REPORT

ON THE

MANUFACTURE OF GLASS.

BY

JOS. D. WEEKS,
SPECIAL AGENT.

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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 Britannica*, 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	$19,844,099	$13,826,142
Wages paid	9,144,100	7,580,110
Amount of materials used	8,028,621	5,904,365
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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	605
Glassware	73	6, 007, 278	130	1, 247
Green glass	42	4, 607, 166	74	443
Total	169	18, 804, 599	288	2, 430

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	156	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.
Managers	23	$1 16 to $6 00	$3 90
Boss blowers	44	2 57 to 12 00	5 47
Blowers	424	2 18 to 12 00	5 30
Gatherers or tending-boys:			
16 years and upward	424	1 76 to 6 00	2 72
Under 16 years	34	30 to 39	35
Master teasers	56	2 11 to 5 00	3 35
Master teasers' helpers	55	1 17 to 2 50	1 83
Teasers	158	1 00 to 2 36	1 74
Lime sifters	34	1 00 to 2 16⅔	1 70
Mixers	65	1 00 to 3 00	1 72
Batch wheelers or fillers-in	55	1 00 to 2 00	1 75
Coal wheelers	46	96 to 2 25	1 63
Flatteners	109	2 50 to 5 77	3 82
Layers-out	67	77 to 2 25	1 80
Layers-in	78	77 to 2 33⅓	1 61
Leer tenders	71	96 to 2 26	1 64
Roller-boys:			
16 years and upward	70	38 to 1 50	78
Under 16 years	22	75 to 1 00	88
Pot makers	36	1 54 to 5 00	2 96
Clay trampers	89	1 00 to 2 00	1 25
Boss cutters	22	2 88 to 7 00	4 21
Cutters	144	$2 00 to $4 50	$3 14
Packers:			
16 years and upward	52	1 15 to 5 68	2 14
Under 16 years	2	50	50
Drivers	80	1 00 to 2 50	1 36
Laborers	251	1 00 to 1 40	1 18
Box makers	26	75 to 1 75	1 31
Blacksmiths	13	1 17 to 2 50	1 95
Engineers	5	1 50 to 3 15	1 83
Watchmen	5	1 00 to 1 50	1 23
Assorters	5	2 00 to 3 00	2 40
Sawyers	2	1 12½ to 2 00	1 56
Clay grinders	2	1 00 to 1 46	1 23
Carpenters	6	1 75 to 1 80	1 78
Warehouse men	2	2 00 to 2 50	2 25
Clerks	7	1 66 to 4 00	1 88
Blow-furnace teasers	1	2 00	2 00
Masons	4	2 00	2 00
Bookkeepers	1	4 00	4 00
Pot-arch men	2	1 12½	1 12½
Teamsters	2	1 25	1 25
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	$3 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 53	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 00	1 29
Gatherers:				Ware boys	62	58⅓ 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	83⅔ 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.

Classes.	Number.	Range.	Average.	Classes.	Number.	Range.	Average.
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 30	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 20	2 00	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 40	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.

Classes.	Number.	Range.	Average.	Classes.	Number.	Range.	Average.
Managers	52	$3 00 to $8 11	$4 46	Cutters:			
Pressers	306	2 00 to 5 00	3 53	Males 16 years and upward	228	$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	70 to 80	79	Mold makers	120	1 50 to 6 00	3 05
Gatherers:				Machinists *	30	1 50 to 6 50	2 80
Males 16 years and upward	800	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 34	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 50	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 62⅔	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	1,028	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, (21	100. 00
Plate-glass	438, 457	5. 46
Window-glass	1, 849, 530	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.
The United States	$21, 154, 571	100. 00
Pennsylvania	8, 720, 584	41. 22
New Jersey	2, 810, 170	13. 28
New York	2, 420, 796	11. 44
Ohio	1, 549, 320	7. 32
Missouri	919, 827	4. 35
Illinois	901, 343	4. 26
Massachusetts	854, 345	4. 04
Indiana	$790, 781	3. 74
West Virginia	748, 500	3. 54
Maryland	587, 000	2. 77
Kentucky	388, 405	1. 84
Connecticut	160, 000	0. 76
California	140, 000	0. 66
Michigan	90, 000	0. 43
New Hampshire	70, 000	0. 33
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	332,000	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	215,330	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	1,616,750	28.51
New York	722,322	12.74
Illinois	528,030	9.31
Missouri	392,790	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 70⅝ 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 888,639 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: 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: Total cast.	Total polished.	Sold rough.	Total value of products.
															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	......	......	120,000	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.	Number of furnaces: Gas.	Number of furnaces: Tank.	Number of furnaces: Other kinds.	Number of furnaces: 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, 130, 536	$1, 840, 530	1, 864, 734	$5, 047, 313
Illinois	4	235, 000	6	....	....	6	58	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, 750	229, 397
Iowa*	1	25, 000	1	....	....	1	8	......	......	......	......	......	......	......	......	......
Maryland	4	305, 000	5	....	....	5	42	222	222	......	......	......	131, 454	147, 277	141, 000	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	35, 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	280, 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, 691	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.	Number of furnaces: Gas.	Number of furnaces: Tank.	Number of furnaces: Other kinds.	Number of furnaces: 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	16	......	......	......	......	......	......	......	......
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	400, 000
New York	14	775, 600	24	......	......	24	215	1, 847	1, 157	30	653	7	501, 576	426, 826	1, 157, 571
Ohio	10	579, 750	18	5	......	13	191	1, 225	781	81	363	......	452, 650	300, 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, 901	4, 881, 312
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.

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

States.	No. of establishments.	Capital.	Number of furnaces: Total.	Number of furnaces: Gas.	Number of furnaces: Tank.	Number of furnaces: Other kinds.	Number of furnaces: 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, 691	4, 948	136	1, 574	33	$2, 259, 894	$2, 448, 254	$5, 670, 483
California	1	75, 000	1	......	......	1	7	113	80	......	33	......	45, 924	48, 070	140, 000
Illinois	2	190, 000	4	......	......	4	36	507	410	......	97	......	196, 824	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, 000
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, 066	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, 600	293, 297	722, 322
Ohio	4	160, 100	5	......	......	5	30	190	120	......	70	......	45, 000	43, 553	115, 000
Pennsylvania	14	1, 381, 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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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	26
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		10	22	201

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

States.	No. of establishments.	Capital.	FURNACES. Kind and number. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. Gas.	Tank.	Other kinds.	Total number.	Total number of pots.
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. 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	211	$19,844,699	348	21	5	322	2,082	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	108	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	8	436,000	10	......	......	10	76	612	524	......	88	......	234,254	230,682	587,000
Massachusetts	11	828,000	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	2,810,170
New York	32	1,933,600	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	8,720,584
West Virginia	4	550,522	8	2	......	6	82	946	615	100	228	3	311,650	208,004	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. Total.	Gas.	Tank.	Other kinds.	Pots.	NUMBER OF HANDS EMPLOYED. Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
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	235,000	6	......	......	6	60	387	337	......	50	195,508	168,755	523,343
Madison	1	140,000	2	......	......	2	14	280	230	......	50	101,519	92,707	285,000
Rock Island	1	50,000	2	......	......	2	20	65	65	......	......	45,000	36,880	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. Total.	Gas.	Tank.	Other kinds.	Pots.	NUMBER OF HANDS EMPLOYED. Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
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	16	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
Total for State	11	$823,000	22	1	......	21	206	946	828	58	60	$383,342	$320,864	$854,345
Barnstable	2	206,000	5	......	......	5	50	217	180	25	12	100,000	85,000	200,000
Berkshire	4	120,000	6	1	......	5	52	157	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
Wayne	1	$65,000	1	......	......	1	8	54	50	......	4	$30,000	$35,113	$90,000

MISSISSIPPI.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
Jackson *	1	$25,000	1	......	......	1	8	......	......	......	......	......	......	......

* Building.

MISSOURI.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
Total for State	6	$1,430,000	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Wages.	Materials.	Products.
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	130,000	4	......	......	4	34	......	......	......	......	....	....	....
Camden	4	200,000	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	373,900	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
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	10,000	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	489,593	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	......	......	63,170	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	28,257	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
Total for State	20	$1,194,850	29	5	......	24	277	1,688	1,170	81	437	$644,520	$459,333	$1,549,320
Belmont	9	485,350	15	3	......	12	151	829	528	51	250	335,805	225,872	794,920
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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
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	318	310	......	8	137,959	84,043	361,315
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	1,212,419	18	2	......	16	158	2,237	1,358	128	751	655,022	606,393	1,021,959
Tioga	2	66,000	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.

Counties.	Number of establishments.	Capital.	Furnaces: Total.	Gas.	Tank.	Other kinds.	Pots.	Hands: Total.	Males above 16 years.	Females above 15 years.	Children and youths.	Total amount paid in wages during the year.	Total value of materials.	Total value of products.
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.	Limestone.	Litharge.	Pearl-ash.	Arsenic.	Manganese.
	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	718, 974	191, 146
California	1, 200	....	520	....	....	55	6, 875	....	....	....	....	....
Connecticut	....	....	....	....	....	....	....	....	....	....	....	....
Illinois	9, 767	....	2, 495	....	648	611	49, 607	300	....	....	26, 100	....
Indiana	7, 124	32, 300	2, 854	....	....	83	47, 842	....	....	....	32, 000	....
Iowa	25	....	10	2	....	....	650	....	....	....	....	400
Kentucky	3, 543	....	840	40	337	25	10, 300	12	7, 000	20, 000	302	1, 600
Maryland	5, 344	....	1, 902	36	30	40	62, 865	....	....	....	2, 710	1, 500
Massachusetts	2, 205	....	392	75	255	....	2, 348	346	208, 260	130, 111	6, 697	9, 040
Michigan	650	....	225	....	....	2	3, 500	....	....	....	930	....
Missouri	8, 042	7, 200	3, 071	31	....	233	47, 275	360	....	....	24, 000	3, 000
New Hampshire	500	....	200	....	200	....	2, 800	....	....	....	....	....
New Jersey	26, 282	....	8, 274	120	1, 320	163	174, 680	455	20, 000	100	88, 453	12, 000
New York	16, 122	....	5, 805	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	392	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, 208
California	120, 000	24, 000	56, 000	60	1, 050	....	875	128	100	50	72
Connecticut	....	....	....	16	1, 800	300	50	....	....	....	....
Illinois	817, 000	....	16, 000	627	35, 242	400	4, 212	2, 612	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	982	60	1, 115	400	600	1, 155
Maryland	68, 000	....	624, 000	587	15, 723	....	1, 848	2, 210	1, 200	503	409
Massachusetts	253, 679	60, 000	152, 800	150	10, 899	1, 017	1, 184	301	53, 475	148	825
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	81, 000	3, 596	3, 902
New York	242, 000	....	1, 595, 650	1, 661	52, 266	2, 484	11, 247	5, 201	147, 977	1, 698	2, 828
Ohio	706, 425	....	147, 600	835	54, 045	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, 894	516, 520	5, 062	9, 787
West Virginia	933, 720	....	....	332	19, 819	1, 923	....	838	70, 812	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	....	4	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.

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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: silicate 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.

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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	8.01	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	3.07	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	...	38.30	...	...	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.

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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.	
	Fontainebleau.*	Fontainebleau.†	Leighton Buzzard.*	Alum Bay.†	Herzogenrath.‡	Hohenbooka.§
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. Chance. †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.				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.§	Will's Mountain, Cumberland, Maryland.‖	Speer, Hancock county, West Virginia.‡	Crystal City.¶	Lincoln county.**
Silica	99.78	99.61	99.69	...	...	98.824	98.850	99.720	98.84	08.35	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	$1,555,328
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 $2\frac{1}{2}$ 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 mouths 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 *Balneæ 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. Sauzay, 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 continously 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	3,738	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

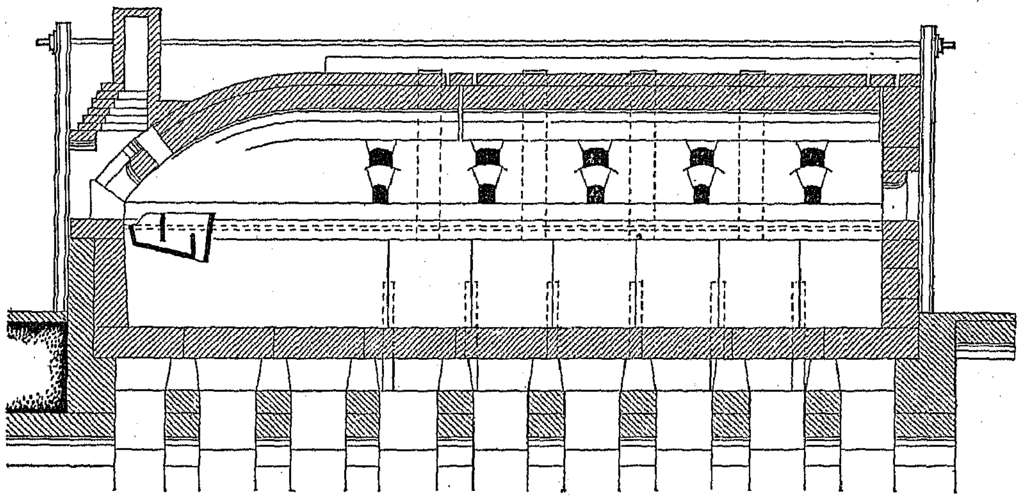


Fig. 1.

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

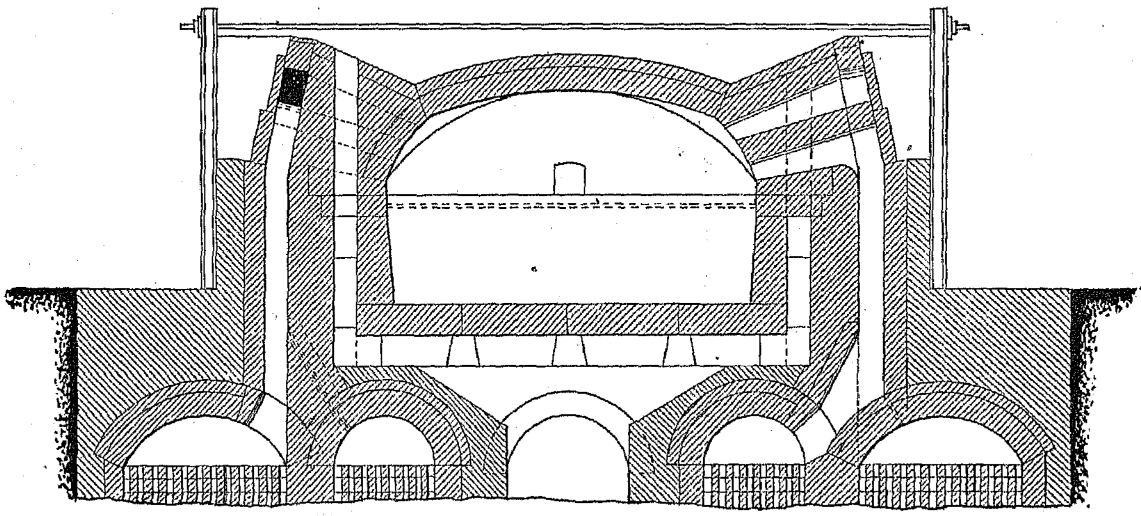


Fig. 2.

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	....	....	9.80	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	....	3.80	....
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 Bouchade	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	20.90	....	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	....

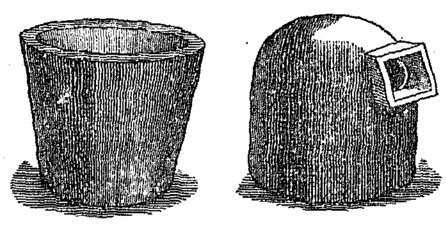
Manufacture of pots.—The manufacture of the melting-pots for a glass furnace is one of the most important, careful, and tedious of the operations about a glass works. From the digging of the clay till it is refined, mixed, kneaded, and built into pots, and these are thoroughly dried, heated, and set 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-Gobian.*	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	163	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	1½	4 to 12 oz.		0.5	
Borax					12
Arsenic	1½				

*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.	*Parts.*	*Parts.*	*Parts.*	*Parts.*	*Parts.*
Sand	1,500		300	100	100.0	100.0
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.

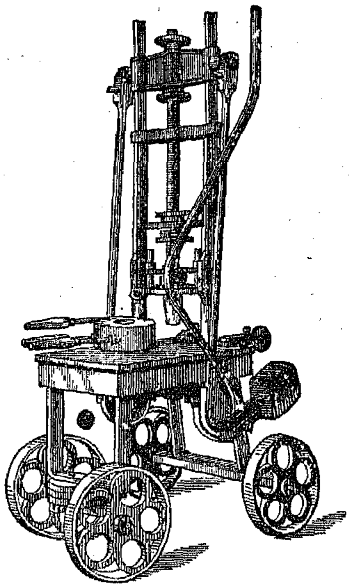
GRINDING, SMOOTHING, AND POLISHING.—The plates having been examined for defects, such as spots, air-bubbles, etc., and, if necessary, cut into such sizes as these defects require, the selected pieces are then polished, which operation consists of three processes: (1), grinding; (2), smoothing; (3), polishing; 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.