacture), 15 raw glass sticks and pipes for beads, and 2 pressed glass. As stated above, wood is the chief fuel used. Of the 360 furnaces, 244 use wood as fuel, 86 peat, 18 coal, and 12 turf and wood.

One hundred and forty-six glass houses manufacture cut glass and other fine ware. Of these, 47 use foot-power, 57 water-power, and 16 steam-power. The total annual production of Austria reaches in value about $12,000,000. I find a statement in the *Bulletin of the Society for the Encouragement of the National Industry in France* to the effect that, in 1873, 70,000 to 80,000 quintals of blown window-glass were made in Bohemia in that year.

MANUFACTURE OF GLASS IN ITALY.—The recent revival of the manufacture of Venetian glass, while it has not added largely to the amount or value of the production of Italy, has given to its glass a reputation that has been wanting since the fires of Murano went out. In 1866 the Venice and Murano Glass Company was established by a few English gentlemen for the purpose of restoring the manufacture of Venetian glass, and the result has been a degree of excellence in product not unworthy of comparison with that which in former days characterized the productions of the glass works of Venice and Murano. Through the kindness of Signor G. Castellani, to whose skill the modern glass houses of Venice are so much indebted, I have received the following statement regarding the works at Murano:

Murano, a small island twenty minutes distant from Venice, contains 4,000 inhabitants, 2,000 of whom are employed in glass works. In these works are made beads, sheet window-glass, blown-glass articles, (*a*) vases, table ware, etc., chandeliers, bottles, green druggists' ware, and enamels for mosaics. There are ten or twelve furnaces in these different establishments. The most important of the Murano works, in a commercial point of view, is *Le Fabbriche Unite*, where beads are made, about a thousand workmen being employed. The Venice and Murano Company, which is the principal factory for blown and artistic glass, employs about seventy men, part of whom are called *maestri*. Its production is limited, the number of *maestri* being very small and not easily increased. The production amounts to about 500,000 francs ($96,500) a year. The entire product of the island does not exceed 5,000,000 francs ($965,000) a year. All the materials used on this island are drawn from other countries; the sand from Dalmatia, soda from England, coloring matter chiefly from Germany.

As to the details of the manufacture of glass in other parts of Italy but little information is obtained. The following statement was obtained from the minister of foreign affairs of Italy through the late Mr. Marsh, American minister:

Kinds of glass.	No. of establishments.	Average number of employés.
Plate-glass		
Window-glass	12	1,200
Glassware	49	3,000
Green glass	14	800
Total	75	5,000

MANUFACTURE OF GLASS IN RUSSIA.—The development of the glass industry in Russia in the last fifteen years has been very marked. All kinds of glass are made in this empire: plate, window, glassware, and bottles. As a rule, however, the works are quite primitive. In the Wilna, Minsk, and neighboring districts only wood is used. The furnaces are very primitive, and average but from four to six pots. In the central district, however, where there are fifty-eight works, the establishments are somewhat larger. The plate-glass establishment is in the northeast district. The entire production of Russia can be placed at about 10,000,000 rubles, or $7,779,000. The number of glass factories in Russia in 1879 was 202, the number of persons employed 14,480.

MANUFACTURE OF GLASS IN SWEDEN.—Sweden manufactures glass somewhat more extensively than Norway, supplying not only the larger part of its own demand, but having some surplus to export to Russia. Its quality, however, is not remarkable, and but little attention is paid to the production of anything but the commoner grades, though some painted glass is made. There are in Sweden 33 glass works, producing window-glass, glassware, and bottles, no plate-glass being made. Of these, 4 manufacture window-glass, making 19,602 cases yearly, (*b*) 15 glassware, and 14 are green-glass factories. In these 33 works are 38 furnaces, with 280 pots and 1 tank. Seven furnaces use gas, 3 coal, 2 peat, and 2 wood, and 31 are direct-firing, using wood as a fuel. The statistics of these factories for 1879 are as follows: (*c*)

Kinds of glass.	No. of establishments.	No. of furnaces.	No. of pots.	Number of employés.			Value of product.
				Men over 16.	Women over 16.	Males under 16.	
Window-glass	4						$93,955
Glassware	15						295,547
Green glass	14						265,323
Total	33	38	280 pots / 1 tank.	1,200	50	800	654,825

a Known as Soffiati.

b These cases are probably of 100 feet each.

c For these figures I am indebted to the courtesy of Mr. Fredr. Brushewitz, of Limmared, Sweden.

MANUFACTURE OF GLASS IN NORWAY.—But little glass is made in Norway. There is but one window-glass factory which uses wood as a fuel in a direct-firing furnace; two flint works making table ware, one using a Boetius and the other a wood-gas furnace, and three bottle houses using Siemens furnaces, two with pots and one tank. The latest statistics at hand, which are only approximately correct, are as follows:

Kinds of glass.	No. of establishments.	No. of furnaces.	No. of employés.	Value of product.
Window-glass	1	1	35	$27,000
Glassware	2	2	300	86,500
Green glass	3	3	270	86,500
Total	6	6	605	200,000

Of the employés 25 are women and 112 are children.

MANUFACTURE OF GLASS IN SPAIN.—Though Spain was one of the first nations of western Europe to make glass, the present condition of this industry by no means justifies the promise of its beginning. There existed in Catalonia, Spain, in the last century many works famous for their beautiful glass, but these are nearly all closed. In the whole of this kingdom at the present time there are only some 23 or 24 glass houses, making bottles, lamp articles, and window-glass, mostly for local use, though some little is exported. At these factories, also, some rude and strange shaped vessels and drinking-cups are made, and these, compared with the specimens remaining, show that the old forms and the old systems of ornamentation are still in use.

GLASS IN HOLLAND.—There are in Holland 19 glass works, all but one of which are engaged in the manufacture of the peculiar square glass bottles used for bottling the Dutch spirits. Many of these bottle factories are in connection with the distilleries, and consequently have a steady business, but little affected by foreign competition. The total production is about 19,000,000 a year, all colored. In addition to these bottle factories there is a glassware works at Maastrecht.

The province of Zealand furnishes a substance largely used in the manufacture of plate-glass, "bergasche", supposed to be the remains of a salt-boiling works which once existed in that province. This substance takes the place of soda, but requires especial preparation.

GLASS IN PORTUGAL.—In Portugal there is one establishment for the manufacture of crystal and fine glass, and some glass of other kinds is made, but not enough for the needs of the country.

CHAPTER XII.—HISTORY OF GLASS-MAKING IN THE UNITED STATES.

GLASS-MAKING IN VIRGINIA AND WEST VIRGINIA.

One of the first attempts at manufacturing within the limits of the thirteen original colonies was the production of glass. The hopes of sudden wealth from the discovery of gold and silver, or from finding the fabled passage through this continent to the South Sea, were doubtless the chief causes of the formation of the London Company and its early attempts to colonize Virginia. At the same time this was a commercial venture, with the hopes of profit, and with a shrewdness characteristic of the English merchants, not only of that but of subsequent centuries, they did not forget entirely the possibilities near at hand in their search for what they believed would be greater ones in the near future. The vessel which carried Captain Newport to this colony on his second voyage, in 1608, also brought out eight Poles and Germans to make "pitch, tar, glass, mills, and soap-ashes". Stith wisely remarks that "had the country been peopled they would have done well, but they only proved a burden and a hinderance to the rest". (*a*) After the return from the fruitless expedition to the country of the "Manakins", the president of the colony, Captain Smith, dispersed as many as "were able, some to make glass, and others for pitch, tar, and soap-ashes". Between the arrival of Captain Newport and the return of his vessel, in 1608 or 1609, some glass was made, and part of the return cargo, the first that conveyed any exports of manufactures from what is now the United States, was the trials of glass thus made.

Stith states that the glass house in which the glass was manufactured, and which was probably the first manufactory erected in the English colonies in America, being erected late in 1608 or early in 1609, stood in the woods about a mile from Jamestown. This enterprise was one of some daring. Glass-making at this time was by

a Stith's *History of Virginia*, page 77. Williamsburg. 1747.

no means well established in Europe. Flint-glass was not yet invented, and plate was not cast, while the art of blowing window-glass and bottles and making glassware was imperfectly practiced in England. Wood, however, was becoming scarce, and the alkalies needed for the manufacture of glass high priced, and those of a good quality were brought from a distance. All of these materials were not only abundant in the new colony, but the wood was a burden and potash could be made readily from the wood-ashes. The great bulk of glass bottles made their importation expensive, and it is possible that the first glass house in Virginia made bottles only. What window-glass was used was imported.

The craze for the raising of tobacco, which had such a disastrous effect upon the colony, interfered with glass-making, and in 1617 Captain Argall, on his arrival as governor, found the glass house fallen to decay.(*a*) In 1620 an attempt was made to restore manufactures to the colony, and a large number of artisans was sent to Virginia. In 1621 a roll or subscription was opened to raise funds for the erection of a glass house to make beads for the Indian trade, and Captain Norton and some Italians were sent over for that purpose. The subscribers to these rolls were to participate in the profits. These beads were currency among the Indians.

The London Company, in its letter of July, 1621, sent in the ship George, commended this Captain William Norton to the governor. He was directed to be lodged in the Guest House with his "gange" until he had found a convenient place for his furnace, and in the choice of place care was to be taken that he and his "gange" be as secure as possible from surprise, "so that the commoditie of glass and beads should not be vilified by too common a sale to the Indians".(*b*) At the time of the massacre, in 1622, the glass house at Jamestown was destroyed, but it does not appear that these Italian glass-workers were massacred, as they must have been had their glass works been at this place. They are referred to in June, 1622, and again in February 20, 1623, by the governor and council in a letter to London, in which they state that a gentleman who was returning to London would inform the company what had been done. This would seem to indicate that the manufacture of beads was not carried on at Jamestown, but that the house that was destroyed was the first one.

What was the history of glass for some years after this date is not, so far as I have been able to discover, a matter of record. No doubt the colonists found that the cheapness of fuel and of alkali was more than offset by the scarcity and high price of labor and its tendency to seek other employment, and it is probable that glass-making was abandoned.

The next account of a glass works in Virginia that I have found is of one that was in existence in 1787 at Alexandria. M. De Warville, who visited this state in the fall of 1788, states that this works exported the previous year glass to the amount of 10,000 pounds and employed 500 hands. This is the last notice of a works in eastern Virginia until early in the nineteenth century. Mr. Jarves states that a Dr. Adams, of Richmond, Virginia, "made large offers of increased wages to the workmen of the Essex-street works, who were induced to abandon their places of work and violate their indentures. They succeeded in reaching Richmond to try their fortune under the auspices of the doctor. A few years' experience convinced them of the fallacy of increased pay, for, after very heavy losses, the works were abandoned and the workmen thrown out of employ".

This is the last record I have been able to find of a glass works in eastern Virginia, or what is now Virginia.

In the census of 1810 Virginia does not appear as a glass-making state. In 1815, however, a glass works for making white flint, hollow, and other glassware was established at Wellsburg, in the western part of the state, at which glassware of an excellent quality was produced. In the census of 1820 a glass works is reported in Brooke county, which was no doubt the Wellsburg works. It made that year $20,000 worth of glass, had $12,000 capital, and paid out $8,000 for wages and $12,000 for material and contingent expenses, or exactly the value of product. It employed 14 men and 12 youths. In 1827 it is reported that glass decanters of great beauty and solidity were made at these works, "while white flint and green glass wares made within a few years rivaled the foreign."

At the tariff convention of 1831 there were two flint-glass furnaces, with 12 pots, reported in operation at Wellsburg, Pennsylvania, evidently a misprint for Virginia, and one with 6 pots at Wheeling, Virginia. Two window-glass works are also reported at Wheeling. In 1840 one glass works is reported in Brooke county (the Wellsburg), and three in Ohio county (the Wheeling).

Regarding the history of the Wheeling factories, Mr. W. Leighton, jr., in an article contributed by him to the Wheeling *Sunday Leader* of March 28, 1880, in some reminiscences, states that—

> The first glass factory built in Wheeling was for the manufacture of window-glass, and the business was commenced some time in the year 1821. I find in the *History of the Pan-Handle* that "in 1829 a flint-glass house was erected in Wheeling by John and Craig Ritchie, located on the side of the hill opposite the second ward market-house. This establishment was operated for several years with great activity and success, and had a widespread reputation for the manufacture of fine-cut glassware. This success and the unrivaled advantages for procuring cheap fuel at Wheeling encouraged other firms to embark in the business, and in 1835 the Messrs. Sweeney put a large flint-glass works into operation in the northern part of the town, which was followed in the course of the next few years by the erection of another large establishment at the extreme south end, built by Plunket & Miller, now owned and operated by the firm of J. H. Hobbs, Brockunier & Co.".

---

a Captain Smith, under date of 1615, states that for a long time the labor of the colony had been misdirected in the manufacture of various articles, among them glass.

b Neal's *Virginia Company of London*, page 231.

The veteran glass manufacturers of this country, Mr. J. L. Hobbs, and his son Mr. J. H. Hobbs, of the South Wheeling glass works, have been, I believe, for a longer time uninterruptedly running their furnaces than any other glass manufacturers in the United States. These gentlemen came to Wheeling in 1845 and purchased the glass works built by Messrs. Plunket & Miller, since which time there has been no break or interruption to their business.

Whether or not the introduction of glass-making at Wheeling encountered the same difficulties as are described to have met Mr. Bakewell at Pittsburgh I do not find set down in the records, but the probabilities are that a similar experience was had. The factories, however, ultimately surmounted all difficulties, and went on to good success. In 1863 the Central Glass Company was established by a number of workmen from the South Wheeling glass works and successfully operated. At later dates several other factories have been built in this valley, among which are the Belmont Company and Goblet Company at Bellaire, the La Belle Company at Bridgeport, and the Excelsior Company at Martin's Ferry. Beside these, window-glass factories and lamp-chimney houses have been located here, and the amount of glass business in this vicinity is assuming year by year greater proportions.

The obvious reason for the establishment of glass factories in Wheeling has already been mentioned—its cheap fuel. This has always been an important consideration; but the success of glass-making here has not been due to this cause alone; it owes much of its prosperity to the enterprise of those engaged in it. While the first great step of progress in glass-making in modern times, the invention of pressing, is claimed, as before mentioned, to be American, so is the second not only American, but had its origin here in Wheeling. This second step was the improvement in the composition of lime glass, which enabled manufacturers to substitute that material in place of the old flint-glass.

For the manufacture of bottles, window-glass, jars, and shades in England and on the continent of Europe lime glass has always been used, and can boast an antiquity perhaps as great as that of flint-glass. The first factories in this country made window-glass, using, of course, the lime composition; the manufacture of bottles followed, but flint-glass making was commenced, and, as in Europe, only inferior grades of ware were made of lime glass. In Pittsburgh, at an early period, common tumblers and cheap table ware were made of lime glass, and some improvement had been made in 1864; but still the lime goods were so much inferior to flint-glass as not to come in competition with it, their lack of purity and luster being very conspicuous faults.

In the winter of 1864 Mr. William Leighton, sr., of the firm of J. H. Hobbs, Brockunier & Co., made a course of experiments in the composition of lime glass, the result of which was so successful that the manufacture of lime glass was commenced by his firm, and ware was produced equaling in beauty the finest flint-glass. The most important feature in the composition of this new lime batch was the use of bicarbonate of soda in place of soda-ash, until that time universally used in lime glass; and this use of bicarbonate, and better proportion of all the materials, constituted the improvement, and led to the most important results. As the improved lime glass was much cheaper than flint-glass, being less than half its cost, other factories commenced using the same material and learned the new composition. The ware thus manufactured could only be distinguished from flint-glass by its less specific gravity, and by the peculiar tone of its sound when struck, the flint-glass having a full metallic tone or ring, while the lime glass emits a dull, dead sound, destitute of vibratory tone. From the time of this improvement in lime glass the flint-glass factories began to languish. The larger number of them, perceiving that the era of flint-glass was past, gave up the old composition and commenced the manufacture of bicarbonate glass, as it was then called. But a few factories still clung to the old lead-glass composition, fondly hoping, and perhaps believing, that lime glass would run a brief course, and that there would be a return to the time-honored flint-glass. It soon became evident, however, that lime glass had gained the ascendant by merits that would stand the test of time, and those who still persevered in the manufacture of lead glass found their ware could no longer be profitably made, and gained the experience that, in an age of progress, whoever clings to the methods of the past will soon be neglected and forgotten.

Beside advantage of cheaper material, lime glass has the property of chilling and becoming rigid more quickly than flint-glass, thus enabling, and even compelling, the workmen to finish the ware more rapidly, and hence making a greater production; and as the specific gravity of lime glass is less than that of flint-glass, articles made of the former have the advantage of this lightness of weight. The result of all these advantages, together with improvements in furnaces, tools, and methods of manufacture, has been to reduce the cost of glassware to about one-fourth part of what it was when the invention and introduction of bicarbonate glass took place in 1864. With this reduced cost, and consequent reduced price, the use of glassware has been extended correspondingly. New factories have been built; old factories have increased their capacity; and a sufficient supply of glassware has been produced to meet the demand which the reduced prices created.

No kind of ware, even if composed of the most common materials, can now compete in cheapness with lime glass for drinking-vessels and table ware; while for beauty of material, finish, shape, and ornamentation glassware is more than equal to, and for cleanliness far beyond, any other.

Speaking of gas furnaces, Mr. Leighton says:

Although Wheeling took no part in experimental gas furnaces, yet as soon as it became evident that a safe form of construction had been reached, that form was at once adopted here. The largest gas furnace for melting glass in this country, and probably in the world, was built and put into operation last year by Messrs. J. H. Hobbs, Brockunier & Co., at their South Wheeling glass works, and after six months' trial they were so well satisfied with its results that they put up another of the same form of construction, which has just been completed.

GLASS-MAKING IN PENNSYLVANIA.

The first mention of a glass works in Pennsylvania is found in a letter written in August, 1683, by Penn to the Free Society of Traders. In this letter he alludes to their tannery, saw-mill, and glass-house, "the last two conveniently posted for water carriage." Where this glass house was located, or for what kind of glass it was intended, is not known; indeed, it is doubtful whether the works were ever used for the purpose for which they were erected. If they were, they proved unsuccessful, as did most of the early glass works in the colonies, and were soon abandoned. (*a*)

a Budd, who wrote in 1685, does not mention them. Dr. More's letter, printed in 1687, mentions a number of industries, but not glass-making, and the same is true of the pamphlet printed some time in 1691, entitled *Letters and an Abstract of Letters from Pennsylvania.* In this pamphlet all the trades which flourished in Pennsylvania are mentioned, but glass is not one of them. Holme, who wrote in 1689, and who refers to a number of trades that were carried on in Pennsylvania, speaks of the scarcity of window-glass. He writes:

The window-glass is often here
Exceeding scarce and very dear,
So that some in this way do take
Isinglass windows for to make.

There is a statement in Bishop's *History of American Manufactures* to the effect that a glass works was built shortly after this one at Frankfort, near Philadelphia, by the English Friends who settled there, but this is probably a mistake, as there were no English Friends in Philadelphia at so early a date. (*a*)

From this time until just before the Revolution the record of glass-making in Pennsylvania is a blank. Governor John Penn, in a letter to the Lords of Trade and Plantations, dated Philadelphia, January 21, 1767, wrote:

> The other is a glass manufactory, which was erected about four years ago in Lancaster county, seventy miles from this city, by a private person. It is still carried on, tho' to a very inconsiderable extent, there being no other vent for their ware, which is of a very ordinary quality, but to supply the small demands of the villages and farmers in the adjacent inland country. (*b*)

This was probably Baron Steigel's establishment, referred to below, who established himself at Manheim in 1762; but however this may have been, there is evidence that Steigel soon after this built a glass house. In June of the same year that Penn's letter was written (1767) Townsend's scheme for raising revenue from the colonies passed the British parliament and was met in this country by a storm of denunciation and agreements of non-importation. At public meetings it was determined to stimulate by all prudent ways and means the manufactures of the colonies, and glass and paper were particularly mentioned as articles deserving of domestic encouragement. Townsend's revenue act was repealed in 1770. At that time a flint-glass manufactory on a much larger scale than any before attempted in the country had been built at the village of Manheim, near Lancaster, by a German baron, Henry William Steigel, and Mr. David Rittenhouse, in a letter to Mr. Barton, dated the 4th of February, 1770, speaks of his intention when he next visited Lancaster to have some pulse-glasses, then just introduced by Dr. Franklin from Germany, and other things he wanted, made there. In another letter, written in the following summer, acknowledging the receipt of a barometer tube made at this factory, he says:

> I am obliged to you for the glass tube; it will make a pretty barometer, though the bore is somewhat too small. I have compared it with an English tube, and do not think the preference can with any reason be given to the latter. (*c*)

This enterprise did not prove remunerative, as the war interfered with remittances from Europe and embarrassment ensued, and the glass works were abandoned. (*d*)

About the time that Steigel built his factory at Lancaster the first glass works in Philadelphia of which we have any details was established at Kensington. The repeal of Townsend's act did not remove the determination of the people of the colonies to establish domestic manufactures in their limits, and though workmen skilled in the manufacture of glass were by no means common, some gentlemen engaged in trades quite foreign to glass-making were found who were willing to risk their capital in this undertaking. In October, 1771, Robert Towars, skinner or leather-dresser, and Joseph Leacock, watchmaker, purchased a piece of land on the east side of Bank street (now Richmond street) and built upon it a glass house, furnace, and other improvements. (*e*)

This works must have begun the manufacture of glass late in 1771 or early in 1772, and it certainly made green bottles, and perhaps flint ware. In Franklin & Hall's *Pennsylvania Gazette* of January, 1772, appears the following advertisement:

> The glass facture, Northern Liberties, next door to the sign of the Marquis of Granby, in Market street, where the highest price is given for broken flint-glass and alkaline salts.

This would indicate the manufacture of flint-glass. The place designated was the store of Robert Towars, which was in Market street, between Second and Third streets. In November, 1772, Towars and Leacock sold the premises to John Elliott and Samuel Elliott, druggists, who took into partnership and interest Isaac Gray. These partners built an additional furnace and continued the manufacture of bottles, carrying on the business for eight years, and as the Elliotts were apothecaries and Gray was a wine merchant, it may be supposed that in this venture the manufacture of bottles for use in their business was an object. The property was sold in May, 1780, to Thomas Leiper, a tobacconist, who must have needed many bottles for the reception of snuff. The latter was owner for twenty years, and sold the glass house on March 6, 1800, to Joseph Roberts, jr., James Butland, and James Rowland for $2,333, subject to £15 ground-rent, who carried on the works under the firm name of James Butland & Co., and in 1801 had their store at No. 80 North Fourth street. Roberts soon sold out his one-third interest to Butland and Rowland for $2,548, who dissolved partnership in 1804, Butland disposing of his interest to Rowland for $2,548, and the latter advertised in 1808 that his store for the sale of bottles made at the Kensington glass works was at No. 93 North Second street. He was also in business as an iron merchant. James Rowland died before the year 1833, and on July 10 of that year James Rowland, jr., who had purchased the interest of his brother, Joseph W. Rowland, sold the works to Dr. Thomas W. Dyott.

Though the records are very meager, there are evidences that several other glass works were built in eastern Pennsylvania between the breaking out of the revolutionary war and the close of the century, and no doubt the

a Mr. F. D. Stone, the librarian of the Historical Society of Pennsylvania, writes me that Pastorious was the agent of the Frankfort Land Company, and Bishop probably confounds this name with the little town of Frankford, now a part of Philadelphia.

b *Pennsylvania Colonial Records*, ix, 354.

c Barton's *Memoirs of Rittenhouse*, page 206.

d In Franklin & Hall's *Pennsylvania Gazette* for January, 1772, in addition to the advertisement for broken flint-glass, elsewhere referred to, is one from the Southwark china factory for flint stones and broken glass. This may have been for "cullett" for the Lancaster works, or for some other factory of which we have found no record.

e For most of the earlier details of this works I am indebted to Thompson Westcott's history of Philadelphia, published in the *Philadelphia Sunday Dispatch*.

scarcity of glass during the war led to the erection of works in this and other states. That there were glass works of some importance in Pennsylvania at its close appears from Lord Sheffield's letter, written shortly after peace was declared. (*a*) In November, 1787, the Society for the Encouragement of Manufactures offered a gold medal for the best specimens of flint glassware and bottles. It is hardly to be supposed that a $20 gold medal was offered as an inducement to parties to undertake the manufacture of flint-glass, but rather as a premium to works already in existence for the best samples of their products, and the fact that window-glass is not mentioned would indicate either that window-glass was not made, or that its manufacture was so well established as not to need encouragement. Some time between 1780 and 1786 Robert Morris and John Nicholson erected works at the falls of the Schuylkill for the manufacture of some kind of glass, probably window-glass. The glass house was about opposite the dwelling of Governor Mifflin, and a row of stone houses a little lower down the river was built to accommodate the hands working in this establishment. John Thoburn, about 1808, altered the glass house for the purpose of a calico-printing establishment, and the building was still standing in 1856. (*b*) Mr. Eichbaum, who had charge of the erection of the Craig & O'Hara window-glass works at Pittsburgh in 1797, was "superintendent of glass works at Falls of Schuylkill, near Philadelphia". (*c*)

Thomas Harrison, Philip Jones, and Robert C. Martin, who were interested in other business (which, however, they did not abandon), invested a portion of their capital in the manufacture of green and flint glass, which they made at the glass house, South street, near the Schuylkill, in 1806–'07, and manufactured largely in 1808 green and white half-gallon, quart, and pocket bottles. This establishment consisted of a brick glass house, forty-three feet square, a brick warehouse, fifty by forty-three feet, and a small house and stable. Philip Jones & Co. were proprietors in 1810. (*d*) It is doubtful if this "white" glass could have been what is known as white to-day; for if it was, it must have been made in the same furnace as the green glass—a difficult operation.

The Schuylkill glass works, "two miles from Philadelphia," which were in operation in 1819, were the same South street works, and Edward Lowber, drug and color merchant, at No. 144 North Third street, had for sale in September, 1819, window-glass from those works. Caleb Foulke was agent for these works at No. 19 Minor street; but in 1820 George and Jacob Peterman, flour merchants, were agents, at No. 366 High street, for the Schuylkill window-glass manufactory, in South street, near the Schuylkill river. In May, 1822, H. & W. Lawrence advertised that the Schuylkill glass works were to let; and in February, 1823, George and Jacob Peterman gave notice that they had again undertaken the "agency of the Schuylkill glass works at South street wharf, recently called the Philadelphia works", and that they had for sale window-glass of all sizes. (*d*) Thum & Bitters, of North Third street, made, in 1808, pint and half-pint pocket bottles and vials. (*d*)

Regarding the attempts to manufacture certain kinds of glass at this time and later and the causes of failure, Dr. T. W. Dyott (*e*) states that "the manufacture of ordinary descriptions of glassware, such as apothecaries' vials and bottles and the common varieties so extensively used for domestic and other purposes, was not successfully prosecuted in this country until long after the period of the late war (1812)".

Owing to the extravagantly high prices of imported vials, many efforts had been made previous to this time in the county of Philadelphia and in the state of New Jersey to establish this business, but in all instances they were unproductive, and were finally abandoned, with a heavy loss to those who projected or were concerned in them.

A number of causes interposed to prevent success in this branch of industry, and the failure of those who had first attempted its introduction among us afterward operated to discourage capitalists from engaging in it. Our knowledge of the business at this period was theoretical, without practice; and our workmen were equally deficient, having but an imperfect acquaintance with the mechanical part of their profession. The metal of our factories was inferior in quality and strength, yet produced from the finest materials and by the most expensive process; the articles we manufactured were also limited in quantity to one-half of what ought to have been produced out of the same amount of materials, yet so rude and shapeless in their appearance that purchasers seldom could be found if a foreign article could be obtained. During the war (1812) I became interested in a factory in New Jersey, which was the first establishment that continued in operation for any number of years, and which afterward became the principal school of instruction to the workmen who were subsequently employed in the business. At a later period two other factories were established, and were in successful operation until after the conclusion of the treaty of peace, when they were compelled to suspend business, owing to the importation of the foreign article, which was designedly sacrificed at auction by the British agents, who publicly acknowledged at the time that they were instructed to sell at any prices for the purpose of breaking up our factories. (*f*)

The furnaces at this time were rude affairs, designed to run only about six months in the year. In 1831, at the date of the tariff convention, several times referred to in this report, the Dyottville factory was the most extensive glass works in the United States, consisting of four furnaces, melting about 8,000 pounds of batch a day, and producing about 1,200 tons of glass per year, which was blown into apothecaries' vials, bottles, shop furniture, etc.

a His statement is: "There are glass works in Pennsylvania;" but he gives no further particulars. Had not the works been of some importance he would hardly have known of its existence.

b *Early History of the Falls of the Schuylkill*, etc., pp. 33 and 34. By Charles V. Hagner. Philadelphia, 1869.

c These works were managed in 1796 by Mr. Nicholson, as appears from a manuscript letter now in my possession from Mr. Eichbaum to Major Craig.

d Westcott's history of Philadelphia in *Philadelphia Sunday Dispatch*.

e See *An Exposition of the System of Moral and Mental Labor Established at the Glass Factory of Dyottville*. By T. W. Dyott, M. D. Philadelphia, 1833.

f See Dr. Dyott's *Exposition*.

It was stated that this glass was composed of "materials altogether the production of American soil, about 15,000 barrels of rosin from North Carolina being annually consumed as fuel in preference to wood or coal". From 250 to 300 men and boys were constantly employed. In 1833 this works had five furnaces, wood and coal, as well as rosin, being used for fuel. It may be well to follow out the history of these works in this place. They were operated for several years after this until the disastrous failure and conviction of Dr. Dyott in 1838 for fraudulent insolvency, when the works passed into other hands, and after being idle for some years were leased in 1842 by Henry Seybert, who became interested in the glass business principally for the purpose of assisting Eugene Roussel in obtaining a supply of bottles for the manufacture of mineral or aerated water, then just being introduced into the United States. He also made flint in one furnace. In 1843 they were leased by a partnership, of which Mr. Henry B. Benners, the present proprietor, was a member. This works is still in operation, the oldest glass works in Philadelphia, and probably in the United States, with a record of one hundred and eleven years of work.

Returning to 1810, the date of the first census of manufactures, we find reported in Pennsylvania, outside of Allegheny county, five glass houses—one in Philadelphia city, two in Philadelphia county, and one each in Lycoming and Wayne counties. The value of the product of the Wayne county works is given at $36,000, while that of the three Philadelphia works was only $26,000. The Lycoming county works, which was probably at Williamsport, had a product of $20,000. This would indicate that glass-making in Philadelphia was not a prosperous business. At the census of 1820 but one works is reported in Philadelphia county, "a flint-glass works, that had been out of operation for some years", while in Wayne county a window-glass works, with one furnace and six pots, is reported, which had been "in operation for five years with good success". Jarves also states that in 1820 a number of workmen left the New England Glass Company at East Cambridge, Massachusetts, and established a co-operative flint-glass works at Kensington under the title of the Union Flint Glass Company; but after a few years this works passed into other hands, and the first recorded attempt at co-operative glass-making in this country failed.

In 1831, as already stated, the Dyottville works were the most extensive in the country. There was also in Philadelphia a flint-glass works with six pots. No mention is made of the Wayne county works at this time, though it appears at the census of 1840. There were, however, two works in Lycoming county, at Williamsport, one for the manufacture of window-glass and the other for hollow ware (green glass, etc.). In 1840, according to the census, there were but two glass works in the eastern district of Pennsylvania: one in Philadelphia and one in Wayne county. But it is not necessary to follow the history of glass in this section further. While there has been glass made in increasing quantities in eastern Pennsylvania since 1840, the industry has not attained the importance it has reached west of the mountains. It may be interesting to state, however, that though window-glass was at one time made in Philadelphia, none has been made in that city for seven years.

Of early glass-making in western Pennsylvania quite full accounts remain, and at least four of those connected with the earliest works, Albert Gallatin, Colonel James O'Hara, Major Isaac Craig, and Major Ebenezer Denny, were prominent in the affairs of the nation. Their journals and papers have been saved from the destruction or oblivion that usually overtakes such documents, and from these very satisfactory statements of these early undertakings can be obtained.

The generally received opinion for some years has been that the first glass works west of the Allegheny mountains was built by Albert Gallatin at his settlement of New Geneva, on the Monongahela river, some 90 miles south of Pittsburgh. Here Mr. Gallatin established a number of industries, and among them that of glass-making. Various dates have been assigned to his glass works, the most common one being 1787; but the evidence is quite conclusive that this is an error, and that the works was not started until 1797. (*a*)

Not only is the date usually assigned to this works incorrect, but it is very probable that it is not entitled to the credit of being the first west of the Alleghenies, Craig & O'Hara making glass about a month earlier. (*b*) As the Gallatin works was isolated and so remained, not forming, as did Craig & O'Hara's, the nucleus of a great industry, it may be well, though it was not the earliest, to give its history first, that the account of the works at Pittsburgh may be a connected one.

The Gallatin works was used for the manufacture of window-glass. The furnace was a small one, with eight pots, using wood as a fuel and "ashes for alkali". The glass house was 40 by 40 feet, three sides frame and one side stone. The most credible story regarding its erection is that a number of glass-workers, mostly Germans, left Amelung's factory (*c*) at Fredericktown, Maryland, and crossed the mountains for the purpose of building a glass works at the point that is now Louisville, Kentucky. Gallatin accidentally met them at Wheeling and persuaded

a In Adams' *Life of Gallatin*, Philadelphia, 1879, it is stated that the business of "glass-making" at New Geneva began "during Mr Gallatin's absence in the spring of 1797". This is confirmed by Mr. Isaac Craig. (See note below.)

b I am informed by Mr. Isaac Craig, of Pittsburgh, the grandson of Major Craig, who has in his possession many of the letters that passed between Major Craig and Colonel O'Hara on the subject of the glass works, and who is one of the best authorities on the history of western Pennsylvania living, that as the result of a correspondence between himself, Mr. Henry Adams, the author of the *Life of Gallatin*, before referred to, and a son of Mr. Gallatin, he is convinced that the Craig & O'Hara works began to make glass a month earlier than Gallatin's. The Pittsburgh works began in 1797 without doubt, and this would fix the date of Gallatin's as 1797 also. Mr. Craig has kindly allowed me free access to his grandfather's letter-books.

c See account of this works under "Glass-making in Maryland". It is probable that Mr. Amelung was at one time a glass-worker at Pittsburgh. In *Cumming's Journal*, about 1807, mention is made of A. F. Amelung, a glass-worker in Pittsburgh.

them to turn back to New Geneva and establish the works there, Mr. Gallatin agreeing to furnish capital and they to do the blowing. (*a*) The title of the firm at first was Gallatin & Co., but it was afterward changed to the New Geneva glass works.

For a time the business was exceedingly profitable, more so, Mr. Adams tells us, than any other of Mr. Gallatin's enterprises. (*b*) There were but two, possibly three, other window-glass factories in the country, most of the window-glass used coming from England. These works, as well as Craig & O'Hara's, were on or near the route of travel between the East and the rapidly developing West, and the glass commanded a ready market. There seems to have been considerable discussion between Mr. Gallatin and his partners, among whom were a Mr. Nicholson and two brothers by the name of Kramer, who were skilled workmen and had charge of the manufacturing of the glass, as to the price at which it should be sold, and it was fixed at $14 a box of 100 feet, (*c*) though Mr. Gallatin, fearing ruinous competition by reason of the profit at this price, favored a lower rate. The glass, however, by reason of the character of the materials used, was probably of an inferior quality. The works was removed in 1807 to the other side of the Monongahela river, and in 1814 it was operated by Nicholson & Co. (*d*) As late as 1832 a glass house was reported at New Geneva, and glass was made some years later than this. When the works was finally abandoned I have not been able to learn.

In 1796 preliminary steps were taken by Major Isaac Craig and Colonel James O'Hara toward the erection of the first glass house at Pittsburgh. (*e*) This was also the first works west of the mountains to make glass, Mr. Peter William Eichbaum, a German glass-worker, who was superintendent of glass works at the Falls of the Schuylkill, near Philadelphia, being engaged to direct their erection. (*f*) Various causes delayed the work, and it was not until 1797 that the active work of building the furnace was begun, when, as appears from a letter written June 12 of that year by Major Craig to Colonel O'Hara, (*g*) search for coal in the upper part of what is now Allegheny City not showing a vein of workable thickness, a location on Coal Hill, on the south side of the Monongahela river, just above where it unites with the Allegheny to form the Ohio, was purchased, and the erection of the furnace was begun. This site, or part of it, has ever since been continuously occupied by a glass house, the Point Bridge works of Thomas Wightman & Co. occupying it at present.

This was one of the first, if not the first works in the United States to use coal as a fuel; (*h*) indeed, as late as 1810 coal was not used in any glass works in this country but the Pittsburgh houses. (*i*) It was not the force of circumstances or lack of wood that led to the use of coal, but it was the deliberate design of the promoters of this enterprise to melt their glass with coal, and it was the character of the coal in Coal hill that determined the location of the works. (*j*) The use of coal in the state of the art at this time required considerable determination and risk, and it is to the credit of these gentlemen that they dared use it.

The generally received belief that this was the first glass works in Pittsburgh was called in question a few years since by the statement that in 1795 there was a window-glass works, known as "Scott's", at Glass House riffle, on the west bank of the Monongahela. (*k*) This is without doubt an error. Mr. Neville B. Craig, in his *History of Pittsburgh*, speaks of the O'Hara works as "the first glass house here", and as his memory went back distinctly to 1796, if not earlier, it is hardly possible he would not have known of this "Scott's" works if it existed in 1795. It is probable that the works referred to was the "Ohio" works, built about 1800 by Denny & Beelen, which was on the north side of the Ohio, and which gave the name to Glass House riffle, as it appears from a letter of Major Craig's, in connection with the experiment of Mr. Price, that Dr. Hugh Scott, from whom it got its name,

a History of Fayette County, Pennsylvania. Philadelphia, 1882.

b Life of Gallatin, p. 176. Mr. Adams writes me, however, that the glass works were "a constant matter of anxiety" to Mr. Gallatin.

c This does not seem so extravagant a price when it is known that at the census of 1810, when there were at least fifteen works in the country making about 5,000,000 square feet of window-glass a year, the marshals estimated the value of the glass at 16 cents a square foot.

d Cramer's *Navigator*, 8th ed., p. 40. Pittsburgh, 1814.

e History of Pittsburgh, p. 276. By Neville B. Craig. Pittsburgh, 1851.

f I have before me a letter from Mr. Eichbaum to Major Craig, dated Falls of the Schuylkill, August 18, 1796, from which it appears that negotiations had been in progress for some time between these gentlemen looking to the building of the glass house, and "four different sorts of clay" from near Pittsburgh had been sent Mr. Eichbaum for his judgment as to their adaptability for pot-making. He writes they "do not look amiss" with the exception of some roots, and gives directions for the digging and ripening of 20 or 25 tons weight. This letter is in answer to one from Major Craig, of June 6, 1796, in which he had evidently made a proposition to Mr. Eichbaum to go to Pittsburgh, which the latter accepts conditionally if Messrs. Craig & O'Hara's resolve to build glass works is "absolutely fixed".

g Craig's *History of Pittsburgh*, pp. 276, 277.

h Gallatin's works used wood, as did Denny & Beelen's, the third west of the mountains.

i See Gallatin's *Report on Manufactures in* 1810.

j The Glass House riffle works referred to below used wood, its location on the north bank of the Ohio rendering this necessary.

k See *Pittsburgh as It Is*, by George H. Thurston, Pittsburgh, 1857; also Bishop's *History of American Manufactures*, which probably follows Thurston. Mr. Thurston's authority is a statement of the late Mr. William McCully, a well-known Pittsburgh glass manufacturer, who learned the trade of window-glass blowing in the Craig & O'Hara glass house. I think there can be no doubt but that Mr. Thurston either misunderstood Mr. McCully, or that Mr. McCully was mistaken. Mr. Mark Watson, Mr. McCully's son-in-law and his successor in business, authorizes the statement that in their many conversations on the subject Mr. McCully always spoke of the Craig-O'Hara house as the first. Mr. Isaac Craig also states that, as early as 1845, Mr. McCully told him that the Craig & O'Hara works was the first.

was in 1800 connected with this works. There seems to be no doubt that the Craig & O'Hara works was the first glass works not only in Pittsburgh, but west of the mountains, and was the pioneer of Pittsburgh's glass industry.

The building erected was frame, and contained an eight-pot window-glass furnace using coal as fuel, three boxes being made at a blowing, the box at that time containing 100 square feet. What is now known as a box, 50 square feet, was formerly, even as late as 1860, termed "half box (H. B.)", and the rates of wages for blowing are still based on the box of 100 feet. Some idea of the pots in this pioneer factory can be obtained from the output. A box of 100 feet did not probably exceed 125 pounds in weight, which would give 375 pounds as the finished product of the blowing or of one blower at each melting, and allowing that the weight of product was four-fifths of the weight of batch, the amount of material charged into each pot would be but 500 pounds. Now the weight of batch in each pot will average 1,500 pounds, and the average of a blower is nine to ten boxes of 100 feet. An old glass manufacturer expresses this difference in the size of the pots very graphically in saying: "One man could easily lift an old-style pot, now it takes four men."

As was generally the custom in the window-glass houses of that day, one or more pots in the furnace were used for the manufacture of bottles—"hollow ware," as they were termed. Among Colonel O'Hara's papers, found after his death, was a memorandum in his handwriting stating, "To-day we made the first bottle, at a cost of $30,000." (*a*) This remark has led to the belief that the works was a bottle house, but it was a window-glass factory, making some bottles. The partnership between Craig and O'Hara lasted for seven years, when Major Craig was persuaded by his relatives, who feared financial loss, to withdraw. (*b*) The works were continued by Colonel O'Hara.

The difficulty and expense connected with this first attempt at glass-making west of the mountains were such as must have discouraged a less determined man than Major Craig, who seems to have had the immediate management of the works, he being in Pittsburgh most of the time, while Colonel O'Hara's other interests called him frequently from Pittsburgh. The men employed as superintendent and blowers did not always prove to be as highly skilled as their own assertions would have indicated, and many of the workmen seem to have been petulant, easily angered, and constantly threatened to leave the works. For some such reason as this, in December, 1798, the works were leased to Eichbaum, Wendt & Co., a firm composed of workmen who do not seem to have been very successful financially. Great trouble was experienced also in obtaining the proper materials. The clay which was found in the neighborhood, and which, as appears from a letter previously quoted, was supposed to be of the proper quality to make pots, proved unfit for use, and clay had to be brought from New Jersey in barrels over the mountains at great expense, and frequently the delays were so great that the furnace had to go out of blast for want of pots. When the clay came the whole force would be put to work making pots, which would be dried hurriedly, and the furnace would be put in blast again with the result that every glass-maker of to day would have anticipated—the pots were lost. In one case, in an 8-pot furnace, three pots were lost at the first melting, and the next day four more, leaving but one in the furnace. Great trouble was also experienced in getting sand, and Major Craig's letters constantly refer to the different localities from which specimens were procured and the success in their use.

The trials and the results obtained at this works are set forth in the following letter, dated August 5, 1803, written by Major Craig to Samuel Hodgson, of Philadelphia:

> With respect to our glass manufacturing, the establishment has been attended with greater expense than we had estimated. This has been occasioned partly by very extensive buildings necessarily erected to accommodate a number of people employed in the manufacture, together with their families, and partly by the ignorance of some people in whose skill of that business we reposed too much confidence. Scarcity of some of the materials at the commencement of the manufacturing was also attended with considerable expense. We have, however, by perseverance and attention, brought the manufacture to comparative perfection. During the last blast, which commenced at the beginning of January and continued six months, we made on an average thirty boxes a week of excellent window-glass, beside bottles and other hollow ware to the amount of one-third of the value of the window-glass, 8 by 10 selling at $13 50, 10 by 12 at $15, and other sizes in proportion.

In the fall of 1800 the "commissioner of the city of Washington", then just made the seat of government, applied to Craig & O'Hara to make for the public buildings some glass of larger sizes than had ever been produced in this country, but the attempt was unsuccessful. Glass of the size required, to the extent of some 400 square feet, was made "of a transpareney tolerably good", but it was too uneven for the purpose, or was spoiled in flattening, and the glass required was obtained from England.

The second glass house built in the vicinity of Pittsburgh, and the third west of the mountains, was that of Denny & Beelen. This factory was situated on the north side of the Ohio river, in that part of Allegheny now known as Manchester, and gave the name to Glass-House riffle on the Ohio. (*c*) It used wood as fuel, its location being such that coal could not be procured without boating it across the river from the south side of the Monongahela, while wood was easily procurable. The exact date of the erection of this works has not been ascertained, though

a *Military Journal of Major Ebenezer Denny*, p. 487. *b* Craig's *History of Pittsburgh*, p. 278. *c* Major Denny's *Journal*, p. 228.

it was probably built in 1800. (*a*) Window-glass was made, whether crown or blown is not certain, though there is a legend that an attempt was made to manufacture the former. A Frenchman by the name of La Fleur, commonly known as "Falure", was brought to this country to have charge of the works; but they were unsuccessful from the first, and being compelled to cease operations after a short run, the furnace was abandoned, La Fleur entered the employ of Craig & O'Hara, and Beelen (*b*) gave up the glass business.

As has already been stated, the manufacture of green-glass bottles, or "hollow ware", was carried on in these early glass houses in connection with that of window-glass, the "corner pots" in the window-glass furnaces being used for the manufacture of bottles and flasks. The history of the manufacture of bottles in the West is, therefore, for many years the history of the window-glass works. It was nearly forty years before furnaces for making bottles exclusively were built, and the records of the make of glass at Pittsburgh and of the works in that city as late as 1837 combine window-glass and green glass or bottles as one branch of manufacture. In 1837 there is a record of a "vial works" and a "black-bottle factory", (*c*) the latter "the only one of the kind in the western country". This factory made wine, porter, and other black or amber bottles, as well as demijohns and carboys. The custom of using the "corner pot" for bottles is now entirely discontinued in this section, bottle manufacture being a distinct branch of the glass industry.

The first attempt to manufacture flint-glass west of the Alleghenies was made in Craig & O'Hara's window-glass furnace in September or October, 1800, by Mr. William Price, of London, who had then lately arrived in this country, and who "had been employed altogether in flint-glass". September 5, 1800, Major Craig wrote Colonel O'Hara that Mr. Price had arrived, and had "offered to show us a specimen of his abilities without charge", and arrangements were made with Eichbaum, Wendt & Co., who were operating the works under lease, to allow him the use of a pot in the furnace and such assistance as he needed to make the experiment. On September 11, 1800, "one hundred pounds of pearlash, refined in the best manner, so that it may be perfectly pure, as it is to be applied in the composition of crystal glass by a man just from London", was ordered from Aaron Aimés, at Funk's tavern, on Franklin road. October 29, 1800, Major Craig sent a specimen of glass made by Mr. Price to Colonel O'Hara, and on November 17, 1800, in a letter to Colonel O'Hara, which he sent by Price, he wrote: "He [Price] has satisfied me, as well as others, that his ability in white-glass manufacturing is equal to his professions."

These extracts from Major Craig's letters leave no doubt but that at this early date an attempt was made to produce flint-glass in Pittsburgh, and, further, that the advisability of building a furnace for its manufacture was seriously considered. Mr. Craig writes that he had hopes that some part of the window-glass house could have been used for the manufacture of flint-glass, but Price told him it could not be done. Major Craig seems to have had some doubt as to obtaining workmen and materials, and also as to whether the business would pay; but Mr. Price was instructed to make an estimate of the articles needed and drafts of buildings, and submit them to Colonel O'Hara. Nothing seems to have come from this attempt at the time. A careful examination of Mr. Craig's letter-books gives no evidence of the prosecution of flint-glass manufacture, and as late as 1803, as will be seen by the letter previously quoted, flint-glass was not made at these works.

There is, however, a statement that should be quoted in this connection, to the effect that in 1802 Colonel O'Hara built an additional furnace at his works and attempted to establish the manufacture of white and flint glass, sending an agent to England to procure the necessary workmen; but this agent is reported to have failed in his mission. (*d*) I have not been able to verify this statement, and a careful examination of Major Craig's letter-books of 1802 and 1803 gives no evidence of the existence of such a house, though they refer quite at length to Mr. Price's attempt at flint-glass making and to Mr. Edward Ensell, who afterward built a flint-glass works. Nor is any evidence of the existence of such a works found in Cramer's *Almanacks*. In the *Almanack* for 1807 O'Hara's "glass factory" is mentioned, not his factories, as would have been the case were he making both flint- and window-glass, these requiring separate furnaces. (*e*) In the *Almanack* for 1808, which would give the establishments for 1807, the only glass works mentioned is "1 green-glass works". In the *Almanack* for 1809 Robinson & Ensell's works appears for the first time, and is the only "white-glass" works, and the first one, mentioned.

In Cramer's *Almanack* for 1804, among the amounts for each article made from raw material in Pittsburgh in 1803 are mentioned "jars, decanters, tumblers, blue glass". It has been argued that this proved the existence of a flint-glass house at Pittsburgh, as tumblers and decanters would hardly be made out of green glass; but this supposition

a The memoir prefixed to Major Denny's *Journal*, page 228, states that they were built "about the beginning of the present century". In a letter from Major Craig to Colonel O'Hara, dated March 20, 1801, he writes, referring to this factory: "The Ohio glass works have stopped." These two statements would fix the date at least as early as 1800, and it seems from a number of letters that they were built in that year.

b Beelen was a Belgian, son of the Austrian minister "Baron de Beleu Bartholf".—Denny's *Journal*, p. 228. It thus appears that in the early glass works of Pittsburgh were represented the chief glass-making countries of Europe.

c Lyford's *Western Directory*. These houses were on the south side, and have been known in recent years as "Ihmsen's".

d Thurston's *Pittsburgh and Allegheny in the Centennial Year*, p. 128; also, Bishop's *History of American Manufactures*, vol. ii, p. 96.

e A flint-pot could not have been used successfully in the window-glass furnace, as pots for bottle-making were, the method of working precluding this.

is not borne out by the facts, as green-glass tumblers and decanters were quite common at that time. (*a*) In the *Almanack* for 1804 also appears the oft-quoted statement about glass-cutting "equal to any cut in the states of Europe" which was carried on at Pittsburgh, and it has been claimed that this indicated the presence of a flint-glass house. The amount reported cut, $500 a year, and the fact that the specimens of Mr. Eichbaum's skill at this early date seem to have been chandeliers, the beautiful clear glass of the prisms of which could hardly have been made in Pittsburgh, indicate that the glass came from east of the mountains, if not from Europe. The evidence I have found is against the existence of such a works. (*b*)

If such a factory as is mentioned ever existed, it must have been short-lived and of but little note, and cannot be regarded as marking the beginning of the flint-glass industry in Pittsburgh, which dates from 1808. In the fall of 1807 (*c*) Mr. George Robinson, a carpenter by trade, and Mr. Edward Ensell, an English glass-worker, who had been a manufacturer of both window- and flint-glass at Birmingham, England, and had sold his works and come to this country to better his condition, commenced the erection of a flint-glass works at Pittsburgh, on the bank of the Monongahela, at the foot of Grant street, under the firm name of Robinson & Ensell; but the partners appear to have lacked capital and were unable to finish the works, and the establishment, in an incomplete state, was offered for sale, probably without having made any glass.

In August, 1808, Mr. Thomas Bakewell and his friend, Mr. Page, who were visiting Pittsburgh at the time, were induced to purchase the works on the representation of Mr. Ensell that he thoroughly understood the business. This was the beginning of the firm of Bakewell & Page. that by itself and successors has continued the manufacture of flint-glass to the present, Bakewell, Pears & Co., their direct successors, reporting to the present census. (*d*)

Mr. Bakewell soon found that the representations made to him as to the skill of the workmen he relied upon were not borne out, and he was forced to rely upon his own good judgment and his diligence in obtaining information about the business. The difficulties he met with would have disheartened a less determined man, and the lack of skill on the part of his workmen and the inferiority of the material interfered at first with his success. His furnace was badly constructed; his workmen were not highly skilled, and would not permit the introduction of apprentices, and his materials were procured from a distance at a time when transportation was difficult and expensive, pearlash and red lead coming from Philadelphia, and pot-clay from Burlington, New Jersey, all being transported over the mountains in wagons. The sand was obtained near Pittsburgh, but was yellowish, and up to this time had only been used for window- and bottle-glass; the saltpeter from the caves of Kentucky until 1825, when the supply was obtained from Calcutta. These difficulties were in time overcome. Good clay was procured from Holland, and purer materials were discovered; and he rebuilt his furnaces on a better plan, competent workmen being either instructed or brought from Europe, and through his energy and perseverance the works became eminently successful. There can be no doubt that Mr. Bakewell is entitled to the honor of erecting and operating the first successful flint-glass house in the United States.

The furnace built or completed in 1808 held six 20-inch pots. This was replaced in 1810 by a 10-pot furnace, (*e*) and in 1814 another furnace of the same capacity was added to the works. The establishment was burned down in the great fire of 1845, but was immediately rebuilt. The site is now occupied in part by the Baltimore and Ohio railroad depot, the brick part of the depot being a part of the old warehouse.

The success of Messrs. Bakewell & Page induced others to embark in the business. In 1809 another flint-glass house was built, which produced glass on a limited scale, and in 1810 another company was formed, but failed in a short time. In 1812 another works, making the fourth in four years, was built. (*f*) It would thus appear that the manufacture of flint-glass increased much more rapidly than that of window-glass, as at that time there was in Pittsburgh only the O'Hara window-glass works, started in 1797.

In 1810 the manufactures of the United States began to attract considerable attention, and for the first time the census returns include a statement of manufactured articles. In this year Mr. Albert Gallatin, then

---

a These decanters were known as "big-bellied bottles", and were made out of the "corner pots" of the window-glass houses even later than 1837. Mr. Isaac Craig writes me: "I recollect distinctly seeing both tumblers and decanters made of green glass. In old times decanters were used in every house, most commonly by the poorer families, who could not afford cut glass. Whisky was set out to every visitor in these decanters, and before and after every meal. Although of green glass, they were not cut, but ornamented by beads around the neck." These beads were probably pinched on while the glass was still plastic.

b The only evidence I have been able to find that this works ever existed is that contained in Thurston and Bishop. Mr. Thomas Bakewell, who came to Pittsburgh and entered into the glass business in 1808, and who was authority on the early history of glass-making in that city, seems to have had no knowledge of such a works, and speaks of Robinson & Ensell's attempt as the first.

c Jarves, in his *Reminiscences*, who got his information from Mr. Thomas Bakewell, says 1808; but in Cuming's *Tour*, published in Pittsburgh in 1810, is a statement, p. 222, in regard to Pittsburgh, that "an account of the manufacturers and tradesmen was taken in the fall of 1807, the result of which was * * * a glass works for green glass on the opposite side of the Monongahela, another just erected for white glass on the town side of the same river". This latter undoubtedly was the Robinson & Ensell works.

d Since the census year the firm has gone out of existence, after nearly three-quarters of a century of business life.

e See Jarves' *Reminiscences of Glass-making*, to which I am indebted for many of the facts about Mr. Bakewell and his works.

f Jarves' *Reminiscences of Glass-making*, p. 72.

Secretary of the Treasury, made a report to the House of Representatives on our industries, in the course of which he mentioned that "two works, employing together six glass-blowers, had lately been erected at Pittsburgh, and made decanters, tumblers, and every other description of flint-glass of a superior quality".

The Pittsburgh window-glass works is also mentioned, and it is stated that all of this kind of works in the country, with the exception of "that of Pittsburgh", used wood as fuel, the latter using coal. According to the census returns for 1810, there were three glass works in Pittsburgh that year which produced $62,000 in value. If Gallatin's statement is correct, two of these were flint works, and one manufactured window-glass and green bottles. (*a*)

Concerning the condition of glass-making in Pittsburgh in 1813 and 1814 Cramer's *Navigator* (*b*) states:

> The manufacture of glass has succeeded as well as the most sanguine had expected. The situation of this place is particularly favorable, notwithstanding some disadvantages in procuring some of the materials. The first was established by Colonel O'Hara about the year 1798. (*c*) There are two glass works on the opposite side of the Monongahela, erected by Trevor & Ensell, and one in the new town of Birmingham, under the firm of Beltzhoover, Wendt & Co. These, with the three before erected, to wit, O'Hara's, Robinson's, and Bakewell's, will be able to manufacture to the amount of $160,000 annually. Both flint and green glass are now made here to great perfection. Messrs. Bakewell, Page & Bakewell have lately built another flint-glass works in addition to their former one. There are now in the town and opposite two white and three green glass houses. Glass-cutting is likewise executed in this place not inferior to the best cut-glass in Europe. The furniture of the apothecaries' shops is altogether of home manufacture.

This extract would indicate that some of the flint houses had gone out of existence and capital invested in glass-making was wisely turned to the branches that promised profit.

The number of glass houses after this increased so rapidly that it is impossible to enter into the details of the history of each. In 1819, according to the memorial adopted at a town meeting and sent to Congress, the manufacture of glass in Pittsburgh had rapidly declined since 1815. At the latter date 169 workmen were employed, producing $235,000 in value of glass annually, while in 1819 the number had fallen to 40, producing but $35,100, and the statement is made that in flint-glass alone the reduction was $75,000. (*d*) In 1820 the census reports the product of "glassware and colored flint" as $20,000, and of "glass, window and hollow", as $24,000. In Fayette county, at the same time, there were three establishments making window-glass and hollow ware. In 1826 there were eight window-glass works in western Pennsylvania, producing 27,000 boxes (100 feet) of glass per annum, valued at $135,000, and, in addition, $30,000 worth of flint ware was made. In 1831 (*e*) there were four flint houses, with thirty-two pots, and four window-glass houses at Pittsburgh, four or five at Brownsville, one each at New Geneva, Bridgeport, New Albany, Perrypolis, and Williamsport, making window-glass, and one at the latter place making hollow ware. Mr. Bakewell at this time estimated that the value of glass produced in western Pennsylvania was more than $500,000 annually. In 1837 there were thirteen factories in Pittsburgh and its immediate vicinity, six flint and the balance window-glass or green hollow ware, making about $700,000 worth. Among these were the Sligo works of William McCully, established in 1828, and continued at the present day by W. McCully & Co.; the flint-glass works of Curling & Price, known as the Fort Pitt glass works, established in 1830, now carried on by their successors, E. D. Dithridge & Co.; and the window-glass factory of F. Lorenz, now continued by Thomas Wightman & Co. Twenty years afterward, in 1857, there were thirty-three factories at Pittsburgh, of which nine produced flint-glass and twenty-four window, green, and black glass to the value of $2,631,990, employing 1,982 hands, whose wages were $910,116, consuming material to the amount of $2,078,734 40. In 1865 there were fifteen bottle and vial factories, fifteen window-glass factories, and fifteen flint-glass works in Pittsburgh, being forty-five glass houses in all; an increase of 36 per cent. in eight years. These fifteen window-glass works, located immediately at Pittsburgh, had a capacity to make 520,000 boxes of glass in a year, but their average yield was about 400,000 boxes, whose entire value at that time was $2,600,000. The fifteen green or vial works produced annually about 420,000 gross of vials and bottles, worth, at the then rate, $2,100,000. The pressure upon these works at that time is best shown by the fact that, although only customary to run them for ten months in the year, yet many of them had run twenty-one months without stopping. The fifteen flint-glass works then in operation at Pittsburgh produced about 4,200 tons of glassware, worth then, in round numbers, $2,000,000. Their capacity was, however, double the amount produced, or about 8,000 tons. (*f*)

---

a Cramer's *Navigator*, published in 1814, states that in 1810 there were two white and one green glass works in Pittsburgh.

b The copy of Cramer's *Navigator* from which this statement is taken bears the date 1814, though the preface was written in 1811. The statement probably refers to 1813 or 1814, as the work was revised and published in several editions.

c This should, of course, be 1797.

d *Address of the Philadelphia Society for the Promotion of National Industry*, p. 257.

e *Report of the New York Tariff Convention*, 1831, p. 121.

f *Pittsburgh and Allegheny in the Centennial Year.* By G. H. Thurston.

Below, I give in a tabulated form such statistical information as I have been able to gain as to the glass works of Pittsburgh from 1797:

Date.	WINDOW AND BOTTLE.		WINDOW.		FLINT.		GREEN BOTTLE.		ALL KINDS.	
	Works.	Value.	Works.	Value.	Works.	Value.	Works.	Value.	Works.	Value.
1797	.....	.....	1	$10,000	.....	.....	.....	.....	1	*$10,000
1800	.....	.....	1	10,000	.....	.....	.....	.....	1	*10,000
1803	1	$12,500	.....	.....	.....	.....	.....	.....	1	12,500
1810	1	40,000	.....	.....	2	$30,000	.....	.....	3	70,000
1812	.....	.....	.....	.....	.....	.....	.....	.....	3	62,000
1813	.....	.....	.....	.....	.....	.....	.....	.....	5	170,000
1815	.....	.....	.....	.....	.....	.....	.....	.....	5	235,000
1817	3	130,000	.....	.....	2	110,000	.....	.....	5	240,000
1819	.....	.....	.....	.....	.....	.....	.....	.....	5	35,100
1826	.....	†135,000	.....	.....	.....	100,000	.....	.....	7	235,000
1831	4	.....	.....	.....	2	.....	.....	.....	8	500,000
1837	.....	.....	5	.....	6	.....	2	.....	13	728,000
1840	.....	.....	.....	.....	.....	.....	.....	.....	10	.....
1850	.....	.....	11	.....	8	.....	7	.....	26	.....
1857	.....	.....	7	.....	9	.....	9	.....	25	2,631,990
1860	.....	.....	5	$875,520	.....	.....	.....	.....	18	‡2,075,143
1865	.....	.....	15	2,600,000	15	2,000,000	15	$2,100,000	45	§6,700,000
1870	.....	.....	.....	.....	.....	.....	.....	.....	32	‡5,832,429
1876	.....	.....	24	.....	41	.....	11	.....	‖76	.....
1880	.....	.....	12	1,632,687	30	3,215,038	9	820,487	51	5,668,212

* Estimated.
† 27,000 boxes made.
‡ From the census, and evidently incorrect.
§ Evidently estimated.
‖ Number of furnaces, not of works.

At the present census, as will be seen by an examination of the tables, Allegheny county stands first as a glass-making center. Its statistics are as follows:

Kinds of glass.	No. of establishments.	Capital.	No. of furnaces.	No. of pots.	NUMBER OF EMPLOYÉS.				Total wages paid.	Value of materials used.	Total value of product.
					Total.	Males over 16.	Females over 15.	Children and youths.			
Window-glass	12	$1,880,000	23	216	1,133	1,101	.....	32	$809,842	$576,638	$1,632,687
Glassware	30	2,744,500	51	496	4,069	2,691	129	1,249	1,500,833	1,180,851	3,215,038
Green glass	9	856,500	11	85	851	650	12	189	375,750	382,169	820,487
Total	51	5,481,000	85	797	6,053	4,442	141	1,470	2,686,425	2,139,658	5,668,212

It will thus be seen that this county had 24.17 per cent. of the total number of glass establishments of all kinds in the country, 27.62 per cent. of all the capital invested, and produced 26.79 per cent. in value of the products. It had 20.69 per cent. of the number of window-glass establishments, but 37.96 per cent. of the capital invested in window glass, and produced 31⅔ per cent. of the boxes of glass made, and 32 per cent. of value of product. In flint-glass and glassware Allegheny county had 32.97 per cent. of the number of establishments, 37.04 per cent. of the capital invested, and produced 33.60 per cent. of the value of this kind of glass made. In green glass this county had 16 per cent. of the establishments, 17.50 per cent. of the capital invested, and made 14⅖ per cent. of the green glass produced. Of the total of the entire country in the three classes named—window, flint, and green—Allegheny county had 24.88 or 25 per cent. of the establishments, 31.76 or 32 per cent. of the capital, and made in value 28 per cent. of all the product.

It should be noted that these calculations do not include plate-glass, of which none is made in this county, nor do they include the works in Fayette and Beaver counties, which have their offices in Pittsburgh.

While the figures show that the proportion of the glass of the United States made in this county is not so great as has been supposed, it indicates that of all the great industries of the country it is the one that produces at Pittsburgh the largest proportion.

GLASS-MAKING IN MASSACHUSETTS.

The history of the beginning of the manufacture of glass in Massachusetts is involved in some doubt. Bishop, in his *History of American Manufactures*, states that the earliest works was built in a part of what is now the town of Quincy, but in this he is probably mistaken, as the Salem works were undoubtedly the first. He

assigns no date to this Quincy works, but Appleton's *Cyclopædia* gives it as about 1750. This works was, like most of the other early ones in this country, built by Germans, (*a*) and its site is known to this day as Germantown. Only black bottles were made, some specimens of which still exist, which are of very poor metal and of rude make. The proprietors failed some years before the Revolution, and the house having burned down, it was never rebuilt. (*b*)

The first glass house in Massachusetts, and the first to which a date can be assigned, was erected in Salem about 1639. In this year Ananias Concklin, Obadiah Holmes, and Lawrence Southwick received two acres of land each "adjoining to their houses", which was granted to them as "glass men", for the purpose of promoting the manufacture of glass. The next year John Concklin, another "glass man", was allotted five acres more bordering the previous grants.

In December, 1641, the general court, for the encouragement of the enterprise, authorized the town of Salem to lend the proprietors £30, which was to be deducted from the next town rate, and the glass men were to repay it, "if the work succeeded, when they were able." (*c*) The works having been neglected for three years, the Concklins, in 1645, received permission from the court to form a new company to carry on the business. (*d*) Glass was for a considerable time afterward manufactured at that place, which is mentioned in the *Colonial Records*, in 1661, as the Glass House field. In this, and those which for many years succeeded, it is probable that nothing more was attempted than the manufacture of bottles and other coarse descriptions of glass. (*e*)

Assuming the date assigned to this works to be correct, it certainly displayed a great deal of enterprise in the infant colony to thus early undertake the manufacture of glass, and, though the products were coarse, they answered the purposes of the colonists. Window-glass could be imported from England of a much better quality than could be made, but bottles were so bulky and so liable to breakage that they could be made to advantage in competition with the works of the mother country.

The history of the glass works of New England is involved in doubt for some years after this, but it is probable that a works was built at Boston just prior to the Revolution, as Lord Sheffield, writing at the close of the war, says: "A considerable glass manufacture at Boston failed there several years ago." In December, 1752, the general court passed an act granting Isaac C. Winslow and others the sole privilege of making glass in the province. It is probable that this works was established at Boston, and that it was this failure to which Lord Sheffield refers. However this may be, Boston again began the manufacture of glass shortly after the Revolution, and this time with great and long-continued success. This new enterprise, the Boston Crown Glass Company, which was the first really successful glass works in the country, was greatly encouraged by the very liberal action of the state. In July, 1787, Messrs. Whalley, Hunnewell, and others received from the legislature a charter conferring upon them the exclusive right to manufacture glass in Massachusetts for fifteen years, and a fine of £500 was attached to any infringement of this right. The capital stock was exempted from all taxes, and the workmen from all military duties. Jarves also states that to counteract the effect of the bounty paid by England on the exportation of glass from that kingdom the state paid the proprietors of this works a bounty on every table of glass made. A pyramidal factory of brick was erected on a large scale at the foot of Essex street; but being found ill-adapted to the purpose, it was afterward taken down and a wooden one, lined with brick, differently constructed, was put up in its place, its dimensions being 100 feet in length by 60 in width. On account of difficulties in procuring workmen and other embarrassments operations were not fully commenced until November, 1792. (*f*) The corporation commenced with the manufacture of crown window-glass, which was of a quality equal or superior to any imported. Materials were found to be abundant, and some six years later they produced about 900 sheets per week, worth $1 75 per sheet, or $82,000 per annum. (*g*)

This works was incorporated as the Boston Crown Glass Company in 1809. Regarding the success of this company Mr. Jarves says:

> The state bounty had the effect to encourage the proprietors and sustain their efforts, so that by perseverance many difficulties were overcome and a well-earned reputation supported for the strength and clearness of their glass; a glass superior to the imported, and well known throughout the United States as "Boston window-glass". This reputation they steadily sustained, until they made glass in their new works at South Boston in the year 1822.

The early success of this works led to the establishment of others in various parts of the country, and many of the workmen of the Essex-street house were enticed away by flattering offers. In 1811 the proprietors of the Essex-street works erected large and improved works on the shore at South Boston, and to supply the workmen enticed away, as also to meet the wants of their factory, an agent was sent to England to procure a set of glass-workers. By the time they reached this country the war with England broke out, and the enterprise was defeated;

a It is an interesting fact that some or all of the workers in the first glass houses of Virginia, Maryland, Pennsylvania, and New Hampshire were Germans.

b See Jarves' *Reminiscences of Glass Making*, p. 53. Also *Mass. History Col.*, vol. iii, p. 276.

c Felt's *Annals of Salem*.

d *Colonial Records*, vol. i, 344; ii, 137.

e See Bishop's *History of American Manufactures*, vol. i, pp. 233, 234.

f Mr. Jarves says in 1803, upon the arrival of a German by the name of Lint (probably Lindt).

g See Bishop's *History of American Manufactures*, vol. i, p. 241.

for it became difficult to procure fuel and the various means for carrying on the Essex-street works. After the war operations were resumed and continued until 1826, when from bad management the company failed.

In 1802 glass works were established at Middlesex village, then in the town of Chelmsford, but now a part of Lowell, by Hunnewell & Gore, of Boston. Window-glass was the chief product, though some other glass was made. Allen's *History of Chelmsford*, published in 1820, states:

> On the east bank of Middlesex canal, a distance of 200 rods from Merrimack river, a large building, 124 feet long and 62 feet wide, with necessary appendages for manufacture of window-glass, was erected in 1802.
>
> Near it is a two-storied house, handsomely finished, designed for the residence of the overseer, and around it, at convenient distances, a number of smaller houses for the accommodation of the workmen and their families.
>
> There are appertaining to this manufactory about 20 families, consisting of 40 men, 20 women, and 40 children—100 in all. It is now in a flourishing state. About 330,000 feet of window-glass are annually made, or 3,300 boxes of 100 feet each, which, at $13 per box, will amount to $42,900.
>
> The situation is very favorable for transportation to Boston, and those raw materials from thence which it would be expensive to convey by land. A ready and cheap supply of wood is also easily obtained, of which it is estimated that about 2,000 cords are annually consumed in the manufactory and houses attached to it.
>
> The manufactory consists of two furnaces, three flattening ovens, two tempering ovens, six ovens for drying wood, cutting, mixing, and pot rooms, a kiln for burning brick, a mill-house, and sand-house.

The proprietors failed about 1827 or 1828; the works were also burned about this time. In 1828 a corporation was formed and the works rebuilt, but it is uncertain if glass was made before 1829. In 1839 the works were abandoned and moved to Suncook village, Pembroke, New Hampshire. The process of manufacture at this works is thus described: (*a*)

> The process was to mix Morris river (New Jersey) or Massabesic lake (New Hampshire) sand with lime, sal-soda, black and white salts, etc.; no sand was ever procured for the purpose in this region. Ten large pots were heated from one furnace, each pot making about 500 surface feet of glass per "melt", and there were on an average about twenty-five "melts" per month, running nine months of the year. The glass was first blown in cylindrical shape, like a long piece of stove-pipe, then cut along one side lengthwise and flattened.

Various other attempts have been made in eastern Massachusetts to establish the manufacture of window-glass, the details of which I have not been able to ascertain. In 1860 a large establishment, the Boston crystal glass works, was erected at South Boston for the manufacture of sheet window-glass. This was followed by several smaller ones, but they all failed to make glass at a profit, and were abandoned. As an illustration of the losses frequently met with in these manufacturing experiments, it may be stated that the plant of this Boston crystal glass works, which cost about $186,000, after lying idle for fifteen years, was sold in 1881 for $60,000 to the Walworth Tube Manufacturing Company. All the window-glass works in this section have been abandoned, and in the census year the only one in operation in the state was in the western part, in Berkshire county.

Through the kindness of Mr. A. T. Servin, of Lenox Furnace, who has been closely identified with the glass industry of that section, I am enabled to give some details of the attempts to establish its manufacture in western Massachusetts. In 1812 a window-glass factory was started at Cheshire, probably the first attempt at the manufacture of glass away from the seaboard, and about the same time another was built in the near town of Chester Factory. These were brought into existence by the war of 1812, and owing to the superior quality of the sand were located at this place. Both of these ran but a short time. In 1850–'51 a window-glass factory was started at Cheshire, ran about two years, and was changed to a plate-glass factory. It has since been used for window-glass, but is now abandoned. In 1853 a factory was started at Berkshire. This is still in successful operation, and is the only works that made window-glass in New England in the census year. In 1853 another factory was started at Lenox Furnace, but this was changed to plate-glass; and in 1869 still another works was built at this place, which ran for about two years, but is now abandoned.

The beginning of the manufacture of flint-glass in Massachusetts was an outgrowth of the Essex-street factory. Among the workmen brought to this country to operate this works were a number who were not only skilled window-glass blowers, but were flint-glass workers as well. When the window-glass works were compelled to suspend operations in part, owing to the difficulty of procuring materials during the war of 1812, a number of blowers were thrown out of occupation. Among these was Mr. Thomas Caines, who was still living when Mr. Jarves wrote his *Reminiscences*. Mr. Caines, who was not only a skilled blower, but an admirable manager, and was also well acquainted with the art of mixing glass and the proportions employed, prevailed upon the proprietors of the window-glass works to build a small six-pot flint furnace in a part of their unoccupied works at South Boston. This establishment found full employment during the war of 1812. It, however, was compelled to cease operations, and though several attempts were made to operate it between 1820 and 1840 they were unsuccessful. About the same time that this South Boston factory was built the Porcelain and Glass Manufacturing Company was incorporated and built a flint-glass house at East Cambridge. The furnace was a small six-pot one, and workmen were brought from abroad to work it; but it proved a failure. In 1815 some workmen left the South Boston factory, leased this furnace at East Cambridge, and commenced the manufacture of flint-glass under the firm name of Emmet, Fisher & Flowers; but want of harmony among the members of the firm led to a dissolution, and in 1817 the Porcelain Company disposed of their works at auction. These were bought by the New

a See *Vox Populi*, Lowell, Massachusetts.

England Glass Company, which was incorporated in 1817, and from these works has been produced glass the equal of that made in the best English flint houses. This works, when it first started, had a small six-pot furnace, each pot holding about 600 pounds of batch. Some forty hands were employed, and the yearly product was about $40,000. Bishop, in speaking of these works in 1818, which he calls "one of the most extensive flint-glass manufactories in the country", says:

Two flint-glass furnaces and twenty-four glass-cutting mills, operated by steam, and a red-lead furnace, capable of making two tons of red lead per week, enabled them to produce every variety of fine, plain, mold, and the richest cut glass, as Grecian lamps, chandeliers for churches, vases, antique and transparent lamps, etc., for domestic supply and exportation to the West Indies and South America. Virginia coal, New Orleans lead, Delaware sand, and other native materials were used. The capital was about $80,000, and the annual product $65,000.

In 1823 it is stated that 22,400 pounds of glass vessels per week were made, many of which are beautifully cut, and were sent into Boston and other places for sale. Writing of these works in 1865, Mr. Jarves states that five furnaces were run, averaging ten pots each, with a capacity of 2,000 pounds to each pot. Five hundred hands were employed, and the yearly product was $500,000. This works is still in existence, but is leased to Mr. W. L. Libby, who runs only a portion of it. Its reputation for the excellent quality of its glass is still very high.

In 1825 ground was broken for a flint-glass works at Sandwich, and in three months they commenced blowing glass. These works also commenced in a small way with an eight-pot furnace, the weekly melts being some 7,000 pounds; but at the time Mr. Jarves wrote his *Reminiscences* the weekly melts had been increased to about 100,000 pounds, and the one furnace, with eight pots, to four with forty pots.

In 1865 Mr. Jarves states that two flint-glass establishments were in operation in East Cambridge, three in South Boston, and one in Sandwich. At the present time there are six glassware establishments in Massachusetts, of which one was entirely idle and virtually out of existence and another idle in part.

Some of the most interesting chapters in the history of glass in Massachusetts are those recording the successes and defeats connected with the manufacture of plate-glass. These are given in detail in that part of this chapter treating of plate-glass. Here it is only needful to say that these attempts began at Cheshire in 1852–1853. The works was changed from window-glass to plate-glass, run for about two months, and was then moved to Brooklyn, New York. The second effort was at Lenox Furnace. These works, after passing the vicissitudes narrated elsewhere, are still in existence.

Though at one time Massachusetts was in the foremost rank of glass-producing states, the lack of fuel has caused it to fall in the rear as to amount of product. In some lines as to quality, however, it is still unsurpassed.

GLASS-MAKING IN NEW HAMPSHIRE.

Glass-making in New Hampshire dates from near the close of the revolutionary war. In May, 1780, Mr. Robert Hewes, of Boston, began the erection of a glass works in the town of Temple, and in the autumn or early winter he started his fires. At this time glass was in good demand in the rebellious colonies. England, of course, prohibited all exportation from her ports, and the severity of the blockade prevented the glass of other countries from reaching this in any quantities. Indeed, the holds of the blockade runners would scarcely find space for glass, when powder and shot were more in demand.

Mr. Hewes, who had been left by his father quite a fortune, determined to undertake the manufacture of glass. Having secured a number of German Hessians and Waldeckers, who were skilled glass-workers in their own country and had formed part of the mercenaries sent to this country with the British army, and who had deserted from it, he started this Temple works; but the building was hardly completed when it was burned down. This was a serious blow, but to prevent the abandonment of the enterprise the people of Temple came to Mr. Hewes' assistance, and the works were reconstructed. Then frost shattered the furnaces so that they would not stand the fire, and they gave way at the first melt. (*a*)

To add to his difficulties as a result of these delays and loss his capital was seriously impaired and money was needed to continue the enterprise; but the people of Temple had no money to lend, and did not choose to invest it if they had. Mr. Hewes petitioned aid from the state, asking "freedom from taxation on his buildings", exemption of taxes for his men, and the granting of a bounty upon the glass produced. January 2, 1781, the house of representatives of New Hampshire voted to receive and accept Mr. Hewes' petition, but postponed the paying of bounty till good window-glass could be successfully produced.

The persistence of Mr. Hewes is best illustrated by the following petition made to the selectmen of Temple in the winter of 1781, written from Boston:

GENTLEMEN: After due respects, hoping these will find yourselves and families *well*, they are to inform, that, being almost discouraged by the misfortunes I have met with & the little spirit of the People to encourage me, I am almost determined to drop all thoughts of prosecuting the Glass-Manufactory in Temple, for why should I strive to introduce a Manufactory to benefit a people that has not spirit enough to subscribe a trifle to encourage it, when I have met with a misfortune—for if the Business ever comes to perfection it will be a greater service to the *country* than it possibly can be to *me*, even if I make my fortune? But, Gentlemen, *it was not money only*, that

a These facts concerning Mr. Hewes' enterprise are condensed from a paper on "Glass-making in the Merrimack Basin", published in *Contributions of Old Residents' Historical Association*, Lowell, Massachusetts, vol. ii, No. 2.

induced me, but it was because I was satisfied I could do it, & in so doing serve my country most essentially—more especially your Town. You will do well, Gentlemen, to consider this is not a thing for a moment, but it is laying a foundation for the good of Posterity; for certain *I am* if my Glass-works are brought to perfection, they will soon be as universal as the Iron works, or many others; as I said to Esquire Blood the other day, "that the Glass-makers should be employed, if it were only to steal their art."

I think the Town of Temple, as a Town, will be highly culpable if they let this matter slip without a struggle. But it is not for me to point out the advantage you are all sensible of.

What I have to say is what will your Town do to encourage the matter? I shall have to send 60 miles for stones to build my melting furnace, which will take eight teams, & then all the other furnaces are *to be rebuilt;* but all this while, the Glass-makers and families are to be supported, which will be a costly affair.

Your court will make a Lottery, I suppose, but that will be a thing of Time. Can I be credited for one or two Carcasses of Beef, till the Lottery is drawn, or what way can you think of to help me till the works are set a going?

I should be glad to know your opinion of the matter as soon as possible, so that I may know what to determine.

From Your Friend and Humble Servant,

ROBERT HEWES.

P. S.—Mr. Ashley will wait upon you with this and receive your answer, and transmit it to me as soon as possible.

R. H.

P. S.—If I could be properly encouraged, I would come up in the *Spring* and work at it myself till it comes to perfection.

March 5, 1871.—The Town voted to advance upon a loan to Mr. Hewes £3000, with good security, to be assessed in two months, and collected as soon as may be.

On the same day, March 5, Mr. Hewes' agent at the glass house wrote to the selectmen "requesting provisions".

March 11, Mr. Hewes writes to the selectmen from Boston, declining the loan of £3,000, if security is required; states he will not assume any further risk or responsibility; that ten times that sum could be secured in Boston if he wanted it, but that he had determined to recede immediately, and proposed to sell his interest in the works at a low price; had resolved to do nothing further except bring down the workmen, if nobody appears to purchase the houses and tools.

March 24, in a letter from Boston, Mr. Hewes proposes to the selectmen that he be supplied money on a loan, on the strength of the lottery, for which he seems to have petitioned the general court of New Hampshire, and requests that his glass-blowers be furnished with supplies for subsistence.

It was not till March 30, 1781, that the lottery act was passed, giving leave to raise £2,000, new emission, for the Temple glass works, and appointing three men to conduct the lottery and report their proceedings and account to the general court within one year. A fac-simile of the lottery tickets may be found on page 171 of the *History of Temple.*

The tickets would not sell, and I have no statement what their prize was to be. I infer the great obstacle to the success of the lottery to have been want of faith in the glass works, and as a result Mr. Hewes abandoned the enterprise. The works made both window-glass and glassware, and some of its products, among them a glass plate, are preserved in Harvard University.

There is no record of any further attempt to make glass in New Hampshire until 1814, when by an act of the legislature, passed on June 24 of that year, the New Hampshire glass factory was incorporated at Keene. This works made only cylinder window-glass, and the census of 1820 reports it as having a capital of $25,000, paying out $11,400 for materials, $10,000 for wages, $500 for contingent expenses, employing twenty men and five youths, and producing $30,000 worth of window-glass from 1,825 bushels of sand, 200 barrels of lime, 547 bushels of salt, and 36 tons of potash. In the hands of its original owner the enterprise was not successful, and passed under the control of other parties, who, in turn, disposed of it to others. From 1847 to 1851 the works were operated by J. D. Collony, when they were finally abandoned, no part of them remaining.

In 1817 a factory was started in the same town (*a*) for the manufacture of "black and flint bottles" by Justin Perry. This was operated until 1848, when it ceased work, for the same reason that the window factory was abandoned—the high price of fuel.

In 1840 Mr. William Parker, who had been operating a window-glass works at Middlesex village, Massachusetts, then a part of Chelmsford, but since annexed to Lowell, removed it to Pembroke, New Hampshire, where he built a brick glass house for window-glass. The motive for moving the works from Chelmsford to Pembroke was the reduced cost of supporting the workmen, ease of obtaining cheap fuel, and close proximity to an abundant supply of sand at Massabesic pond, in Chester, now Manchester. These works were carried on from 1839 to 1850, but were by no means a success in their new location, the expected supply of suitable sand proving a delusion, that from Massabesic producing glass of so dark a color, by reason of iron, that it was unsalable, and sand from the Maurice river, New Jersey, was the only resort, with increased cost for transportation. The revision of the tariff in 1845 brought another disaster, the duty on imported glass being made so low that the country was supplied with European glass at less price than the cost of production here. In 1848 the manufacture of sheet window-glass was abandoned and that of crown glass undertaken, but with no success, and in 1850 its manufacture was abandoned.

---

a This is the account I have received from Mr. William S. Briggs, of Keene. Bishop, in his *History of American Manufactures,* published in 1868, vol. ii, p. 206, speaking of the year 1814, says: "A glass manufactory was this year incorporated in Keene, New Hampshire, where it is still (1868) a principal business." This is probably an error.

In March, 1866, a glass house for the manufacture of bottles was built at South Lyndeborough, New Hampshire. This works is still in existence. Its characteristics and product will be found in the tables of this report.

GLASS-MAKING IN NEW YORK.

According to Bishop's *History of American Manufactures*, among the early settlers on Manhattan Island was a glass-maker, Jan Smeedes, who is supposed to have been among the first to receive an allotment of land on the present South William street, between Wall and Pearl. He probably carried on the business of glass-making on the east side of the street, just north of Hanover square. This street formerly bore within the above limits the name of "the Glass-maker's street", and afterward Smee street, from its original occupant. Of the history of his works no account has been found. In addition to this early works at the southern end of the island there seems to have been a glass house located between Eighth and Eleventh avenues and north of Thirty-fourth street, as on De Witt's farm map of New York about 1732 there is an estate called "the glass-house farm". The first of these works must have been built early in the seventeenth century, at least during the Dutch occupation of the island, which ended in 1664. It would thus appear that New York, equally with Virginia, Pennsylvania, and Massachusetts, counted glass-making among its very earliest industries, dating not much after the first colonization.

From this time for nearly a hundred years no records of the existence of any glass works have been found; but no doubt there were some factories in operation at various points and at various times in this state, as well as in other states, though glass-making flourished but poorly in these early times. In 1754 a glass works was erected by a Dutch gentleman by the name of Bamber in Brooklyn, probably the first in Kings county, which now ranks second as a glass-producing center in the United States. The Historical Society of that city have in their cabinet a glass bottle having blown on it the name of Mr. Bamber and the date 1754, (*a*) "the first one," so the record reads, "manufactured at the glass works started in 1754 on the site of the present glass works on State street. This enterprise, we are informed, was brought to an untimely end for want of sand; that is, the right kind of sand." From this statement regarding the sand Mr. Jarves is led to believe that the bottle must have been of flint-glass, and the works a flint-glass works, as sand suitable for green or black glass abounds on the shore near its location. This, however, would not be conclusive evidence of the fact that they were flint works, as we have no doubt that in those days, as at the present time, reasons which are not at all the correct ones were frequently given for the failure of manufacturing establishments.

Governor Moore, in a letter to the Lords of Trade and Plantations, dated Fort George, New York, January 12, 1767, says:

> The Master of a Glass House, which was set up here a few years ago, now Bankrupt, assured me that his ruin was owing to no other cause than being deserted in this manner by his servants, which he had imported at great expence; and that many others had suffered and been reduced as he was by the same kind of misfortune. (*b*)

To what works Governor Moore referred does not appear.

From this time until 1786 I have not been able to find any other record, when, as the evils of large importations began to be seen and felt, and the advantage of establishing domestic industry became impressed upon the minds of the inhabitants of this country, efforts were made in New York, as in the other colonies, to re-establish the manufacture of glass. In April, 1786, specimens of white glass made at the glass house that had lately been erected in Albany were presented to the American Philosophical Society. Mr. Elkanah Watson, in his *Reminiscences of Albany*, published in 1788, mentions a visit to the new glass house, erected by John De Neufville at a place about eight miles from Albany. Mr. De Neufville, who was a Dutch gentleman, and had been active on behalf of the American colonies during the revolutionary war, having sacrificed in their behalf nearly the whole of a fortune of a half-million sterling, invested the small amount remaining in what Mr. Watson terms the "hopeless enterprise" of a glass house. (*c*) In January, 1785, Leonard De Neufville and his associates, the proprietors of a glass factory situated at Dowesborough, in the midst of a well-wooded pine forest, described as 10 miles from Albany, and which was probably the same works as that referred to by Mr. Watson in his memoirs, applied to the legislature for aid in their undertaking, urging as a reason for this assistance that £30,000 were sent abroad annually for glass. (*d*) They also stated that they were able to manufacture any size superior to English glass. This expression would lead to the belief that the works was a window-glass works. In 1793 the legislature of New York voted a loan of £3,000 for eight years to the proprietors, three years without interest and five years at 5 per cent; but by this time the works had passed out of the possession of the De Neufville family. In *The Appolo*, published at Boston, under date of September 28, 1792, appears the following regarding this works:

> We learn from Albany that the glass works erected several years ago within a few miles of that city, and which has been deserted ever since for want of *cash*, is now owned by Messrs. McCallen, McGregor & Co., who have completely repaired it, supplied it with every material, and are now manufacturing and advertising for sale *window-glass* of every dimension. They want a good *flint-glass maker*. As this manufactory must be of great public utility, it is to be presumed they will receive the greatest encouragement from all (American) glass dealers. (*e*)

a Stiles *History of Brooklyn*, vol. i, page 309.
b New York *Colonial Documents*, vii, page 889.
c See Munsell's *Annals of Albany*, vol. x, pp. 219, 220.
d See Munsell's *Annals of Albany*, vol. ii, p. 205.
e Quoted from *The Appolo*, p. 416, by *The Historical Magazine*, 2d S., vii, p. 16.

The new proprietors, McCallen, McGregor & Co., offered in 1793 a reward of $50 for the discovery of a bank of sand suitable for their use situated within ten miles of their works. In 1796, for the purpose of consolidating and extending the operations, a village ten miles west of Albany was laid out and named Hamilton, in compliment to Alexander Hamilton, and in the spring of 1797 the Hamilton Manufacturing Company was chartered by the state, and the company and its workmen exempted from taxes for five years. This works was one of the most extensive glass works at that time in the United States. Beside other enterprises in other lines of industry, they had two glass houses, with three large furnaces, employing about thirteen glass-blowers, and making an average of 20,000 feet of window-glass per month, beside bottles and flint-glass. It is stated that they substituted kelp for pearlash in the manufacture of glass. Their glass, however, was in good repute, and the business was actively carried on for some years. Munsell states that this works suspended in 1815 for want of fuel. (*a*)

The next factory of which I have been able to find any record is the Rensselaer glass factory, which was incorporated by the legislature of the state March 21, 1806. In 1809 two more glass works—the Madison and the Woodstock Glass Manufacturing Associations—were also chartered, but I have not been able to find any details of either. In the census for 1810, however, four glass works are reported: one in Albany county, two in Rensselaer, and one in Ontario. These works made that year 3,805,000 square feet of glass, which was valued by the marshals at 16 cents per square foot. In 1810 or 1811, according to Mr. Jarves, a company was formed in Utica for the manufacture of window-glass, and quite a number of workmen from the Essex-street works (Boston, Massachusetts) were induced to leave their employment and break their indentures by the offer of increased wages, but while they were on their way to the New York house, and just before they reached the state line, they, with the agent of the Utica works, were arrested, brought back, and an expensive lawsuit resulted. Mr. Jarves states that the latter works were abandoned and never revived. In the private journal of De Witt Clinton for the year 1810, when, as one of the commissioners of the state of New York, he examined the country between the lakes and the waters of the Hudson, appear several references to the glass works of the state, and under date of Geneva, August 9, 1810, he writes:

> A glass manufactory is erecting about two miles from the village. It was incorporated last winter, and a little village is already rising up around it.

One week later he writes:

> We entered the town of Vernon, in which three glass houses are in contemplation; one has been in operation some time. It is rather to be regretted that this business is overdone. Beside the glass introduced from Pittsburgh, and from a glass house in Pennsylvania, on the borders of Orange county, and the glass imported from Europe, there are ten manufactories in the state already, or about to be established; one in Guilderland, Albany county, one in Rensselaer county, three in Vernon, Oneida county, one in Utica, Oneida county, one in Rome, Oneida county, one in Petersborough, Madison county, and one in Woodstock, Ulster county.

In 1818 the manufacture of window-glass was begun at Sand Lake, in Rensselaer county, by Messrs. Crandall & Fox. This locality was selected on account of its abounding both in sand and in fuel, but a few years' trial convinced the proprietors that the place was ill-chosen, and the location was abandoned. (*b*) In 1845 Mr. Samuel H. Fox, a son of one of the proprietors of the Sand Lake works, built a factory at Durhamville, which was in existence in the census year. The Utica *Observer*, in an article published some months since, claimed for Mr. S. H. Fox, one of the proprietors of this works, and one of the oldest living glass-makers in the country, that he was the first in the country to introduce soda-ash into the manufacture of glass, as he was the first in the state to utilize coal in the furnaces and to introduce wheel ovens.

From the census of 1820 it appears that there were two window-glass factories in Madison county of this state, each containing two furnaces, with ten pots each. In Oneida county there was one cylinder window-glass factory in operation, and one crown-glass factory idle. In Ulster county there were two window-glass factories, manufacturing 800,000 square feet a year; but of these works I have not been able to find any further details. In 1820 some workmen left the New England glass works at Cambridgeport, Massachusetts, and built a factory in New York city, the business being conducted under the firm name of Fisher & Gillerland; but in 1823 the partnership was dissolved, and Mr. Gillerland built a works in Brooklyn. In 1823 there was a manufactory of glass globes at Albany "on a scale which promised to supply the United States with the article". At the tariff convention which was held in New York in 1831 three flint-glass factories, with twenty-two pots, were reported in existence in New York and vicinity, and two cylinder window-glass factories: one at Geneva, and the other at Hamilton; but of these, except the fact of their existence, no details were given. In 1832 the Redford Crown Glass Company was incorporated and began the manufacture of crown glass in Clinton county, making a very good quality until 1841, when it failed. In 1846 crown glass was again made at these works. Of the establishment and history of the later glass works no record at all has been procured.

GLASS-MAKING IN CONNECTICUT.

Information regarding the early history of glass-making in Connecticut is exceedingly meager. It appears, however, that in 1747 a patent was granted by the legislature to Thomas Darling for the exclusive privilege of making glass for twenty years. This act appears to have become void because of the patentee's failing to fulfill its

a See Munsell's *Annals of Albany*.

b This is Mr. Jarves' statement of the close of the works. It would appear, however, from a newspaper paragraph regarding the Durhamville works, that the Sand Lake factory was in existence until 1852, when it was burned down.

conditions, and at various times after this special grants were made to others to introduce its manufacture; but how successful these were I have not been able to find out. It seems that a few years after the organization of the Essex-street factory in Boston, which was built in 1787, a glass house was in operation in Hartford, Connecticut, and from a reference in Washington's diary (1789) it would appear that glass was made in New Haven. In the census of 1820 two glass works are reported in existence in Hartford county, Connecticut, producing $27,360 worth of glass annually. Bottle-glass is also reported as made in Hartford county at the census of 1820 to the extent of $3,350 annually. At the tariff convention held in New York in 1831 a window-glass works is reported as in operation at Wellington. In the census of 1840 two establishments are reported in Tolland county, making $32,000 worth annually; one of these was probably the Wellington works. In 1850 but one establishment is reported; in 1860 two establishments in Windham county; and in 1870 three establishments. Of these works I have been able to get no information other than the fact of their existence. At the census of 1880 but one establishment was in existence in the state, the flint-glass works at Meriden.

GLASS-MAKING IN MARYLAND.

On May 26, 1790, Mr. John Frederick Amelung presented a petition to the national House of Representatives, asking that the patronage of the government be extended to his glass manufactory at New Bremen, in Maryland. This is no doubt the works to which Mr. Carroll, of that state, alluded in his speech of April 17, 1789, when he moved that a duty be placed on window and other glass, with the exception of black quart bottles. Mr. Carroll's reason for his motion was that the manufacture of window-glass had been begun in Maryland, and had been attended with considerable success, and he believed that with small encouragement it would be permanently established. Mr. Carroll's motion was successful, and in the first tariff law passed under the present Constitution a duty of 10 per cent. *ad valorem* was levied on the kinds of glass mentioned. The patronage that Mr. Amelung desired was a loan from Congress. The investigation and discussion that followed is memorable as raising, and for the time being deciding, the policy of Congress relative to bounties and protection. The committee to which was referred Mr. Amelung's petition for "patronage" reported June 30, 1790, authorizing the Secretary of the Treasury of the United States to make him a loan, not exceeding $8,000, Mr. Amelung giving satisfactory security for the reimbursement of the same within a certain number of years. In the debate which followed the presentation of this resolution a history of this gentleman's exertions in endeavoring to establish an American glass manufactory was given by Mr. Carroll. He commenced in 1775, brought into the country upward of 200 persons, mostly glass-workers, and had expended at that time over £20,000 in the undertaking. Owing to a variety of accidents, and particularly to the extraordinary rise in the price of grain, he now found himself "greatly embarrassed in prosecuting the business; but stated if he could be so far patronized by the government as to be favored with a loan of $15,000 or $20,000 it would afford him such relief as would enable him to surmount every difficulty".

Congress, however, did not look upon this appeal favorably. Some of the members doubted the constitutional power of Congress to loan money in this way; others objected to it on account of the precedent it would establish, while others urged that the encouragement and assistance could be asked for with more propriety from the state government. Mr. Boudinot gave an account of the manufactory, and said: "I have seen the glass made in it, which is superior to any ever produced in America." He contended that Congress had a right by the Constitution to loan the money, and cited several instances in point. He enlarged on the merits of the petitioner "in embarking such large property to prosecute a business of so general utility", and pointed out the consequences which would result from a "failure of this application, which would be greatly injurious to the petitioner and to the public". The report, however, was negatived, and the question between bounties and protection was virtually decided by this debate. In 1794 Mr. Amelung presented a petition for an increase of duties, and in this he was joined by others, among them Thomas Whalley and his associates, of Boston, Massachusetts. Mr. Amelung's works appears to have been originally built on Tuscarora creek, four miles above Fredericktown, and were known as the Etna glass works. Window-glass and wine-bottles were made, and it is probable that some of the workmen from this factory were among those that crossed the mountain to New Geneva and aided Albert Gallatin to establish their manufacture on the Monongahela. The works of Amelung were moved to Baltimore "in 1788, and located on the south side of the basin", and an account of Baltimore, published some years since, declares "they still continue". In Lossing's *Home of Washington* (pages 204–205) is an extract from a letter of a gentleman of Cincinnati describing the presentation to Washington by Mr. Amelung of two flint goblets bearing the general's coat-of-arms. Amelung's ventures did not succeed, and it is possible that he crossed the mountains to Pittsburgh with some of his glass-workers. (*a*)

In 1790, according to Howard, a factory known as the "Baltimore glass works" was established on Federal Hill. Colonel Scharf, in his *Chronicles of Baltimore*, page 236, makes the date 1799. This was the window-glass works at present operated by Baker Brothers & Co., and still known by the same name. This firm also have flint and green glass houses. Concerning the latter, they write me that it was originally established in 1790, though the present works date only from 1852; the flint works date from 1873.

a Cuming's *Journal*, page 66, speaks of a Mr. Amelung, a glass-worker, at Pittsburgh.

The census of 1810 gives statements of three glass works in this state, two in Frederick county, at which 40,000 square feet of window-glass and 7,000 bottles were made, and one in Baltimore county, at which 500,000 square feet of window-glass were produced.

The census of 1820 reports a glass works in Alleghany county, at which both window-glass and hollow ware were made, and gives the date of the establishment of the works as 1817. The value of the products is given as $30,000, thirty men and eight children and youths being employed. The same census gives statistics of a window-glass works in Baltimore county that had been in operation twenty years, and was producing 3,400 boxes annually, valued at from $8 to $10 a box.

At the tariff convention held in New York in October, 1831, two flint-glass furnaces, with twelve pots, were reported in operation in Baltimore; also one cylinder window-glass factory in Baltimore and one in Cumberland; but no details are given of the same.

The works other than the above at present in existence in Maryland are of comparatively recent date, and are all situated in Baltimore, with the exception of a glassware factory building at Cumberland.

GLASS-MAKING IN NEW JERSEY. (a)

The first glass factory in New Jersey was located about 2½ miles from Allowaystown, Salem county, and was built some time from 1760 to 1765 by a German named Wistar, who brought a company of workmen with him from Germany. He carried on the works a few years, and failed about the outbreak of the revolutionary war, and upon his failure, in 1775, the workmen went to what is now known as Glassborough, Gloucester county. Two objects led to the selection of this place as a site for works: it was so far inland that the operations were not interfered with by the armies, and it was a yellow-pine country, which wood was better for melting glass than the oak of Allowaystown. Mr. Bodine is of the opinion that "the principal kind of glass made was hollow ware or bottles; but from some recollections of an old man that descended from and knew some of the old Glassborough settlers and heard them talk when he was a boy, I think part of them, if not all, could make both bottles and window-glass, such as was used in those days".

The blowers at these works also made the pots, cut the glass into lights, and packed the same. In the scheme of division of labor in more modern works each of these operations is a separate branch of work. At this works the bottles were made without molds, and crown-glass was made. Mr. Bodine says:

> I knew some blowers, when I was a small boy, that were then old men, and could make both bottles and window-glass. I have been unable to fix a time when window-glass commenced to be made in cylinder form. I find that about 1812 or 1813 a crown-glass (window-lights) factory was started up the Delaware river, 10 miles from Belvidere, at a place called Columbia, in what was then Sussex county, now being Warren county. This factory run until 1833, when it ceased operations. I personally know of cylinder window-glass being made in 1827 or 1828 at Millville. About the time of starting the Columbia works a factory was started at a place called Clemonton, now in Camden county, where bottles were made part of the time and window-glass the balance. My informant worked at Clemonton in 1814 as an apprentice, learning to blow.

About the years 1814 and 1815 there were factories started at Port Elizabeth, Cumberland county, and at Malaga, Gloucester county. Both of these were run as window-glass factories, and in 1816 to 1819 Tuckahoe and Hammonton were started and manufactured principally window-glass.

The next works was Millville, started in about 1822. For some years after this no new works were started, until 1827, when between that date and 1832 Waterford, Jackson, old Brooklyn, and Winston were built. These last-mentioned places were in what was Gloucester, now Camden county. The next location was Squankum, now Williamstown, built in 1835, making bottles; then Estilville, Bridgeton, and Temperanceville (now part of Glassborough), built in 1836 and 1837; then Jersey City flint-glass works, built in 1840 or 1845. Somewhere about this date there was a flint-glass works built at Kaign's Point, now part of Camden. Then Greenbank, 1840 to 1845; New Columbia, 1845 to 1848; Jansboro', 1848; Balsto, about 1850; Crowleytown, 1850 to 1851; Clayton and New Brooklyn, about 1851 to 1852; Medford, Milford, and Lebanon, 1855; Bulltown, 1858; Quinton, 1858 to 1860; Salem, 1863; Westville, 1868; Riverside and Herman City, about 1870.

There was a glass works started at Elizabethport some twenty-five years ago and run for a short time; also, one started in Camden about 1868, and run for a short time.

This makes in all thirty-seven locations in New Jersey. Of these the following have gone out of existence entirely: Allowaystown, Columbia, Clementon, Tuckahoe, Hammonton, Jackson, Old Brooklyn, Estilville, Greenbank, New Columbia, Balsto, Crowleytown, Kaign's Point, Milltown, Bulltown, Lebanon, Westville, Jersey City, and Elizabethport—nineteen in all; two run two years, one three years, two five years, two ten years, four fifteen years, four twenty years, two thirty years, one thirty-five years, one forty-five years, while Waterford, Medford, Camden, New Brooklyn, Riverside, Herman City, and Port Elizabeth, seven in all, have not run for several years.

The balance of the locations, eleven in all, have forty-five furnaces, of which thirty-nine furnaces have run the past year, to wit: twelve window-glass, twenty-one green hollow ware, and six lime or white glass. Four of the green hollow ware and the six lime or white glass furnaces are situated at Millville, and are run by one firm, Messrs. Whitall, Tatum & Co.

---

a For most of the data contained in the very interesting account of glass-making in New Jersey I am indebted to Hon. John T. Bodine, of Williamstown, New Jersey, whose personal recollections extend back fifty-three years.

About four miles below Millville are located the largest beds of glass-house sand in the state, sand being dug for the Millville and the Philadelphia, New York, and Boston factories. The pits have been opened for more than fifty years. There are also large sand-beds near Williamstown that supply twelve factories a thousand tons each per year. There is sand in very many other localities in south Jersey, but there is none better than the Maurice river, Millville, or Williamstown sand.

Up to 1855 care was taken to locate glass works upon or near to large tracts of woodland. About the year 1856 the factories in New Jersey commenced to use anthracite coal, and since that time the pots have been enlarged at various times until they are more than three times the size they were when wood was used for melting. Mr. Bodine says:

> The use of coal has made locations of glass factories at places other than upon water navigation in New Jersey very expensive, even with railroads. The cost of freight in getting coal and materials to and manufactured products from the marketable points of Philadelphia and New York is about 9 to 10 per cent. of the gross receipts of manufactured goods, while the only offset thereto is about 2 per cent. in the cost of sand and wood for annealing the ware. Many of the New Jersey works have been located where wood could be used. If the locations were abandoned, and the works removed to the large consuming points, the whole plant, so far as the building is concerned, would be lost. I find twenty-six of the factories among the forty-five contained in the eleven locations upon water navigation, and but for the advantage of water transportation we should not have as many glass factories as we now have.

GLASS-MAKING IN OHIO.

The information regarding glass-making in this state is exceedingly meager. It does not appear among the manufactures of the state at the census of 1810. In 1811 John Mellish, in his *Travels*, suggests that a well-organized manufactory of glass bottles would succeed, intimating that no such works existed. An account of Cincinnati, of date of June, 1815, states that a manufactory of green and window-glass and hollow ware was about to go into operation, to be followed the ensuing summer by another for white flint. Palmer's *Travels* in 1817 speaks of two glass houses in operation. The census of 1820 enumerates "glass, window, and hollow ware, chemical and philosophical apparatus", as among the manufactures of Hamilton county, the value of the product being $19,000, and the statement is made that the works are languishing, owing to the supply overrunning the demand. Glass, both cut, flint, and window, was also reported as made at this census in Muskingum county. (*a*) At the tariff convention held in New York in 1831 a window-glass works is reported at Zanesville and another at Moscow, while at the census of 1840 none are reported. In 1850 Ohio is credited with six works; in 1860 with four, and in 1870 with nine, three of which are reported as plate, probably window-glass, and six as glassware. Of the history of these several establishments I have no details.

GLASS-MAKING IN MISSOURI. (*b*)

As early as 1842 efforts were made to establish the manufacture of glass at Saint Louis. In that year a company of gentlemen, with Mr. James B. Eads, who has since become known in connection with the magnificent Saint Louis bridge and the jetties at the mouth of the Mississippi river, established the works now known as the Saint Louis glass works. This works at first made flint-glass tumblers, etc., and it is stated that Mr. Eads, finding it impossible to get the proper workmen, himself made the pots used in this factory. Five years of toil and vexation was the only result, and he and his associates, finding success impossible, were forced to suspend payment and abandoned further effort. To the credit of Colonel Eads, it should be stated that in after years he paid up every dollar of indebtedness incurred. Thus the first glass-making venture west of the Mississippi river passed into history as a failure. The factory was changed to a green-bottle works by Mr. Eads' successors, and then in 1854 back to a flint works. In 1855–'56 a green-bottle house was added, and in 1861 Bayot & Cummings took the works, since which it has been a flint house, now manufacturing only flint bottles.

The second works, those of the Missouri Glass Company, began operations in 1851, making window-glass, but ceased after running two years, remaining idle until 1856, when they were purchased and changed to flint-glass; but after sinking considerable sums in fruitless efforts the parties owning them sold out and abandoned the field. These works, then, like the Saint Louis glass works, became the property of various persons, who at different times encountered unvarying failures, until at last, in 1865, operations were wholly abandoned and the building taken for the manufacture of agricultural machinery. The other Saint Louis glass works have all been established since 1870.

GLASS-MAKING IN OTHER STATES.

As to the history of glass in other states but little has been learned. Glass has been made in Vermont, but there is none made at present. Two glass-houses are reported in that state at the census of 1840, one in Addison and one in Chittenden county, but none are reported in 1850, 1860, or 1870, nor at the present census. In Rhode Island no glass, as far as I have been able to learn, was ever made, and the same is true of Maine and Delaware. In the southern states, with the exception of Virginia, Kentucky, and possibly Tennessee, I can find no record of glass-making.

---

a I have seen a statement that this Zanesville works was the first in Ohio, but I have been unable to verify it.

b For the facts in this sketch I am indebted chiefly to an article in the Saint Louis *Trade Review* and to Mr. J. K. Cummings, of Saint Louis.

It has already been stated that the glass-blowers that Albert Gallatin induced to aid him in starting the New Geneva works were on their way to establish a glass house near Louisville, Kentucky; but it seems to have been many years before any other glass-makers sought this state to practice their art. Cramer's *Navigator* for 1814 states that a glass house had lately been built at Louisville, but neither the census of 1820 nor that of 1830 gives any evidence of the existence of this factory. At that of 1840 one glass-cutting establishment is reported in Kentucky, but no glass works. In 1850 no glass works is reported, though the Covington flint-glass works was established in 1848. In 1860 statistics of one glassware establishment are given in Jefferson county, in which Louisville is situated, but no facts are given regarding Kenton county, in which Covington is located, though the Covington glass works inform me that their flint-house was established in 1848, and their green-glass house in 1860. In 1870 three works are reported.

The statement is frequently made that the first glass works west of Cincinnati was built at Alton, Illinois, and in the returns received from the Alton factory the date of establishment of this works is given as 1867. No glass is reported as made in this state in any of the censuses until that of 1870. A similar statement can be made of Indiana. Michigan has no place in the several censuses as a manufacturer of glass. No glass is reported as made in Wisconsin at any census, though an establishment was started shortly after the close of the census year 1880. Mississippi was building a works during the census year. Glass-making was established in California in 1863, or at least a works was in operation, but of the details of its history I have no record.

HISTORY OF THE MANUFACTURE OF PLATE-GLASS IN THE UNITED STATES. (*a*)

It is probable that the first attempt to manufacture in this country what is now known as plate-glass was made at Cheshire, Massachusetts, though some rough cast plate may have been made earlier at some of the window-glass works. The extensive deposits at this place of exceedingly good sand, which was at one time supposed to be the only sand in the country from which good glass could be made, no doubt had much to do with this early attempt to make plate-glass and determined the location of the works. In 1850 a window-glass factory was erected at Cheshire, which was run for two years on blown glass. In 1852–'53 this was changed to a rough cast-plate factory. A large amount of money was expended in fitting up the works and putting in the necessary machinery and tools, but it was operated only for about six months, when the tables, tools, fixtures, etc., were removed to Brooklyn, New York, and a factory was there fitted up and operated through 1854 and 1855. Very little glass of a merchantable quality was made, and in 1856 the works were abandoned, (*b*) one of the chief causes of the failure, no doubt, being the small scale on which the works were projected and operated and the inexperience of the promoters. The manufacture of plate-glass requires large capital and experience, and it was not until these were brought together that the plate-glass industry was firmly established in this country and the product could compete with the foreign.

The second effort was made at Lenox Furnace, Massachusetts. In 1853 a glass works was erected at this place at a cost of $30,000 for making window-glass by the Lenox iron works, a corporation owned by William A. Phelps, Oliver Peck, and James Colling, who ran the works for about two years on window-glass at a loss. In the fall of 1855 the window-glass business was abandoned. This property was leased with contract to sell to James N. Richmond, who organized a company called the National Plate Glass Company, and was converted into a plate-glass factory. The company spent a large amount of money in reorganizing the establishment and experimenting, having bought the tables and tools of the Brooklyn company. In 1856, after a heavy loss, the company failed, and in 1857 the property came back to the original owners, who started up the works and continued to run them with success till the spring of 1865. In 1862 the factory buildings, with a large amount of glass, were destroyed by fire. There was no insurance, and the loss was over $25,000. In 1865 a company was organized, called the Lenox Plate Glass Company, consisting of the old parties with Messrs. Theodore and James Roosevelt, of New York city. Up to this time only rough plate was made, but it was the intention of this company to commence polishing as soon as suitable machinery could be obtained. It is worthy of notice that, although for a number of years plate-glass had been produced in England and in France, there had been scarcely any improvements in the machinery used. Some few years previous to this parties in the western part of the state of New York had invented and patented a machine for grinding and polishing marble slabs, and this was found to work admirably in polishing glass; but through the influence of Mr. John R. Platte, then agent for the British Plate Glass Company of England, the owners of the patent were induced to put up one of these machines for the company, on condition that if the working was satisfactory they were to buy the patent. The machine worked with satisfaction, doing its work in much less time than the old system. Mr. Servin states that the company paid about $50,000 for the patent. The principle of this machine is now generally used, though with improvements, in

a The statements of fact contained in this history are derived chiefly from letters from Mr. A. T. Servin, of Lenox, Massachusetts, Mr. E. Ford, of Jeffersonville, Indiana, and Mr. E. A. Hitchcock, of Saint Louis, and from Mr. W. C. De Pauw's testimony before the tariff commission.

b This is Mr. Servin's statement. Mr. Ford, however, states that the first attempt was made at Williamsburg, New York, in 1850, on a small scale, for the manufacture of rough plate-glass only, but was abandoned. The next effort, he states, was by the same party at Green Point, New York, but this was also a failure. This, Mr. Ford states, was the parent of the Lenox works.

polishing plate. About this time the Lenox Plate Glass Company was organized. The inventor having patented another machine in 1866 and 1867, this company bought the patents and put up some costly machinery, which was not completed till 1868 and 1869. About this time, and for two or three years previous, a company in Philadelphia held patents for making cryolite, a mineral from Greenland, into a material called cryolite or hot-cast porcelain, resembling white marble when worked, but having all the qualities of glass. This material was worked in the same way as glass. Through statements of great profits in this manufacture the Lenox company were induced to allow a new company to be formed January 1, 1870, called the Lenox Glass Company, which took all the property of the old company and gave the Philadelphia company $200,000 for their patents, also purchasing a large amount of cryolite from them. This new company expended a large amount in preparing for the cryolite manufacture, but after six or eight months working it was found to be a perfect failure, resulting in a total loss to the company of the cryolite and patents purchased, and in 1871 the company failed. The furnace has since been run on rough plate for a part of the time. In 1879 a large proportion of the glass property was sold at about one-thirtieth of its cost, and a new company has been formed, called the Lenox glass works.

The next works built in the United States were at New Albany, Indiana, and it was here that polished plate-glass was first successfully and continuously manufactured. In the year 1869 Mr. J. B. Ford conceived the idea of erecting works for manufacturing polished plate-glass, and with this in view he visited Lenox, gathered what information he could on the subject from the workmen there who had been employed abroad, and returned to New Albany with a determination to make polished plate. He immediately entered into negotiations with manufacturers of plate-glass machinery in Europe, and purchased one each of the best machines for grinding, smoothing, and polishing, and while waiting for their arrival, in company with his associates, built a works for rough plate. About the time the machinery arrived the works was burned, but a new one was built on a more extended scale. This new plant was measurably successful, but had to undergo the reverses that seems the fate of all plate-glass houses in this country. In 1872 Mr. Ford withdrew, since which time it has been run by Mr. W. C. De Pauw, who stated before the tariff commission that until 1879 the works made no money, though the quality of the glass for some time had equaled the imported.

In the same year that he withdrew Mr. Ford organized and built another works at Louisville. These he managed until 1875, when he left there and organized a works at Jeffersonville, Indiana, the city having offered him some ground valued at $20,000. These works have been largely increased, make excellent plate, and were, with New Albany and Crystal City, Missouri, the works that made polished plate in the census year.

Shortly after the organization of the New Albany plate-glass works Mr. E. B. Ward, of Detroit, and others, induced by the very extensive deposit of sand of an excellent quality at Crystal City, Missouri, organized the American Plate Glass Company, with a capital stock of $250,000, and began in 1872 the erection of works at the point named, this sum being increased in January, 1874, to $500,000. In 1875 the manufacture of plate-glass was begun, though with appliances much inferior to those now in use, and a considerable quantity of glass of good quality was produced. The usual difficulties, however, which attend new industries, by reason of lack of the requisite experience, were encountered. The production was irregular and uncertain as to quality, and in 1876 the work was suspended for several months, with a view to its resumption under more favorable conditions. In October, 1876, the enterprise was reorganized by the formation of a new corporation (the present Crystal Plate Glass Company), composed of most of the stockholders in the old company, in which additional capital was invested, and which acquired the entire premises, plant, and a large stock of materials on hand. Mr. E. A. Hitchcock, of Saint Louis, president of the old company, continued in charge as president. During the winter of 1876–'77 preparations were made for resuming work under such conditions as to profit by the experience already gained. Convinced by thorough examination of its superior advantages, a Siemens furnace was erected. These works have since been largely increased, and are producing plate-glass the equal of any made in the world.

An extensive works for the manufacture of plate-glass is also being built at Hite's station, on the West Pennsylvania railroad, near Pittsburgh, by Mr. Ford, who built the works near Louisville. (*a*)

Regarding the manufacture of plate-glass in this country, Mr. W. C. De Pauw, in his paper before the tariff commission, made some statements which he summarizes as follows:

First. That all money put into plate-glass works in America prior to 1879 had been a total loss.

Second. That some of the shrewdest, most energetic, and successful business men in Boston, New York, Philadelphia, Detroit, Chicago, Saint Louis, and Louisville had in the aggregate invested millions in plate-glass enterprises and lost the whole of it.

Third. That no plate-glass had been made in America without loss to the maker prior to 1879.

Fourth. That I, instead of having made a large fortune in a few years, as represented, have actually lost more than half a million dollars over and above all (very small) profit made since 1878.

Fifth. That after a long, earnest struggle, I have succeeded in making good glazing glass at a small profit.

Sixth. That Americans are paying about half as much for plate-glass to-day as they paid prior to the time plate-glass was made in the United States at my works.

IMPORTS OF GLASS INTO THE UNITED STATES.

In order to show the amount of glass received into this country, I append a table giving the imports of glass into this country in the years 1876 to 1880, showing quantities and values so far as they are given in the reports of the bureau of statistics, and also the value of each unit of quantity.

a It is now (April, 1883) in successful operation.

TABLE SHOWING IMPORTS OF GLASS INTO THE

	Articles.	1876.			1877.		
		Quantities.	Value.	Value per unit of quantity.	Quantities.	Value.	Value per unit of quantity.
	Total glass, and manufactures of		$4,803,091 25			$3,952,703 22	
	Bottles:						
1	Empty		25,306 44			22,125 84	
2	Containing liquors, number	3,740,473.74			3,313,957.73		
3	Or jars filled with articles not otherwise provided for						
4	Crystals for watches		6,970 00			10,078 00	
5	Disks, or plates unwrought, for optical instruments		1,748 00			1,119 00	
	Glassware:						
6	Porcelain, Bohemian, cut, engraved, painted, colored, printed, stained, silvered or gilded, not including plate-glass silvered, or looking-glass plates.		567,269 17			496,705 62	
7	Plain, mold, and press, not cut, engraved, or painted		60,833 97			54,319 15	
	Plate-glass, cast, polished, not silvered:						
8	Not above 10 by 15 inches, square feet	15,500.00	2,822 00	0.182	17,365.00	2,836 00	0.163
9	Above 10 by 15 inches, and not above 16 by 24, do	8,117.75	3,615 00	0.445	12,643.00	5,113 00	0.404
10	Above 16 by 24 inches, and not above 24 by 30, do	101,949.00	67,008 00	0.657	88,802.75	55,781 00	0.628
11	Above 24 by 30 inches, and not above 24 by 60, do	442,705.50	340,998 00	0.770	458,704.00	326,150 00	0.711
12	Above 24 by 60 inches, do	1,024,318.33	943,958 00	0.922	1,017,317.55	871,744 00	0.857
	Plate-glass, cast, polished, silvered, or looking-glass plate:						
13	Not above 10 by 15 inches, square feet	250,895.50	52,791 00	0.210	219,531.00	40,437 00	0.184
14	Above 10 by 15 inches and not above 16 by 24, do	812,671.33	223,407 00	0.275	755,919.00	175,798 00	0.233
15	Above 16 by 24 inches and not above 24 by 30, do	838,597.00	319,964 00	0.382	821,439.00	268,274 00	0.327
16	Above 24 by 30 inches and not above 24 by 60, do	168,753.19	117,096 00	0.694	102,556.00	55,456 00	0.541
17	Above 24 by 60 inches, do	65,778.75	76,467 00	1.162	12,149.25	17,064 00	1.405
	Plate-glass, rough, fluted, or rolled (excess of 1 pound per square foot in proportion):						
18	Not above 10 by 15 inches, square feet	2,265.00	120 00	0.053	4,077.00	395 00	0.097
19	Above 10 by 15 inches and not above 16 by 24, do	2,668.00	75 00	0.028	2,787.00	96 00	0.034
20	Above 16 by 24 inches and not above 24 by 30, do	23,838.00	1,800 00	0.076	20,832.00	1,616 00	0.078
21	Above 24 by 30 inches, do	870,783.50	33,741 00	0.039	258,708.00	13,261 00	0.051
	Window-glass, cylinder, crown, or common, unpolished:						
22	Not above 10 by 15 inches, pounds	6,330,449.00	215,619 88	0.034	4,677,124.00	154,815 00	0.033
23	Above 10 by 15 inches, and not above 16 by 24, do	7,542,537.50	304,205 46	0.040	5,662,851.00	202,878 00	0.036
24	Above 16 by 24 inches, and not above 24 by 30, do	8,985,927.00	376,706 34	0.047	7,220,534.80	288,382 47	0.040
25	Above 24 by 30 inches, do	6,879,206.00	425,486 00	0.062	7,378,928.00	381,517 00	0.052
	Window-glass, cylinder, and crown, polished:						
26	Not above 10 by 15 inches, square feet	539.00	117 00	0.217	5,438.00	1,144 00	0.210
27	Above 10 by 15 inches, and not above 16 by 24, do	1,244.00	477 00	0.383	6,208.00	1,704 00	0.274
28	Above 16 by 24 inches, and not above 24 by 30, do	72,084.75	8,391 00	0.116	15,662.00	5,288 00	0.338
29	Above 24 by 30 inches, and not above 24 by 60, do	2,316.00	1,221 00	0.527	2,404.00	1,078 00	0.448
30	Above 24 by 60 inches, do						
31	Manufactures of, not otherwise provided for		624,877 99			497,528 14	

UNITED STATES IN THE YEARS 1876 TO 1880.

1878.			1879.			1880.			
Quantities.	Value.	Value per unit of quantity.	Quantities.	Value.	Value per unit of quantity.	Quantities.	Value.	Value per unit of quantity.	
.....	$3,331,857 25	.....	.....	$3,281,420 09	.....	.....	$5,133,272 42	.....	
.....	23,710 40	.....	.....	20,676 00	.....	.....	43,760 56	.....	1
3,200,087.00	.....	.....	3,360,793.00	.....	.....	4,276,410.00	.....	.....	2
.....	.....	.....	.....	56,412 00	.....	.....	199,459 00	.....	3
.....	7,271 00	.....	.....	11,049 00	.....	.....	7,391 00	.....	4
.....	428 00	.....	.....	1,607 00	.....	.....	2,668 00	.....	5
.....	458,447 93	.....	.....	591,541 38	.....	.....	722,637 41	.....	6
.....	29,965 00	.....	.....	41,958 80	.....	.....	38,381 36	.....	7
10,252.00	1,858 00	0.181	14,338.00	2,711 00	0.189	108,732.00	16,200 00	0.149	8
12,601.16	4,413 00	0.350	27,317.60	8,724 00	0.319	46,185.80	14,721 00	0.319	9
58,340.50	33,106 00	0.567	90,434.91	32,888 00	0.364	157,804.92	50,326 00	0.319	10
392,594.16	286,537 00	0.729	562,071.08	240,480 00	0.428	719,373.06	285,419 00	0.397	11
756,779.29	658,560 00	0.870	869,635.12	421,401 00	0.485	874,521.64	390,741 00	0.447	12
121,213.00	18,607 75	0.154	128,904.75	23,992 00	0.186	230,728.42	50,823 00	0.220	13
619,379.50	133,430 00	0.215	697,652.50	165,437 00	0.237	1,000,349.42	269,421 00	0.269	14
912,375.50	277,113 00	0.304	1,081,357.00	342,750 00	0.317	1,648,187.31	557,998 00	0.339	15
85,545.00	41,865 00	0.489	102,961.00	45,460 00	0.442	153,637.00	75,218 00	0.490	16
1,284.50	1,251 00	0.974	1,034.66	1,245 81	1.204	6,020.66	4,274 73	0.710	17
80.00	5 00	0.063	.....	.....	.....	.....	.....	.....	18
2,441.00	163 00	0.067	405.00	29 00	0.072	10,785.00	196 00	0.018	19
3,585.00	153 00	0.043	7,202.00	365 00	0.051	1,957.00	89 00	0.045	20
78,588.00	5,432 00	0.069	173,384.00	7,693 00	0.044	757,908.00	25,426 00	0.034	21
4,330,949.00	124,033 91	0.029	3,582,364.00	90,356 62	0.025	12,041,215.00	308,978 11	0.026	22
5,903,795.00	176,184 84	0.030	5,045,243.00	140,367 05	0.028	11,077,758.00	333,063 23	0.030	23
6,576,448.00	226,396 85	0.034	5,836,463.00	184,885 64	0.032	10,693,808.25	351,463 90	0.033	24
6,242,560.50	274,624 61	0.044	6,225,791.83	237,232 87	0.038	10,137,070.00	412,472 44	0.041	25
3,563.00	828 00	0.232	1,675.00	325 00	0.194	11,900.66	2,110 00	0.177	26
8,724.00	2,601 00	0.298	15,460.50	3,256 00	0.211	26,575.58	4,153 00	0.156	27
10,779.00	4,185 00	0.388	21,031.00	6,023 00	0.286	36,938.75	10,605 00	0.287	28
1,661.00	690 00	0.415	4,039.00	1,690 00	0.418	12,651.66	4,229 00	0.334	29
.....	.....	.....	.....	.....	.....	.....	.....	.....	30
.....	539,996 96	.....	.....	690,863 92	.....	.....	951,047 68	.....	31

INDEX TO GLASS.

A.

	Page.
Advantages of Siemens' gas furnaces	36
Aggry beads made in Phœnicia	60
Agricola's time, furnaces in	34
Air blast, cooling heated molds by	49
Air bubbles in glass	44
Air, effect of, on pots	43
Albany, account of glass-making at	93, 94
Alexandria, Virginia, manufacture of glass at	78
Alicant, Spanish soda of	31
Alkalies and other materials used in glass-making	30–34
Alkalies, the chief, used in glass-making	30
Alkaline rocks in Germany, Friederich Siemens quoted on use of	28
Alkaline rocks in Germany, Julius Fahdt quoted on use of	28
Alkaline rocks, use of, for bottle-glass	28
Allegheny county, manufacture of glass in, in the census year	88
Alumina in glass	34
Amelung, John Frederick, petition of, for aid in glass-making	95
Amelung, presentation of flint goblets by, to Washington	95
American fire-clay used	18
American glass, quality of (note)	69
American invention, pressed glass an	58
American pot-clay, analyses of	40
American sand, Bontemps quoted on	26
American sand, character of	28
American sand, deposits of	28
American sand, mode of occurrence of	25
American sand, Mr. Henry Chance quoted on	26
American sand, Thomas Webb & Son quoted on	26
American stained glass (note)	69
Ammonia process for making soda	31
Amount of production of Roman glass	62
Analyses of bottle-glass	23
Analyses of English sand	26, 27
Analyses of flint-glass	23
Analyses of foreign glass sands	29
Analyses of French pot-clay	40
Analyses of French sand	27
Analyses of German pot-clay	40
Analyses of glass sands of the United States	30
Analyses of lead glass	23
Analyses of lime glass	23
Analyses of plate-glass	23
Analyses of sand not always indicative of quality	25
Analyses of Scotch pot-clay	40
Analyses of Stourbridge pot-clay	40
Analyses of window-glass	23
Analysis of American pot-clay	40
Analysis of window-glass found at Pompeii	56
Ancient Egyptian glass furnaces, remains of, found by Napoleon I	60
Ancient factories, location of, at mouths of rivers	25
Ancient factories, sand used in	26
Ancient glass	59–64
Ancient glass a soda glass	30
Ancient glass, coloring matter of	59
Ancient glass houses, sources of supply of soda for	30
Ancient pressed glass	58
Ancients, extent of use of window-glass by the	56
Ancient soda impure	31
Ancient window-glass, method of manufacture of	56
Annealing flint-glass	51
Annealing ovens for plate-glass, description of	46
Annealing ovens in glassware factories, number of	4
Annealing ovens in green-glass factories, number of	4
Annealing ovens in plate-glass factories, number of	4
Annealing plate-glass	45
Annual settlement of wages	8
Antiquity of window-glass, Winckelman's views on	56
Approximate composition of glass	19
Arsenic used, amount of	18
Arsenic, use of, in glass-making	25–34
Art glass	52
Artificial glass, definition of (note)	20
Art uses of glass	22
Assyrian glass, character of	61
Aurelian, ordinance of, regarding tribute on glass	59
Austria, glass-spinning in	75
Austria-Hungary, cooling in glass houses of	44
Austria-Hungary, dimension of pots in glass houses of	44
Austria-Hungary, duration of heating in glass houses of	44
Austria-Hungary, duration of melting in glass houses of	44
Austria-Hungary, manufacture of glass flowers in	75
Austria-Hungary, manufacture of glass wearing fabrics in	75
Austria-Hungary, manufacture of plate-glass in	75
Austria-Hungary, number of plate-glass factories in	70
Austria-Hungary, present condition of manufacture of glass in	74
Austria-Hungary, proportion of batch in glass houses of	44
Austria-Hungary's specialty in glass-making	70
Austria-Hungary, statistics of glass manufacture in	75
Austria-Hungary, working in glass houses of	44
Austrian glass houses, sources of supply of sand for	28
Austrian glass pots, size of	41
Austrian sand, sources of supply of	28
Austria, quartz still used in	28
Austro-Hungarian glass houses, use of Siemens' tank furnaces in	44
Average daily earnings, fallacy of usual statements regarding	

B.

Baccarat works, establishment of	66
Bakewell, Mr. Thomas, and the manufacture of glass at Pittsburgh	86
Balls, method of manufacture of, by pressing	48
Baltimore glass works, establishment of	95
Barbarians, influence of, upon glass-making	65

	Page.
Barec of Bretagne	31
Barilla, Spanish	31
Barrels and casks used	18
Basalt, decomposed, use of, for manufacturing (note)	20
Bastie glass, method of manufacture of	53
Batch, constituents of the	41
Batch, definition of	41
Batch, preliminary heating of	43
Batch, proportion of, in glass houses of Austria-Hungary	44
Battery jars, method of manufacture of, by pressing	48
Beads, manufacture of, in Virginia	78
Beer-bottles, number made	11
Beets and grapes, potash made from	32
Belgian bottle-glass, constituents of	43
Belgian glass, exportation of	73
Belgian glass, quality of	73
Belgian glass, statistics of manufacture of	74
Belgian sand, sources of supply of	27
Belgian window-glass	69
Belgian window-glass, export of	69
Belgian window-glass, importation of, into the United States	69
Belgium, production of plate-glass in	70
Belgium's specialty in glass-making	69
Bellaire, Ohio, glass-making at	79
Beni-Hassan, figures on tombs at	57
Beni-Hassan, glass-making figured on tombs at	59
Benrath's definition of glass (note)	19
Benzine, use of	4
Blast-furnace slag, a glass (n)	20
Blast-furnace slag, relative composition of, and glass	54
Blast-furnaces, slag-glass from	54
Blast, use of, in cooling	44
Blister in glass, cause of	45
Blowing and pressing united to produce same form of glass	45
Blowing flint ware, description of process	51
Blowing glass	50
Blowing in molds, description of method	51
Blown plate, definition of	20
Blown plate, how made	51
Blown window-glass, early manufacture of	57
Blown window-glass, Theophilus' account of	57
Bodine, John T., on early glass-making in New Jersey	96
Bohemian glass	67
Bohemian glass, character of	68
Bohemian glass, definition of	21
Bohemian glass houses, time of melting in	44
Bohemian glass pots, size of	41
Bohemian glass, quality of	70, 74
Bohemian lime flint-glass, constituents of	42
Boilers in glassware factories, number of	4
Boilers in green-glass factories, number of	5
Boilers in plate-glass factories, number of	4
Boilers in window-glass factories, number of	4
Bontemps quoted on American sand	26
Boston, manufacture of crown-glass at	89
Bottle-glass (note)	20
Bottle-glass, analyses of	23
Bottle-glass, Belgian, constituents of	43
Bottle-glass, English, constituents of	43
Bottle-glass, flint and, manufactured in Europe	72
Bottle-glass, French, constituents of	43
Bottle-glass, the term hollow-ware applied to	21
Bottle-glass, materials used for, proportion of	43
Bottle-glass, Pittsburgh, constituents of	43
Bottle-glass pots, size of	41
Bottle-glass, use of alkaline rocks for	28
Bottles, manufacture of, in France	73
Bottles, manufacture of, in window-glass houses	84
Bottles, pressing	48
Bridgeport, Ohio, glass-making at	79
British exports of glass	72
British imports of glass	72
British islands, modern manufacture of glass in	68
Bubbles in glass	44
Building glass works, statistics of	3, 13, 14
Bulk, difference in, of melted and unmelted charge	43
Burgin furnaces, number of	4
Byzantine glass	62
Byzantine glass, character of	62
Byzantine glass, extent of its manufacture	62

C.

Calcar arch	43
California, history of glass-making in	98
California, statistics of all works in, by counties	15
Capital invested in glass manufacture	3
Carbonate glass, color of	31
Carbon, use of, in glass	34
Carthaginian glass	61
Carts in glass factories, number of	4, 5
Casks and barrels used	18
Castellani on Venetian glass manufacture	76
Casting and pressing, related processes	45
Casting plate-glass	45
Casting tables, description of	45
Casting tables in plate-glass factories, number of	4
Cast plate, composition of	19
Cathedral plate, establishments producing	3
Cause of the decline of the manufacture of glass in Rome	62
Causes of failure of early attempts to establish glass manufacture	81
Cave	35
Censuses, previous, comparison with	2
Censuses, previous, omissions in	2
Chance, Mr. Henry, quoted on American sand	26
Chance's mixing machine	43
Character of ancient window-glass	56
Character of Egyptian glass	60
Character of French sand	27
Character of lead glass	21, 33
Character of modern Spanish glass	67
Character of Phœnician glass	61
Character of Roman glass	62
Character of sulphate glass	31
Chargers, mechanical	43
Charging	43
Cheapness of glass at Rome	62
Chemical glass	19
Chemical lime flint-glass, constituents of	42
Chemical classification of glass, difficulty of	19
Chemists' ware not included in report	1
Chief alkalies used in glass-making	30
Chief constituents of glass	19
Chief glass-making countries of Europe	69
Children in glass factories	5
China, glass-making in	64
Christianity, influence of, on the manufacture of glass	63
Churches, use of window-glass in early	56
Church, influence of the, on glass-making	65
Classification, chemical, of glass, difficulty of	19
Classification, commercial, of glass, difficulty of	20
Classification, composition and properties of glass	19–23
Classification of glass	1, 20
Classification of glass according to method of manufacture (note)	20
Classification of glass, Tomlinson's (note)	20
Classification of glass, Ure's (note)	20
Classification of *Gobeleterie*	21
Clay-grinding mills in glass factories, number of	4
Clear white lime flint-glass, constituents of	42
Clinton, De Witt, on glass-making in New York	94
Coal first used as a fuel in United States at Pittsburgh	83

	Page.
Coal, mineral, first use of	36
Coal, substitution of, for wood in glass-melting	57
Coal used, amount of	18
Coal, use of, in glass-making in 1810	87
Coke used, amount of	18
Colbert and glass-making in France	66
Cold stoking	44
Colored glass, classification of, chemically	20
Colored glass, definition of	20
Colored glass pots, size of	41
Coloring matter of ancient glass	59
Color of carbonate glass	31
Color of glass, effect of use of manganese on	25
Color of sand not always indicative of quality	25
Color of slag-glass	55
Color of sulphate glass	31
Commercial classification of glass, difficulty of	20
Common flint, definition of	21
Comparison with previous censuses	2
Composition, approximate, of glass	19
Composition, classification, and properties of glass	19, 23
Composition of cast plate	19
Composition of enamel	21
Composition of Egyptian glass	60
Composition of glass, difficult to obtain	41
Composition of green bottle-glass	19
Composition of green glass	21
Composition of lead flint	19
Composition of lead glass	21
Composition of lime flint	19
Composition of window-glass	19
Composition, variability of	19
Condition of glass-making in 1608	78
Conductivity of glass	21
Connecticut, first glass house in	94
Connecticut, history of glass-making in	94, 95
Connecticut, monopoly of glass-making in, granted	95
Connecticut, statistics of all works, by counties	15
Connecticut, statistics of glass-making in, at various dates	95
Consolidated statistics of production, etc., of glassware	12
Consolidated statistics of production, etc., of green glass	12
Consolidated statistics of production, etc., of plate-glass	12
Consolidated statistics of production, etc., of window-glass	12
Consolidated statistics of the materials used in the manufacture of glass	18
Constituents of Belgian bottle-glass	43
Constituents of Bohemian lime flint-glass	42
Constituents of chemical lime flint-glass	42
Constituents of clear white lime flint-glass	42
Constituents of English bottle-glass	43
Constituents of English lead flint-glass	42
Constituents of English plate-glass	42
Constituents of English window-glass	42
Constituents of French bottle-glass	43
Constituents of French lead flint-glass	42
Constituents of French lime flint glass	42
Constituents of French plate-glass	42
Constituents of French window-glass	42
Constituents of lead flint-glass	42
Constituents of lime flint-glass	42
Constituents of lime-white flint-glass	42
Constituents of Pittsburgh bottle-glass	43
Constituents of Pittsburgh lead flint-glass	42
Constituents of Pittsburgh lime flint-glass	42
Constituents of Pittsburgh window-glass	42
Constituents of plate-glass	42
Constituents of the batch	41
Constituents of window-glass	42
Constitutionality of loans of money to encourage manufactures discussed in Congress	95
Construction of furnaces for different kinds of glass	35
Cooling in glass houses of Austria-Hungary	44
Cooling molds by air blast	49
Cooling, time of	44
Cooling, use of blast in	44
Cooper's mixer	43
Cost of making glass, items of	x
Cost of Siemens' tempered glass	54
Council of Ten, action of, on glass-making	65
Counties making glass, relative production of	11
Covered pots, time of melting in	44
Covered pots, use of, in glass-making	57
Craig & O'Hara asked to manufacture glass for public buildings at Washington	84
Craig & O'Hara, glass manufacturers in Pittsburgh	83
Craig & O'Hara's glass works	82–84
Cristanx same as lead flint	21
Crown-glass, definition of	20
Crown-glass making in New York in 1846	94
Crown glass, manufacture of, at Boston	89
Crown-glass, method of manufacture	20
Crown-glass, time of melting, in English houses	44
Crown optical glass	21
Crushing strength of glass	21, 22
Crystal glass, definition of	21
Cullet, proportion of	43
Curvette, use of, in plate-glass works	45
Cutting flint-glass	51
Cylinder glass, definition of	20

D.

	Page.
Dampness, effect of, on soda window-glass	30
Decadence of Venetian glass-making	65
Decanters, early manufacture of, in Pittsburgh	86
De Cesnola's discoveries of glass	61
Decline of the English glass industry	72
Decolorizer, manganese not a permanent	33
Decolorizer, use of manganese as a	24
Definition of glass, Benrath's (note)	19
Definition of glass, Fownes' (note)	19
Definition of glass, Lardner's (note)	19
Definition of glass, Ure's (note)	19
Denny & Beelen's glass house at Pittsburgh	83, 84
Destruction of first glass house in Virginia	78
Devitrification in its relation to manipulation of glass	22
Difference in bulk of melted and unmelted charge	43
Difficulties attending the early manufacture of glass at Pittsburgh	84–86
Difficulties attending the early manufacture of glass in Maryland	95
Difficulties attending the manufacture of glass in Virginia	78
Difficulties attending the manufacture of plate-glass in the United States	98
Difficulty of comparison with previous censuses	2
Dimension of pots in glass houses of Austria-Hungary	44
Direct-firing furnaces, number of	4
Directory of glass works	ix
Discovery of glass	59
Discovery of soda-ash	31
District of Columbia, statistics of works in	15
Division of labor at early glass works	34
Double glass, definition of	20
Double process, glass-making a	19
Draft animals used in glass works, number and kind of	5
Drays in glass factories, number of	4, 5
Drinking-glasses, Saxon	63
Druids' beads	64
Drying of pots	41
Duties on imports of glass, early action of Congress in levying	95
Ductility of glass	22
Dyottville glass works	81, 82

E.

Page.

Earliest date assigned to the manufacture of Egyptian glass. 59
Early action of Congress levying duties on imports of glass.. 95
Early attempts at the use of salt-cake 31
Early attempts to establish glass manufacture..... 81
Early attempts to make plate-glass in the United States 98
Early French glass works..... 63
Early furnaces 34
Early glass furnaces, description of..... 90
Early glass-making in the British islands..... 64
Early glass-making near Philadelphia..... 80
Early glass, variety of 34
Early glass works, division of labor at 34
Early glass works in Gaul 63
Early glass works in Spain 63
Early manufacture of decanters in Pittsburgh..... 86
Early manufacture of glass in Pittsburgh 84
Early manufacture of mirrors in Germany..... 63
Early manufacture of window-glass in Germany..... 63
Early specimens of German glass 67
Early times in France, use of window-glass in..... 56
Early use of flint in glass-making..... 26
Early use of quartz in glass-making 26
Early Venetian glass-making 65
Early window-glass works in England 56
Earnings, average daily, elements necessary to ascertain.... 6
Economy of Siemens' tank furnace 38
Effect of air on pots..... 43
Effect of lead in the manufacture of glass..... 33
Effect of lime on glass..... 32
Effect of pressing in cheapening glass..... 58
Egypt, glass-making in, after the Christian era..... 59
Egypt, glass-making materials in..... 60
Egyptian furnaces, early..... 34
Egyptian glass 59
Egyptian glass, character and composition of 60
Egyptian glass, earliest date assigned to the manufacture of.. 59
Egyptian glass furnaces, ancient, remains of, found by Napoleon I 60
Egyptian glass-making, process of 60
Egyptian glass, varieties of 60
Egyptian soda, where procured 30
Egypt, natron lakes of..... 30
Egypt, state of the art in ancient..... 59
Eichbaum, P. W., glass-worker 81–83
Employés, number of 6
Enamel, composition of 21
England, early window-glass works in..... 56
England, number of plate-glass factories in 70
England's specialties in glass-making 69
English art glass 69
English bottle-glass, constituents of 43
English fire-clay used, amount of 18
English flint-glass 69
English glass houses, sources of supply of sand for..... 27
English glass houses, time of fining in..... 44
English glass houses, time of melting in..... 44
English glass industry, decline of 72
English houses, time of melting flint-glass in 44
English lead flint-glass, constituents of 42
English plate-glass, constituents of 42
English sand, analyses of 26, 27
English sand, sources of supply of..... 26
English window-glass, constituents of..... 42
Engraving flint-glass 51
Essex-street glass works 89
Establishments in which glass was made in the census year. 3
Etching flint-glass..... 51
Etching, invention of..... 67
Etruscan glass 61
Europe, chief glass-making countries of 69
Europe, number of plate-glass factories in..... 70
Europe, present condition of glass-making in 69–77
Europe, production of plate-glass in..... 71
Excellence of Phœnician glass 60
Exportation of Belgian glass 73, 74
Export, first United States, of glass 77
Export of Belgian window-glass 69
Exports of glass, British..... 72

F.

Factories, plant of..... 4
Fahdt, Julius, quoted on use of alkaline rocks in Germany.. 28
Failure of early attempts to establish glass manufacture, causes of..... 81
Falls of the Schuylkill, glass works at the 81
Faults in glass 44, 45
Fining 43, 44
Fining, duration of, in glass houses of Austria-Hungary..... 44
Fining, effect of too long continued 43
Fining, heat of..... 43
Fining, time of, in English houses..... 44
Fining, time of, in lime glass houses..... 44
Fining, time of, in the glass houses of the United States 44
Fire-clay, American, used, amount of 18
Fire-clay, English, used, amount of 18
Fire-clay, German, used, amount of 18
Fire polishing 49
First export of glass from the United States 77
First glass house in New York 93
First glass house in Pittsburgh..... 83
First glass house in the United States 77
First glass made in the United States 77
First glass works in Connecticut 94
First glass works in Massachusetts 89
First glass works in Missouri 97
First glass works in New Hampshire 91
First glass works in New Jersey..... 96
First glass works in Pennsylvania..... 79
First glass works in Philadelphia, Pennsylvania..... 80
First glass works west of the Allegheny mountains 82
First mention of glass in Rome 62
First pressed glass 58
First pressed tumbler 58
First Roman glass works..... 62
Flashed glass, definition of..... 20
Flattening-ovens in window-glass factories, number of..... 4
Flattening window-glass, description of process of 50
Flint still used in Germany 27
Flint- and bottle-glass manufacture in Europe..... 72
Flint, common, definition of..... 21
Flint, early use of, in glass-making..... 26
Flint, German, definition of..... 21
Flint-glass, analyses of 23
Flint-glass, annealing..... 51
Flint-glass, Bohemian lime, constituents of 42
Flint-glass, chemical lime, constituents of 42
Flint-glass, clear white lime, constituents of 42
Flint-glass, cutting 51
Flint-glass, definition of 20
Flint-glass, English lead, constituents of..... 42
Flint-glass, engraving 51
Flint-glass, etching 51
Flint-glass, first attempt at the manufacture of, west of the Allegheny mountains 85
Flint-glass, French lead, constituents of..... 42
Flint-glass, French lime, constituents of..... 42
Flint-glass houses, time of melting in 44
Flint-glass, lead, constituents of 42
Flint-glass, lead, proportion of materials used in the manufacture of 42
Flint-glass, lime, proportion of materials used in the manufacture of..... 42

Page.

Flint-glass, lime, constituents of 42
Flint-glass, lime-white, constituents of 42
Flint-glass making, early in Massachusetts, account of 89, 90
Flint-glass, manufacture of, in Philadelphia, Pennsylvania .. 82
Flint-glass, permanent establishment of the manufacture of, at Pittsburgh 86
Flint-glass, Pittsburgh lead, constituents of 42
Flint-glass, Pittsburgh lime, constituents of 42
Flint-glass pots, size of 41
Flint-glass, tools used in the manufacture of 51
Flint, use of, in manufacture of glass 24
Flowers, glass, manufacture of, in Austria-Hungary 75
Foreign glass sands, analyses of 29
Form of furnaces, object aimed at in the 35
Fowne's definition of glass (note) 19
France, Colbert and glass-making in 66
France, glass of 63
France, manufacture of bottles in 73
France, manufacture of lead flint-glass in 66
France, manufacture of mirrors in 73
France, manufacture of plate-glass in 73
France, modern glass-making in 66
France, number of plate-glass factories in 70
France, plate-glass making in 66, 73
France, quartz still used in 27
France's specialties in glass making 69
France, use of window-glass in early times in 56
French bottle-glass, constituents of 43
French glass houses, time of melting in 44
French glassware, taste displayed in the manufacture of 73
French glass works, early 63
French lead flint-glass, constituents of 42
French lime flint-glass, constituents of 42
French plate-glass, character of 69
French plate-glass, constituents of 42
French pot-clay, analyses of 40
French sand, analyses of 27
French sand, character of 27
French sands, mode of occurrence of 25
French stained glass 69
French white glass, character of 69
French window-glass, constituents of 42
Frequency of payment 8
Fritting 43
Fritting furnaces 34
Fruit jars, number made 11
Fuel, coal first used as a, in United States at Pittsburgh 83
Fuel, economy of, in Siemens' gas furnace 36
Fuel used in early glass houses 36
Fuel used in Germany 74
Fuel used in glass-making 4
Furnaces 34–41
Furnaces, building 1, 3, 13, 14
Furnaces, construction of, for different kinds of glass 35
Furnaces, description of early glass 90
Furnaces, early 34
Furnaces idle during census year 1, 2, 3, 13, 14
Furnaces, number of 3
Furnaces, size of 36
Furnaces used in Germany 74
Fusion, effect of too long continued 43
Fusion, heat of 43
Fusion, time of 43

G.

Gallatin's glass works 82
Gallatin's return on the manufacture of glass in the United States 87
Gas bubbles in glass 44
Gas furnaces 36
Gas furnaces at Wheeling 79

Page.

Gas furnaces, number of 4
Gas furnaces, time of melting in 44
Gaul, early glass works in 63
German fire-clay used, amount of 18
German flint, definition of 21
German glass, early specimens of 67
German glass houses, location of 74
German glass pots, size of 41
German glass-workers in the United States, early 91
German pot-clay, analyses of 40
German sand, sources of supply of 27
German silvered plate, importation of, into the United States. 70
Germany, early manufacture of mirrors in 63
Germany, early manufacture of window-glass in 63
Germany, flint still used in 27
Germany, furnaces used in 74
Germany, influence of, on French glass-making 66
Germany, influence of Rome on glass manufacture in 63
Germany, manufacture of mirrors in 74
Germany, number of plate-glass factories in 70
Germany, present condition of manufacture of glass in 74
Germany, production of mirrors in 70
Germany, quartz still used in 27
Germany, statistics of manufacture of glass in 74
Germany's specialty in glass-making 70
Gill furnace, description of 37
Gill furnaces, number of 4
Glass, a fused mixture of two or more silicates 19
Glass and metallurgical slags 59
Glass-bead manufacture in Venice 70
Glass-blowing, early, description of 57
Glass-blowing figured on tombs at Beni-Hassan 57
Glass, chemical 19
Glass, chief constituents of 19
Glass, classification of 1, 20
Glass, definition of, Benrath's (note) 19
Glass, definition of, Fownes' (note) 19
Glass, definition of, Lardner's (note) 19
Glass, definition of, Ure's (note) 19
Glass, difficulty of chemical definition of 19
Glass found at Poitiers 63
Glass-gall 30
Glass-gall, or sandiver 43
Glass, how used commercially 19
Glass in France 63
Glass, in the dark ages 66
Glass, its composition, classification, and properties 19–23
Glass-makers, special privileges given to 63
Glass-making a double process 19
Glass-making at Bellaire, Ohio 79
Glass-making at Jamestown, Virginia 77
Glass-making at Keene, New Hampshire 92
Glass-making at Martin's Ferry, Ohio 79
Glass-making at Newcastle-on-Tyne 64
Glass-making at Pembroke, New Hampshire 92
Glass-making at Wheeling, West Virginia, history of 78
Glass-making figured on tombs at Beni-Hassan 59
Glass-making, history of some processes of 56, 58
Glass-making in Bridgeport, Ohio 79
Glass-making in California, history of 98
Glass-making in China 64
Glass-making in Connecticut, history of 94, 95
Glass-making in Egypt, after the Christian era 59
Glass-making in Germany 63
Glass-making in Illinois, history of 98
Glass-making in India 64
Glass-making in Ireland 64
Glass-making in Kentucky, history of 98
Glass-making in Maryland, history of 95, 96
Glass-making in Maryland in 1810 96
Glass-making in Maryland in 1820 96

	Page.
Glass-making in Maryland in 1831	96
Glass-making in Massachusetts, history of	88–91
Glass-making in Massachusetts in 1818	90
Glass-making in Massachusetts in 1823	90
Glass-making in Missouri, history of	97
Glass-making in New Hampshire, history of	91–93
Glass-making in New Hampshire in 1820	92
Glass-making in New Jersey, history of	96
Glass-making in New York, history of	93, 94
Glass-making in New York in 1820	94
Glass-making in New York in 1831	94
Glass-making in Normandy	63
Glass-making in Ohio, history of	97
Glass-making in Ohio in 1820	97
Glass-making in Ohio in 1831	97
Glass-making in Ohio in 1840	97
Glass-making in Ohio in 1850	97
Glass-making in Ohio in 1860	97
Glass-making in Ohio in 1870	97
Glass-making in Pennsylvania, history of	79–88
Glass-making in Persia	64
Glass-making in Rome after the Christian era	62
Glass-making in Scotland	64
Glass-making in Spain	63
Glass-making in Virginia, history of	77–79
Glass-making in Virginia in 1831	78
Glass-making in Vermont, history of	97
Glass-making in Western Massachusetts, history of	90
Glass-making in West Virginia in 1840	78
Glass-making materials in Egypt	60
Glass-making, profit in, no attempt to show	ix
Glass manufacture in France, present state of	73
Glass manufacture in Germany	67
Glass-melting, substitution of coal for wood in	57
Glass-pressing, application of compressed air to	49
Glass-pressing, application of steam to	49
Glass-pressing, *London Pottery Gazette* on the invention of	58
Glass-pressing, Pellatt on the invention of	58
Glass-refining in Austria	44
Glass sand in New Jersey	97
Glass-spinning in Austria	75
Glassware, capital invested in	3
Glassware, consolidated statistics of production, etc	12
Glassware factories, definition of	1
Glassware, French, taste displayed in the manufacture of	73
Glassware, number of pieces made not reported on	10
Glassware, product of, value of	9
Glassware, relative productive rank of the states in	9
Glassware works, furnaces in, number of	3
Glassware works, pots in, number of	3
Glass working, methods of	45–55
Glass works in New Hampshire in 1820	92
Glass works in Pennsylvania in 1810	82
Glass works in Pennsylvania in 1820	82
Glass works in Pennsylvania in 1831	82
Glass works in Pennsylvania in 1840	82
Glass works in western Pennsylvania, early history of	82
Glory-holes in glassware factories, number of	4
Glory-holes in green-glass factories, number of	4
Gobeleterie, classification of	21
Grapes, beets and, potash made from	32
Great Britain, localities of the manufacture of glass in	72
Great Britain, statistics of the manufacture of glass in	72
Great Britain, window-glass used in, in the Roman period	56
Greek glass	61
Greek glass, earliest reference to	61
Green and black bottles, number of	11
Green bottle-glass, composition of	19
Green glass, capital invested in	3
Green glass, composition of	21
Green glass, consolidated statistics of production, etc	12
Green glass, definition of	21
Green-glass factories, definition of	1
Green-glass houses, time of melting in	44
Green glass, production of	11
Green glass, relative productive rank of the states in	9
Green-glass works, furnaces in, number of	3
Green-glass works, pots in, number of	3
Grinding- and engraving-machines in glass factories, number of	4, 5
Grinding plate-glass, description of machinery for	46
Grinding plate-glass, description of process	46
Grinding sand used	18
Ground glass, definition of	21
Guinand's method of making optical glass	46
H.	
Hardened glass	52
Hardened glass, definition of	21
Hardness of glass, on what it depends	24
Hay and straw used, amount of	18
Heating in glass houses of Austria-Hungary, duration of	44
Heating of batch, preliminary	43
Heat of furnaces (note)	35
Heiss-schüren, heat of	43
Herzogenrath (German) sand	28
Hewes, Robert, attempts to establish glass-making in New Hampshire	91
History of glass-making in California	98
History of glass-making in Connecticut	94, 95
History of glass-making in Illinois	98
History of glass-making in Kentucky	98
History of glass-making in Maryland	95, 96
History of glass-making in Massachusetts	88–91
History of glass-making in Missouri	97
History of glass-making in New Hampshire	91–93
History of glass-making in New Jersey	96, 97
History of glass-making in New York	93, 94
History of glass-making in Ohio	97
History of glass-making in Pennsylvania	79–88
History of glass-making in Russia	68, 69
History of glass-making in the United States	77–99
History of glass-making in Virginia	77, 78
History of glass-making in West Virginia	78, 79
History of manufacture of plate-glass in France	56
History of some processes of glass-making	56–58
History of the invention of pressed glass	58
Hohenbocka (German) sand	28
Hohlglas, definition of	21
Holland, glass-making in	70
Holland, present condition of glass-making in	77
Holland, statistics of glass-making in	77
Hollow-ware, the term, applied to bottle-glass	21
Horse-power in glass factories, number of	4, 5
Horses in glass factories, number of	4, 5
Hot stoking, heat of	43
I.	
Idle and building glass works, statistics of	2, 3, 13, 14
Idle furnaces	1
Illinois, history of glass-making in	98
Illinois sand	29
Illinois, statistics of all works in, by counties	15
Importation of Belgian window-glass into the United States	69
Importation of German silvered plate into the United States	70
Imports, British, of glass	72
Imports of glass, early action of Congress in levying duties on	95
Imports of glass into the United States	99–101
Imports of soda	31
Improvements in the pressing process	47
Impurities in sand and their removal	24
India, glass-making in	64
Indiana, manufacture of plate-glass in	99

Page.

Indiana, statistics of all works in, by counties 16
Influence of barbarians upon glass-making 65
Influence of Christianity on the manufacture of glass 63
Influence of Germany on French glass-making 66
Influence of Rome on glass manufacture in Germany 63
Influence of the church on glass-making 65
Influence of the Renaissance on glass-making 65
Influence of the Roman conquest in extending glass manufacture 63
Influence of Venice on modern glass-making 64
Influence of Venice on the manufacture of English glass 68
Influence of weather on composition of glass 41
Influence of weather on melting glass 41
Influences that determine the glass mixture 41
Insolubility of glass 22
Insulators, method of manufacture of, by pressing 48
Intervals of payment 8
Introduction of glass-making into Rome 62
Iowa, statistics of all works in, by counties 16
Ireland, glass-making in 64
Iridescent glass, definition of 21
Iron in glass 33
Iron in sand, effect of, on glass 24
Italian glass manufacture, statistics of 76
Italy, present condition of manufacture of glass in 76

J.

Jamestown, Virginia, glass-making at 77
Jarves, Mr., on Venetian glass-making 65
Johnson's *Rambler* quoted 22
Joint molds 47

K.

Kalt-schüren 44
Keene, New Hampshire, glass-making at 92
Kensington, Pennsylvania, glass works at 80
Kentucky, history of glass-making in 98
Kentucky, statistics of all works in, by counties 16

L.

Lablanc's discovery of soda-ash 31
Labor, division of, at early furnaces 34
Lamp chimneys, number made 11
Lamps, number made 11
Lamps, pressing 48
Lancaster, Pennsylvania, Baron Steigel's glass works at 80
Lancaster, Pennsylvania, glass-making at 80
Lardner's definition of glass (note) 19
Largest plates of glass made 46, 73
Lead, effect of, in the manufacture of glass 33
Lead, effect of proportion of, on time of melting 44
Lead flint-glass, composition of 19
Lead flint-glass, constituents of 42
Lead flint-glass, English, constituents of 42
Lead flint-glass, French, constituents of 42
Lead flint-glass, manufacture of, in France 66
Lead flint-glass, Pittsburgh, constituents of 42
Lead flint-glass, proportion of materials used in the manufacture of 42
Lead glass, analyses of 23
Lead glass, characteristics of 21
Lead glass, character of 33
Lead glass, composition of 21
Lead glass, early manufacture of 57
Lead glass, how distinguished from lime glass 21
Lead glass, invention of 57
Lead glass, where made 33
Lead, use of, as a glass-making material a modern discovery 33
Leer, description of 51
Legislature, action of early Massachusetts, encouraging glass-making 89
Letter of transmittal ix

Page.

Lever-press for making pressed glass, description of 47
Life of pots 41
Lime an important glass-making material 32
Lime, effect of, on glass 32
Lime flint-glass, Bohemian, constituents of 42
Lime flint-glass, clear white, constituents of 42
Lime flint-glass, chemical, constituents of 42
Lime flint-glass, composition of 19
Lime flint-glass, constituents of 42
Lime flint-glass, French, constituents of 42
Lime flint-glass, Pittsburgh, constituents of 42
Lime flint-glass, proportion of materials used in the manufacture of 42
Lime glass, analyses of 23
Lime glass as a rule a cheap glass 32
Lime glass, definition of 21
Lime-glass houses, time of fining in 44
Lime-glass houses, time of melting in 44
Lime present in nearly all glasses 32
Lime, sources of supply of 33
Limestone used, amount of 18
Lime used, amount of 18
Lime, use of, a modern discovery 32
Lime-white flint-glass, constituents of 42
Litharge or red lead used, amount of 18
Litharge, use of 33
Loans of money to encourage manufactures, constitutionality of, discussed in Congress 95
Localities in which glass was produced 11
Localities of the manufacture of glass in Great Britain 72
Location of ancient factories at mouths of rivers 25
Location of German glass houses 74
Location of plate-glass factories in Europe 70
Location of window-glass factories in Europe 71
London Pottery Gazette on the invention of glass pressing 58
Looking-glass manufacture in Austria, thin sheet glass for 44
Loss in melting 44
Loss of plate-glass in grinding, smoothing, and polishing 46
Lottery for raising funds to establish glass-making in New Hampshire 92
Low countries, modern manufacture of glass in 68
Lowell, Massachusetts, early glass works in 90
Lumber used, amount of 18

M.

Machinery for grinding plate-glass, description of 46
Machines used in glass works, kind and number of 5
Making soda, Solvay process for 31
Making soda, the ammonia process for 31
Manganese, effect of use of, on color of glass 25
Manganese used, amount of 18
Manganese, use of 33
Manganese, use of, as a decolorizer 24
Manipulation of glass, devitrification in its relation to 22
Manufacture of beads in Virginia 78
Manufacture of bottles in window-glass houses 84
Manufacture of bottles west of the Allegheny mountains 85
Manufacture of glass in Allegheny county in the census year 88
Manufacture of glass in Germany, statistics of 74
Manufacture of glass, use of salt in the 32
Manufacture of salt-cake in the United States 32
Manufacture of soda-ash in the United States 32
"Market-money," payment of 8
Martin's Ferry, Ohio, glass-making at 79
Marver, use of 51
Maryland, history of glass-making in 95, 96
Maryland sand 20
Maryland, statistics of all works in, by counties 16
Massachusetts, account of early flint-glass making in 90
Massachusetts, early plate-glass manufacture in 98
Massachusetts, first glass works in 89

	Page.
Massachusetts, history of glass-making in	88–91
Massachusetts legislature, action of early, encouraging glass-making	89
Massachusetts, state bounty in, for glass-making	89
Massachusetts, statistics of all works in, by counties	16
Materials, alkalies and other, used in glass-making	30–34
Materials, mixing of	41–45
Materials, mixing the, influence of, on the character of the glass	43
Materials, proportion of, used in the manufacture of glass	42, 43
Materials, proportion of, variable	41–45
Materials used in manufactnre of glass, consolidated statistics of	18
Materials used in manufacture of glassware, value of	9
Mechanical chargers	43
Mechanical mixers, use of	43
Melting	43
Melting, duration of, in glass houses of Austria-Hungary	44
Melting, effect of proportion of lead on time of	44
Melting, effect of proportion of sand on time of	44
Melting, effect of too long continued	43
Melting glass	41–45
Melting, loss in	44
Melting-pots, size of, for manufacture of plate-glass	45
Melting, time of, depends on furnace, materials, and size of pots	43
Melting, time of, in Bohemian glass houses	44
Melting, time of, in covered pots	44
Melting, time of, in English glass houses	44
Melting, time of, in French glass houses	44
Melting, time of, in gas furnaces	44
Melting, time of, in the glass houses of the United States	44
Metallurgical slags, glass and	59
Metallurgy, influence of, on early glass-making	59
Method of manufacture, classification of glass according to (note)	20
Method of manufacture of ancient window-glass	56
Method of washing sand to remove impurities (note)	24
Methods of glass-working	45–55
Methods of payment	8
Michigan, statistics of all works in, by counties	16
Milton vase	52
Mineral coal, first use of	36
Mirrors, early manufacture of, in Germany	63
Mirrors, manufacture of, in France	73
Mirrors, manufacture of, in Germany	74
Mirrors, production of, in Germany	70
Mirrors, tin amalgam for, a German invention	63
Mississippi, statistics of all works in, by counties	16
Missouri, history of glass-making in	97
Missouri, manufacture of plate-glass in	99
Missouri sand	29
Missouri, statistics of all works in, by counties	16
Mixer, Cooper's	43
Mixers, mechanical, use of	43
Mixing-machine, Chance's	43
Mixing materials	41–45
Mixing sand used, amount of	18
Mixing the materials, influence of, on the character of the glass	43
Mixture of two or more silicates, glass, a fused	19
Mode of occurrence of French sand	25
Modern furnaces, description of	35
Modern glass	64–69
Modern glass-making dates from Venice	64
Molded glass, Roman	57
Molding articles with lateral designs	47
Molding curved hollow articles	48
Mold marks on pressed ware	47
Molds, blowing in, description of method of	51
Molds, cooling, by air blast	49
Molds, early use of	57
Molds for making pressed glass, description of	47
Monkey-ovens in window-glass factories, number of	4
Monopoly of glass-making in Connecticut granted	94
Moore, Governor, on glass-making in New York	93
Mouths of rivers, location of ancient factories at	25
Mules in glass factories, number of	4, 5
Murano, establishment of glass manufacture at	65

N.

Nails used	18
Natron lakes of Egypt	30
Natural glass, definition of (note)	20
Newcastle-on-Tyne, glass-making at	64
New England sand	29
New Hampshire, description of early method of glass-making in	90, 91
New Hampshire, history of glass-making in	91–93
New Hampshire, statistics of all works in, by counties	16
New Jersey, glass sand in	97
New Jersey, history of glass-making in	96, 97
New Jersey, John T. Bodine on early glass-making in	96
New Jersey sand	29
New Jersey, statistics of all works in, by counties	17
New Jersey, statistics of glass-making in, at various dates	96
New York, crown-glass making in, in 1846	94
New York, De Witt Clinton on glass-making in	94
New York, glass-making in, early in the 19th century	94
New York, Governor Moore on glass-making in	93
New York, history of glass-making in	93, 94
New York, statistics of all works in, by counties	17
Nicholson furnace, description of	37
Nicholson furnaces, number of	4
Nitrate of soda used, amount of	18
Nitrate of soda, use of	32
Normandy, glass-making in	63
Norton, Captain, sent to Virginia to make glass	78
Norway, glass-making in	70
Norway, present condition of manufacture of glass in	77

O.

Object aimed at in the form of furnaces	35
Obsidian (note)	20
Ohio, history of glass-making in	97
Ohio, statistics of all works in, by counties	17
Omissions in previous censuses	2
Optical glass	21
Optical glass, character of	46
Optical glass, Guinand's method of making	46
Ordinance of Aurelian regarding tribute on glass	59
Ovens used in glass works, kind and number of	5

P.

Painted glass a German invention	63
Painted glass, classification of, chemically	20
Painted glass, definition of	20
Painted glass, statistics of, not included in report	1
Palmer, Mr. Charles, on the production of plate-glass in England, France, and Belgium	70, 71
Patent plate, definition of	20
Patent plate, how made	51
Payment, frequency of	8
Payment in kind	8
Payment, methods of	8
Payment, peculiarities of	8
Pearl-ash used, amount of	18
Pelé's hair (note)	20
Pellatt on the invention of glass pressing	58
Pembroke, New Hampshire, glass-making at	92
Pennsylvania, glass works in, in 1810	82
Pennsylvania, history of glass-making in	79–88
Pennsylvania, statistics of all works in, by counties	17

	Page.
Permanent establishment of the manufacture of flint-glass at Pittsburgh	86
Persia, glass-making in	64
Petition of John Frederick Amelung for aid in glass-making	95
Petroleum, use of	4
Philadelphia, early glass-making near	80
Philadelphia, manufacture of flint-glass in	80
Phœnicia, Aggry beads made in	60
Phœnician glass	25, 60
Phœnician glass, character of	61
Phœnician sand	25
Pittsburgh bottle-glass, constituents of	43
Pittsburgh, history of glass manufactures in	85–87
Pittsburgh glass houses, sources of supply of sand for	29
Pittsburgh lead flint-glass, constituents of	42
Pittsburgh lime flint-glass, constituents of	42
Pittsburgh, statistics of the manufacture of glass in, for a series of years	87, 88
Pittsburgh window-glass, constituents of	42
Plant of factories	4
Plate-glass, analyses of	23
Plate-glass, annealing	45
Plate-glass, annealing-ovens for, description of	46
Plate-glass, casting	45
Plate-glass, capital invested in	3
Plate-glass, chemically, classification of	20
Plate-glass, consolidated statistics of production, etc	11
Plate-glass, constituents of	42
Plate-glass, description of machinery for grinding	46
Plate-glass, difficulties in the way of the manufacture of, in the United States	98
Plate-glass, early attempts to make, in the United States	98
Plate-glass, English, constituents of	42
Plate-glass factories, definition of	1
Plate-glass factories in Europe	70
Plate-glass, French, character of	69
Plate-glass, French, constituents of	42
Plate-glass, grinding, description of process of	46
Plate-glass, history of manufacture of, in France	56
Plate-glass in the United States, history of the manufacture of	98
Plate-glass, kind of, produced at the different establishments	3
Plate-glass, largest plates made	46, 73
Plate-glass, loss of, in grinding, smoothing, and polishing	46
Plate-glass making in France	66
Plate-glass manufacture, early, in Massachusetts	98
Plate-glass manufacture in Belgium, establishment of	57
Plate-glass manufacture in England, establishment of	57
Plate-glass, manufacture of, in Austria-Hungary	75
Plate-glass, manufacture of, in France	73
Plate-glass, manufacture of, in Indiana	99
Plate-glass, manufacture of, in Missouri	99
Plate-glass, Mr. Charles Palmer on the production of, in England, France, and Belgium	70, 71
Plate-glass, polishing	46
Plate-glass pots, size of	41
Plate-glass, prices of, in Europe	71
Plate-glass, process of manufacture of	45
Plate-glass, statistics of production of	10
Plate-glass, production of, in Belgium	70
Plate-glass, production of, in England	70
Plate-glass, production of, in Europe	70, 71
Plate-glass, production of, in France	70
Plate-glass, production of, value of	10
Plate-glass, product of, value of	9
Plate-glass, proportion of materials used in manufacture of	42
Plate-glass, relative productive rank of the states in	9
Plate-glass, results of the attempt to manufacture, in the United States	99
Plate-glass, rolling	45
Plate-glass, size of, made at Saint-Gobain	73
Plate-glass, size of melting-pots for manufacture of	41, 45
Plate-glass, smoothing	46
Plate-glass, Thevart's invention of	56
Plate-glass, thickness of	46
Plate-glass, time of melting, in English houses	44
Plate-glass works, furnaces in, number of	3
Plate-glass works, pots in, number of	3
Pliny's story of the discovery of glass	59
Poitiers, glass found at	63
Poitiers, variety of glass found in tombs at	63
Polished plate, definition of	20
Polished plate, establishments producing	3
Polished plate-glass, value per square foot of	10
Polishing-machines in plate-glass factories, number of	4
Polishing plate-glass	46
Pompeii, window-glass discovered at	56
Pontil, use of	51
Portland vase, the	52
Portugal, glass-making in	70
Portugal, present condition of glass-making in	77
Potash, early history of use of	32
Potash, early sources of supply of	32
Potash, use of, recent	32
Pot-clay, American, analyses of	40
Pot-clay, analyses of	40
Pot-clay, different localities in which produced	39
Pot-clay, preparation of, for making pots	40
Pot-metal	26
Pots	34, 41
Pots, covered, use of, in glass-making	57
Pots, difficulty of setting	40, 41
Pots, drying of	40
Potsherds, use of	40
Pots, how made	40
Pots, life of	41
Pots, number of	3
Pots, shape of	41
Pots, size of	41–44
Pots, size of, effect of, on time of melting	44
Pots, soundness of, how tested	41
Pots used, number of	18
Power used in glass works	5
Preliminary heating of batch	43
Preliminary report, March 30, 1880	ix
Prepared quartz, sand and, relative cost of, in Vienna	28
Presentation of flint goblets to Washington by Mr. Amelung	95
Present condition of glass-making in Austria-Hungary	74, 75
Present condition of glass-making in Europe	69–77
Present condition of glass-making in Germany	74
Present condition of glass-making in Holland	77
Present condition of glass-making in Italy	76
Present condition of glass-making in Norway	77
Present condition of glass-making in Portugal	77
Present condition of glass-making in Russia	76
Present condition of glass-making in Spain	77
Present condition of glass-making in Sweden	76
Pressed glass an American invention	58
Pressed glass, ancient, how made	58
Pressed glass, description of process of manufacture	47
Pressed glass, history of the invention of	58
Pressed glass, lever-press for making, description of	47
Pressed glass, molds for making, description of	47
Pressed glass, the first	58
Pressed tumbler, the first	58
Presses in glassware factories, number of	4
Pressing, blowing and, united to produce same form of glass	45
Pressing bottles	48
Pressing, casting and, relative processes	45
Pressing curved hollow articles	48
Pressing, effect of, in cheapening glass	58
Pressing goblets	48
Pressing lamps	48
Pressing, method of manufacture of balls by	48
Pressing, method of manufacture of battery jars by	48

	Page.
Pressing, method of manufacture of insulators by	48
Pressing process, improvements in	47
Pressing taper articles	48
Prices of plate-glass in Europe	71
Prince Rupert's drops	21, 53
Privileges, special, given to glass-makers	63
Prize offered for glass-making	81
Process for making soda, the ammonia	31
Process for making soda, the Solvay	31
Process of manufacture of plate-glass	45
Productive rank of the states, relative	9
Product of glass, value of	9
Profit in glass-making, no attempt to show	ix
Properties, composition, and classification of glass	19–23
Properties of glass	21, 22
Proportion of batch in glass houses of Austria-Hungary	44
Proportion of materials used in the manufacture of glass	41–43
Proportion of silica in glass	24

Q.

Quality of American glass (note)	69
Quality of Belgian glass	74
Quality of Bohemian glass	70, 74
Quality of German glass	74
Quartz, early use of, in glass-making	26
Quartz still used	27, 28
Quartz, use of, in manufacture of glass	24

R.

Rambler, Johnson's, quoted	22
Range of wages	6, 7
Raw glass, production of, in Austria	44
Reaumur's porcelain	22
Red lead or litharge used, amount of	18
Red lead, use of	33
Refining glass in Austria	44
Refining, heat of	43
Refining, time of	43
Remains of ancient Egyptian glass furnaces found by Napoleon I	60
Renaissance, influence of the, on glass-making	65
Report, preliminary, March 30, 1880	ix
Report, this, scope of	1
Revenue scheme, Townsend's, effect of, on glass-making	80
Revival of Venetian glass-making	65
Reworked glass not included in report	1
Richmond, Virginia, manufacture of glass at	78
River or sea sand	25
Rochette of Syria	31
Rolled cathedral plate, definition of	20
Rolled plate	46
Rolled plate, definition of	20
Rolling plate-glass	45
Roman conquest, influence of the, in extending glass manufacture	63
Roman glass, amount of production of	62
Roman glass, specimens of, found in many countries	62
Roman molded glass	57
Romans, use of window-glass by the	56
Rough plate	46
Rough plate, definition of	20
Rough plate, establishments producing	3
Russia, history of glass-making in	68, 69
Russian glass manufacture, statistics of	76
Russia, number of plate-glass factories in	70

S.

Saint-Gobain Company	73
Salt-cake, early attempts at the use of	31
Salt-cake first used in the United States	31
Salt-cake, manufacture of, in the United States	32
Salt-cake used, amount of	18
Salt used, amount of	18
Salt, use of, in the manufacture of glass	32
Salviati and Venetian glass-making	65
Sand	24–30
Sand, American, Bontemps quoted on	26
Sand, American, character of	28
Sand, American, mode of occurrence of	25
Sand, American, Mr. Henry Chance quoted on	26
Sand, American, Thomas Webb & Son quoted on	26
Sand, analysis of, not always indicative of quality	25
Sand and prepared quartz, relative cost of, in Vienna	28
Sand, Austrian, sources of supply of	28
Sand, Belgian, sources of supply of	27
Sand, color of, not always indicative of quality	25
Sand, deposits of American	28
Sand, effect of proportion of, on time of melting	44
Sand, English, analyses of	26, 27
Sand, English, sources of supply of	26
Sand for English glass houses, sources of supply of	27
Sand for Pittsburgh glass houses, sources of supply of	29
Sand for Swedish glass houses, sources of supply of	28
Sand for Wheeling glass houses, sources of supply of	29
Sand, French, analyses of	27
Sand, French, character of	27
Sand, French, mode of occurrence of	25
Sand, German, sources of supply of	27
Sand, grinding, used, amount of	18
Sand, Herzogenrath (German)	28
Sand, Hohenbocka (German)	28
Sand, Illinois	29
Sand, impurities in, and their removal	24
Sandiver, or glass-gall	30, 43
Sand, Maryland	29
Sand, Missouri	29
Sand, mixing, used, amount of	18
Sand, mode of occurrence of	25
Sand, New England	29
Sand, New Jersey	29
Sand of the river Belus	59
Sand of United States, superiority of the	26
Sand, Phœnician	25
Sand, river or sea	25
Sand, glass, analyses of foreign	30
Sand, glass, analyses of United States	30
Sand, sources of supply of, for Austrian glass houses	28
Sand, Swedish, sources of supply of	28
Sand, tests of	25
Sand used in ancient factories	26
Saxon drinking glasses	63
Scope of report	1
Scotch pot-clay, analyses of	40
Scotland, glass-making in	64
Scott's glass house at Pittsburgh	83
Sea or river sand	25
Sea-plants, soda from ashes of	31
Second attempt at glass-making in the United States	78
Seed in glass, cause of	45
Setting of pots	41
Seybert's *Statistical Annals of the United States* quoted (note)	2
Shape of pots	41
Sheet glass, definition of	20
Sheet glass, thin, for looking-glass manufacture in Austria	44
Siége shops worked in glassware factories, number of	4, 35
Siemens, Friederich, quoted on use of alkaline rocks in Germany	28
Siemens' furnaces, number of	4
Siemens' furnace, use of, in the United States	37
Siemens' gas furnaces	36
Siemens' tank furnace	37, 38
Siemens' tank furnace for window-glass, illustration of	39
Siemens' tank furnaces, use of, in Austro-Hungarian glass houses	44
Siemens' tempered glass	54

	Page.
Siemens' tempered glass, process of manufacture of	54
Silica in glass, proportion of	24
Siliceous rocks, use of in manufacture of glass	24
Size of Austrian glass pots	41
Size of Bohemian glass pots	41, 44
Size of bottle-glass pots	41
Size of colored-glass pots	41
Size of English pots	41, 44
Size of flint-glass pots	41
Size of French pots	41, 44
Size of furnaces	36
Size of German glass pots	41
Size of melting-pots for manufacture of plate-glass	45
Size of plate-glass made at Saint-Gobain works	73
Size of plate-glass pots	41
Size of pots, effect of, on time of melting	44
Size of pots in different countries	41
Slag, blast-furnace, a glass (note)	20
Slag glass, color of	55
Slag glass from blast furnaces	54
Slag glass, manufacture of	55
Smoothing-machines in plate-glass factories, number of	4
Smoothing plate-glass	46
Soda, ancient, impure	31
Soda-ash, Lahlanc's discovery of	31
Soda-ash, manufacture of, in the United States	32
Soda-ash used, amount of	18
Soda, Egyptian, where procured	30
Soda from ashes of sea-plants	31
Soda glass, ancient glass a	30
Soda, imports of	31
Soda, nitrate of, use of	32
Soda, production of	31
Soda, sources of supply of, for ancient glass houses	30
Soda, Spanish, of Alicant	31
Soda window-glass, effect of dampness on	30
Soluble glass, definition of	21
Soluble glass, uses of	21
Solvay process for making soda	31
Soundness of pots, how tested	41
Sources of supply of Austrian sand	28
Sources of supply of Belgian sand	27
Sources of supply of English sand	26
Sources of supply of German sand	27
Sources of supply of lime	33
Sources of supply of potash, early	32
Sources of supply of sand for Austrian glass houses	28
Sources of supply of sand for English glass houses	27
Sources of supply of sand for Pittsburgh glass houses	29
Sources of supply of sand for Swedish glass houses	28
Sources of supply of sand for Wheeling glass houses	29
Sources of supply of soda	31
Sources of supply of soda for ancient glass houses	30
Sources of supply of Swedish sand	28
Spain, early glass works in	63
Spain, glass-making in	70
Spain, modern glass manufacture in	66, 67
Spain, present condition of glass-making in	77
Spain, statistics of glass factories in	77
Spanish barilla	31
Spanish glass, character of modern	67
Spanish soda of Alicant	31
Special privileges given to glass-makers	63
Specialties, England's, in glass-making	69
Specialties, France's, in glass-making	69
Specialty, Austria-Hungary's, in glass-making	70
Specialty, Belgium's, in glass-making	69
Specialty, Germany's, in glass-making	70
Specific gravity of glass	21
Specimens of Roman glass found in many countries	62
Spun glass, definition of	21
Stained glass, definition of	20
Stained glass, French	69
Stained glass, statistics of, not included in report	1
State bounty in Massachusetts for glass-making	89
State of the art in ancient Egypt	59
States, relative productive rank of the	9
Statistics for 1870	2
Statistics for 1880, summary of	1
Statistics of all the glass works of the United States, consolidated, by states	15
Statistics of all the glass works of the United States, by states and counties	15, 16, 17
Statistics of glass factories in Spain	77
Statistics of glass-making in Austria-Hungary	75
Statistics of glass-making in Belgium	74
Statistics of glass-making in Connecticut at various dates	95
Statistics of glass-making in Great Britain	72
Statistics of glass-making in Holland	77
Statistics of glass-making in Italy	76
Statistics of glass-making in New Jersey at various dates	96
Statistics of glass-making in Norway	77
Statistics of glass-making in Pittsburgh for a series of years	87, 88
Statistics of glass-making in Russia	76
Statistics of glass-making in Sweden	76
Statistics of glass-making in Venice	76
Statistics of idle and building glass works	2, 3, 13, 14
Steam-engines in glass factories, number of	4, 5
Steigel's, Baron, glass works, at Lancaster	80
Stirring of the materials, how accomplished	43
Store-pay	8, 9
Stourbridge pot-clay, analyses of	40
Strass	21
Strass, use of, in imitations of precious stones	46
Straw and hay used, amount of	18
Strength, crushing, of glass	21, 22
Strength, tensile, of glass	21, 22
Striæ in glass, cause of	45
Strings in glass, cause of	45
Sulphate glass	31
Summary of statistics for 1880	1
Superiority of the sand of the United States	26
Sweden, glass-making in	70
Sweden, present condition of manufacture of glass in	76
Sweden, statistics of glass manufacture in	76
Swedish glass houses, sources of supply of sand for	28
Swedish sand, sources of supply of	28
Syria, rochette of	31

T.

	Page.
Tank furnace for window-glass, illustration of Siemens'	39
Tank furnaces, general description of	39
Tank furnace, Siemens'	37, 38
Tank furnaces, number of	4
Tears in glass, cause of	45
Tear-sown bottles	61
Teaser, duties of	43
Tempered glass	52
Tempered glass, defects of	53
Tempered glass, definition of	21
Tempered glass, Siemens, cost of	54
Tempered glass, Siemens, tests of	54
Tempered glass, Siemens, uses of	54
Temple, New Hampshire, glass-making in	91
Tensile strength of glass	21, 22
Tension of glass	21
Tests of sand	25
Theophilus' account of blown window-glass	57
Thevart's invention of plate-glass	56
Thickness of plate glass	46
Thin pots, use of, in France	44
Thin sheet glass for looking-glass manufacture in Austria	44
Threads in glass, cause of	45
Time occupied in melting	43

Page.

Time of cooling 44
Time of fining in English houses 44
Time of fining in lime-glass houses 44
Time of fining in the glass houses of the United States 44
Time of melting crown-glass in English houses 44
Time of melting depends on furnace, materials, and size of pots 43
Time of melting, effect of proportion of lead on 44
Time of melting, effect of proportion of sand on 44
Time of melting, effect of size of pots on 44
Tin amalgam for mirrors a German invention 63
Tomlinson's classification of glass (note) 20
Tools used in the manufacture of flint-glass 51
Toughened glass 52
Toughened glass, definition of 21
Townsend's revenue scheme, effect of, on glass-making 80
Transmittal, letter of ix
Transparent glass, earliest specimen of 61
Tribute on glass, ordinance of Aurelian regarding 59
Truck payment 8
Tumblers, number made 11
Tumbler, the first, pressed 58

U.

United States, first glass house in the 77
United States, glass sands of the, analyses of the 30
United States, history of glass-making in 77–79
United States, history of the manufacture of plate-glass in the 98, 99
United States, imports of glass into the 99–101
United States, results of attempts to manufacture plate-glass in the 99
United States, salt-cake first used in the 31
United States, second attempt at glass-making in the 78
United States, superiority of sand of 26
United States, time of fining in the glass houses of 44
United States, time of melting in the glass houses of 44
Ure's definition of glass (note) 19
Ure's classification of glass (note) 20
Use of flint in manufacture of glass 24
Use of glass in ancient Rome 62
Use of quartz in manufacture of glass 24
Use of window-glass by the ancients, extent of 56
Uses of soluble glass 21
Uses of water glass 21

V.

Varec of Bretagne 31
Variability of composition 19
Varieties of Egyptian glass 60
Variety of early glass 34
Variety of glass found in tombs at Poitiers 63
Variety of Roman glass 62
Vases de verre, manufacture of, in France 66
Vehicles used in glass works 5
Venetian glass 70
Venetian glass-making, early 65
Venetian glass-making, revival of 65
Venetian glass manufacture 76
Venice, glass-bead manufacture in 70
Venice, influence of, on modern glass-making 64
Venice, influence of, on the manufacture of English glass 68
Venice, modern glass-making dates from 64
Vermont, history of glass-making in 97
Virginia, Captain Norton sent to, to make glass 78
Virginia, history of glass-making in 77, 78
Virginia, manufacture of beads in 78

W.

Wages, annual settlement of 8
Wages paid 6
Wages, range of 6, 7
Wagons in glass factories, number of 4, 5
Washing sand, method of, to remove impurities (note) 24
Washington, presentation of flint goblets to, by Mr. Amelung 95
Water glass (note) 20
Water glass, definition of 21

Page.

Water glass, uses of 21
Watson, Elkanah, on glass-making in Albany 93
Waves in glass 45
Wearing fabrics, glass, manufacture of, in Austria-Hungary 75
Weather, influence of, on composition of glass 41
Weather, influence of, on melting glass 41
Webb, Thomas, & Son, quoted on American sand 26
Wellsburg, West Virginia, manufacture of glass at 78
West Virginia, history of glass-making in 78, 79
Wheeling, gas furnaces at 79
Wheeling glass houses, sources of supply of sand for 29
Wheeling, West Virginia, history of glass-making at 78, 79
White glass, French, character of 69
Winckelman's views on the antiquity of window-glass 56
Window-glass, analyses of 23
Window-glass, ancient, character of 56
Window-glass, average value per box of 10
Window-glass, Belgian 69
Window-glass, Belgian, importation of, into the United States 69
Window-glass blowing 50
Window-glass, blown, early manufacture of 57
Window-glass, blown, Theophilus' account of 57
Window-glass, capital invested in 3
Window-glass, classification of, chemical 20
Window-glass, composition of 19
Window-glass, consolidated statistics of, production, etc 12
Window-glass, constituents of 42
Window-glass cylinders, how opened 50
Window-glass, decoration of, in France 73
Window-glass, defects of 50
Window-glass discovered at Pompeii 56
Window-glass, English, constituents of 42
Window-glass, extent of use of, by the ancients 56
Window-glass factories, definition of 1
Window-glass found at Pompeii, analysis of 56
Window-glass, French, constituents of 42
Window-glass in Germany, early manufacture of 63
Window-glass known to the ancients 56
Window-glass, largest size of, made 51
Window-glass manufacture in Europe 71
Window-glass, method of manufacture of 50
Window-glass, method of manufacture of ancient 56
Window-glass, number of boxes made 10
Window-glass, Pittsburgh, constituents of 42
Window-glass, price of, in 1797 83
Window-glass, product of, value of 9, 10
Window-glass, proportion of materials used in the manufacture of 42
Window-glass, relative productive rank of the states in 9
Window-glass, Siemens' tank furnaces for, illustration of 39
Window-glass, size of 20, 51
Window-glass, time of melting in English houses 44
Window-glass used in Great Britain in the Roman period 56
Window-glass, early use of 56
Window-glass works, early, in England 56
Window-glass works, furnaces in, number of 3
Window-glass works in the United States in 1787 83
Window-glass works, pots in, number of 3
Women, number of, in glass factories 6
Women, work of, in glass factories 6
Wood ashes, potash made from 32
Wood furnaces, number of 4
Wood used, amount of 18
Work of children in glass factories 5
Work of women in glass factories 5
Work of youths in glass factories 5
Works building in census year, statistics of 3, 13, 14
Works idle in census year, statistics of 2, 13, 14

Y.

Youths, number of, in glass factories 5
Youths, work of, in glass factories 5