PENS AND PENCILS.

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The statistics of the manufacture of pens and pencils in the United States at the census of 1900 are presented in this report under the following groups: Pens, fountain and stylographic; pens, gold; pens, steel; and lead pencils. Statistics for each of these groups are shown separately in this report.

A summary for the combined industry, as reported for 1900, is presented in Table 1.

Table 1.—PENS, FOUNTAIN, GOLD, AND STEEL, AND PENCILS, LEAD: SUMMARY FOR THE UNITED STATES, 1900.

	Total.	Pens, fountain and stylographic.	Pens, gold.	Pens, steel.	Pencils, lead.
Number of establishments	55	23	22	3	7
Capital	$3,671,741	$590,629	$496,246	$357,460	$2,227,406
Land	$212,950	$8,150	$33,000	$20,000	$151,800
Buildings	$317,132	$13,632	$7,000	$43,000	$253,500
Machinery, tools, and implements	$535,574	$79,074	$129,775	$82,000	$244,725
Cash and sundries	$2,606,085	$489,773	$326,471	$212,460	$1,577,381
Salaried officials, clerks, etc., number	240	84	62	13	81
Salaries	$281,636	$80,808	$67,522	$21,416	$111,890
Wage-earners, average number	3,331	318	378	473	2,162
Total wages	$1,192,405	$141,012	$229,679	$138,433	$683,281
Miscellaneous expenses	$471,655	$113,334	$42,740	$37,405	$278,176
Cost of materials used	$1,747,852	$351,932	$312,587	$52,466	$1,030,917
Value of products	$4,222,148	$906,454	$799,078	$294,340	$2,222,276

It appears from Table 1 that pens, fountain and stylographic, led in the number of establishments reporting in 1900, closely followed by the gold pen industry, which reported but 1 establishment less. Of the total amount of capital invested in the four industries, lead pencils, with 7 establishments, contributed 60.7 per cent; steel pens, with 3 establishments, 9.7 per cent; gold pens, with 22 establishments, 13.5 per cent; fountain and stylographic pens, with 23 establishments, 16.1 per cent. Of the total value of products for the four industries, that reported for lead pencils formed 52.6 per cent; for fountain and stylographic pens 21.5 per cent; for gold pens, 18.9 per cent; and for steel pens, 7.0 per cent.

It should be noticed, however, that the four industries are very closely allied, and in many instances overlap. Many establishments principally engaged in manufacturing fountain and stylographic pens produced gold pens and lead pencils; and establishments principally engaged in the manufacture of gold pens reported fountain and stylographic pens and lead pencils as subsidiary products; while establishments reporting lead pencils as the principal product manufactured pens as a secondary product. In the tabulation of the reports the rule was adopted of classifying establishments in accordance with the predominating product. In following out this plan, in many instances a product that appears as the principal product of one of the industries included in this report may appear again as a subsidiary product of one or more of the other industries.

Table 2 shows the production of pens, fountain, stylographic, gold and steel, and of lead pencils, manufactured during the census year, irrespective of the classification of the establishments in which they were produced, and it seems as convenient to present this information here as at any place in the report.

Table 2.—SUMMARY: KINDS, QUANTITIES, AND VALUE OF PRODUCTS, BY STATES, 1900.

PRODUCTS.	United States.	New York.	All others.
Aggregate value	$4,119,809	$2,337,788	$1,782,021
Pens:			
Total value	$1,855,658	$1,004,401	$851,257
Fountain—			
Gross	8,028	3,760	4,268
Value	$902,734	$567,667	$335,067
Stylographic—			
Gross	1,809	1,613	196
Value	$82,676	$71,684	$10,992
Gold—			
Gross	6,735	5,210	1,525
Value	$458,376	$365,050	$93,326
Steel—			
Gross	1,764,079	.....	1,764,079
Value	$411,872	.....	$411,872
Pencils, lead:			
Total value	$2,264,151	$1,333,387	$930,764
Wood—			
Gross	1,653,973	909,170	744,803
Value	$2,053,484	$1,151,495	$901,989
Gold—			
Gross	31	26	5
Value	$32,526	$32,326	$200
Silver—			
Gross	2,281	2,055	226
Value	$111,518	$102,718	$8,800
Plated—			
Gross	3,988	3,204	784
Value	$64,523	$46,848	$17,675
Other varieties—			
Gross	581	.....	581
Value	$2,100	.....	$2,100

The aggregate value of the pens and pencils produced in the United States during the census year was $4,119,809, of which 45 per cent represented the value of pens and 55 per cent that of pencils. New York state produced 56.7 per cent of the aggregate product; and "all others," comprising those states which reported less than 3 establishments, and which are shown collectively in order to avoid disclosing the operations of individual establishments, manufactured 43.3 per cent of the entire output of pens and pencils. Of the total production of pens, 54.1 per cent were manufactured in New York state. Fountain and stylographic pens represented 53.1 per cent of the total value of pens produced, gold pens 24.7 per cent, and steel pens 22.2 per cent. New York led also in the manufacture of pencils during the census year, having produced 58.9 per cent of the total output. Lead pencils inclosed in wooden cases contributed 90.7 per cent of the total value of pencils.

The lack of uniformity in the value of the products manufactured by the establishments located in the various states is due to the variation in the quality of materials used and the design and workmanship of the articles produced. This difference in the value of the various designs is particularly noticeable in the statistics presented in the accompanying tables for establishments engaged in the manufacture of fountain, stylographic, and gold pens, and lead pencils incased in silver and gold.

Attention should be here directed to the fact that the figures reported in Table 2 possibly do not represent the total quantity and value of pens and pencils manufactured in the United States during the census year. Establishments engaged primarily in other industries may have manufactured one or more of these articles as a subsidiary product and made no direct mention of that fact in their returns. Notwithstanding these facts the figures reported may be accepted as fairly representing the quantities and values of pens and pencils manufactured during this period.

FOUNTAIN AND STYLOGRAPHIC PENS.

Although fountain and stylographic pens were manufactured in the United States prior to 1890, the census of that year was the first to publish separate statistics for the industry. The manufacture was successfully established as early as 1880, but it was included under some other classification in that year. At the close of the first ten years of its existence the industry was established in 6 states and had in operation 15 plants, well capitalized and reporting a considerable product.

Table 3 is a comparative summary of the statistics for the manufacture of fountain and stylographic pens as returned at the censuses of 1890 and 1900, with the percentages of increase for the decade.

TABLE 3.—PENS, FOUNTAIN AND STYLOGRAPHIC: COMPARATIVE SUMMARY, 1890 AND 1900, WITH PER CENT OF INCREASE FOR THE DECADE.

	DATE OF CENSUS.		PER CENT OF INCREASE.
	1900	1890	1890 to 1900
Number of establishments	23	15	53.3
Capital	$590,629	$142,265	315.2
Salaried officials, clerks, etc., number	84	[1] 24	250.0
Salaries	$80,808	[1] $28,902	179.6
Wage-earners, average number	318	152	109.2
Wages	$141,012	$73,897	90.8
Men, 16 years and over	241	128	88.3
Wages	$122,777	$67,822	81.0
Women, 16 years and over	66	24	175.0
Wages	$16,008	$6,075	163.5
Children, under 16 years	11	.....	.....
Wages	$2,227	.....	.....
Miscellaneous expenses	$113,334	$12,380	815.5
Cost of materials used	$351,932	$123,214	185.6
Value of products	$906,454	$351,775	157.7

[1] Includes proprietors and firm members, with their salaries; number only reported in 1900, but not included in this table. (See Table 9.)

The table shows that during the decade the industry made rapid advancement, not only in number of establishments, but also in the amount of capital invested and the value of products. The percentage of increase in the number of women and children employed, as compared with the percentage of increase in the number of men employed, would indicate that some branches of the work performed by men in 1890 were done by women and children in 1900. Each item in Table 3 shows a good percentage of increase for the decade, and indicates that although the industry is yet in its infancy, it is firmly established and in a healthy and prosperous condition.

Table 4 presents, by states arranged geographically, the number of establishments actively engaged in the manufacture of fountain pens in 1890 and in 1900, and the increase for the decade.

TABLE 4.—PENS, FOUNTAIN AND STYLOGRAPHIC: COMPARATIVE SUMMARY; NUMBER OF ESTABLISHMENTS 1890 AND 1900, AND INCREASE DURING THE DECADE, BY STATES ARRANGED GEOGRAPHICALLY.

STATES.	1900	1890	Increase.
United States	23	15	8
New England states	5	5	.....
Connecticut	2	1	1
Massachusetts	2	3	[1] 1
Rhode Island	1	1	.....
Middle states	11	9	2
New York	9	8	1
Pennsylvania	2	1	1
Central states	7	1	6
Illinois	.....	1	[1] 1
Indiana	1	.....	1
Iowa	1	.....	1
Ohio	4	.....	4
Wisconsin	1	.....	1

[1] Decrease.

It appears from Table 4 that there were 8 more establishments engaged in this industry in 1900 than in 1890, showing an increase of 53.3 per cent for the decade. The largest addition to the number of establishments was made by Ohio, which reported 4 establishments in 1900, having none in 1890. Massachusetts and Illinois reported decreases of 1 establishment each.

Table 5 is a comparative summary of capital as returned at the censuses of 1890 and 1900, with the per cent each item is of the total and the per cent of increase for the decade.

TABLE 5.—PENS, FOUNTAIN AND STYLOGRAPHIC: CAPITAL, 1890 AND 1900.

	1900		1890		Per cent of increase.
	Amount.	Per cent of total.	Amount.	Per cent of total.	
Total	$590,629	100.0	$142,265	100.0	315.2
Land	8,150	1.4	3,100	2.2	162.9
Buildings	13,632	2.3	3,600	2.5	278.7
Machinery, tools, and implements	79,074	13.4	36,625	25.7	115.9
Cash and sundries	489,773	82.9	98,940	69.6	395.0

The most important item reported under the head of capital, both in 1890 and in 1900, was that of cash and sundries, including cash on hand, bills receivable, unsettled ledger accounts, raw materials, stock in process of manufacture, finished products on hand, and other sundries. In 1890 this item represented 69.6 per cent of the total, and in 1900, 82.9 per cent, the increase for the decade being $390,833, or 395 per cent. The items of land, buildings, and machinery, tools, and implements, each show a large percentage of increase for the decade, but represent a smaller per cent of the total in 1900 than in 1890. The smallest increase and the most considerable reduction of percentage of the total is shown by machinery, tools, and implements, indicating that there has been but little progress made during the ten years in the way of application of new and improved machinery in this industry. The amounts reported for land, buildings, and machinery represent only such as are owned by the establishments engaged in the industry, and do not include the value of leased property.

Table 6 shows the cost of materials for 1900, and the proportion of each item to the whole amount.

TABLE 6.—PENS, FOUNTAIN AND STYLOGRAPHIC: COST OF MATERIALS USED, 1900.

	Amount.	Per cent of total.
Total	$351,932	100.0
Principal materials	347,201	98.7
Purchased in raw state	10,000	2.9
Purchased in partially manufactured form[1]	337,201	95.8
Fuel	864	0.2
Rent of power and heat	3,224	0.9
Freight	643	0.2

[1] Includes mill supplies and all other materials, which are shown separately in Table 9.

Materials purchased in partially manufactured form represented 95.8 per cent of the total cost of materials. This item includes those reported under Table 9, as "mill supplies" and "all other materials." "Mill supplies" consisted of materials, such as oil, waste, belting, and other articles which did not enter into the product, but were necessary to the process of manufacture. "All other materials" comprised those not otherwise specified in the schedule of inquiry and included such articles as boxes, bags, and packages. Materials purchased in raw state are those upon which no manufacturing force has been expended. The amount paid for fuel included that used both for motive power and for heating purposes, and is correlative with the amount paid for rent of power and heat leased from other establishments. Some establishments found it impossible, in making returns, to separate from the cost of materials the amount paid for freight, and reported the two together. For that reason, the amount of freight paid, as shown in Table 6, does not represent the entire cost of freight and should be considered only in connection with the cost of materials.

Table 7 shows in detail, by states, the quantity and value of fountain and stylographic pens manufactured during the census year, and the subsidiary products reported by the establishments engaged in this industry.

TABLE 7.—PENS, FOUNTAIN AND STYLOGRAPHIC: QUANTITY AND VALUE OF PRODUCTS, BY STATES: 1900.

STATES.	AGGREGATE VALUE.	PRODUCTS.											
		Total gross.	Total value.	Pens.									
				Total gross.	Total value.	Fountain (complete).		Gold.		Stylographic.		Other varieties.	
						Gross.	Value.	Gross.	Value.	Gross.	Value.	Gross.	Value.
Total	$906,454	8,695	$842,248	8,113	$832,748	5,836	$707,023	584	$47,945	1,686	$77,280	7	$500
New York	524,079	3,396	502,363	3,396	502,363	1,806	417,123	80	18,000	1,510	67,240	.....	.....
Ohio	52,000	650	38,985	650	38,985	165	12,000	365	21,945	120	5,040	.....	.....
All other states[1]	330,375	4,649	300,900	4,067	291,400	3,865	277,900	139	8,000	56	5,000	7	500

[1] Includes establishments distributed as follows: Connecticut, 2, Indiana, 1; Iowa, 1; Massachusetts, 1; Pennsylvania, 2; Rhode Island, 1; Wisconsin, 1.

TABLE 7.—PENS, FOUNTAIN AND STYLOGRAPHIC: QUANTITY AND VALUE OF PRODUCTS, BY STATES: 1900—Continued.

STATES.	PRODUCTS—continued.								ALL OTHER PRODUCTS.
	Pencils.								
	Total gross.	Total value.	Gold.		Plate.		Other varieties.		
			Gross.	Value.	Gross.	Value.	Gross.	Value.	Value.
Total	582	$9,500	5	$200	521	$8,000	56	$1,300	$64,206
New York									21,716
Ohio									13,015
All other states[1]	582	9,500	5	200	521	8,000	56	1,300	29,475

[1] Includes establishments distributed as follows: Connecticut, 2; Indiana, 1; Iowa, 1; Massachusetts, 1; Pennsylvania, 2; Rhode Island, 1; Wisconsin, 1.

Of the total value of the products of the establishments engaged in this industry, New York produced 59.6 per cent. The overlapping of the industries is very strikingly exemplified in the above table, especially in the production of gold pens.

The tables which have thus far been shown for this industry give an incomplete statement of the quantity and value of fountain and stylographic pens manufactured during the census year because of the rule adopted, as explained above, of classifying establishments according to the predominating product.

Table 8 makes up for this deficiency by showing the total quantity and value of fountain and stylographic pens produced during the census year, as reported by establishments of any character.

TABLE 8.—PENS, FOUNTAIN AND STYLOGRAPHIC: QUANTITY AND VALUE OF PRODUCTS, BY STATES, 1900.

STATES.	Total.	FOUNTAIN.		STYLOGRAPHIC.	
		Gross.	Value.	Gross.	Value.
United States	$985,410	8,028	$902,734	1,803	$82,676
New York	639,351	3,760	567,667	1,613	71,684
Ohio	47,740	346	42,000	130	5,740
All other states[1]	298,319	3,922	293,067	60	5,252

[1] Includes establishments distributed as follows: Connecticut, 2; Illinois, 2; Indiana, 1; Iowa, 1; Massachusetts, 1; Pennsylvania, 2; Rhode Island, 2; Wisconsin, 1.

Table 8 includes the quantity and value both of the fountain and stylographic pens produced in establishments engaged principally in their manufacture, and of those reported as a subsidiary product in establishments engaged primarily in the manufacture of gold pens and lead pencils. The values reported do not include the amounts reported as the value of "all other products," in the tables showing products by establishments, therefore the totals given in Table 8 do not agree with the totals elsewhere given in this report, or with those dealing with this industry in the general report on Manufactures, Parts I and II.

HISTORICAL AND DESCRIPTIVE.

Fountain pens are the most modern variety of pens made and represent the highest type of the pen-maker's art. The first successful manufacture of these pens in the United States dates back but twenty-one years before the taking of the Twelfth Census, although attempts were made to manufacture them before that time. They were manufactured in England as early as 1835, but they were not satisfactory enough to warrant their use to any extent.[1] At that time there were two fountain pens invented, known as the Schaeffer pen and the Parker hydraulic pen. Schaeffer's pen had a reservoir for ink in the holder and the ink was admitted to the pen by the pressure of the thumb on a projecting stud. Parker's pen also had a reservoir in the holder, which contained a piston operated by a screw stem and a nut on the end of the holder. The lower end of the reservoir being dipped in ink, the piston was drawn up by rotating the nut, thus filling the reservoir. The ink was ejected as required by a reverse motion of the thumb nut. The early attempts to construct fountain pens were generally confined to the invention of contrivances such as internal tubes, ducts, valves, or springs, which were operated upon by the action of the nibs, and which forced the ink from a feeding pipe upon the pen, assisted by air admitted at the top of the holder

[1] Universal Cyclopædia, vol. 9, page 198.

to take the place of the exhausted ink. Pens dependent upon such mechanism were very erratic in their work, as the ink flowed either too slow or too fast. After many experiments to secure a continuous and properly regulated flow of ink into the pen, it was found that the best results were obtained by the use of a tubular holder tightly closed at its upper end, and at the lower end fitted with an ordinary nib pen made of gold, with an ink feeder lying adjacent to the pen to attract the ink from the reservoir. As the ink in the process of writing is withdrawn, air enters at the lower end of the holder and ascends in globules through the column of ink to fill the space left vacant. There are many varieties of fountain pens made in the United States, but the basic principles underlying all are practically the same, the retention of the ink by atmospheric pressure and the furnishing of a supply ready for use throughout many hours of continuous writing.

The stylographic pen is a variety of fountain pen in which a blunt needle incased in a sheath at the end of the holder serves as a valve to release the ink when the point is pressed on the paper.

Table 9 presents a detailed statement of the statistics for the fountain and stylographic pen industry, by states, 1900.

TABLE 9.—PENS, FOUNTAIN AND STYLOGRAPHIC: BY STATES, 1900.

	United States.	New York.	Ohio.	All other states.[1]
Number of establishments	23	9	4	10
Character of organization:				
Individual	11	5	2	4
Firm and limited partnership	7	2	2	3
Incorporated company	5	2	.....	3
Capital:				
Total	$590,629	$261,670	$25,540	$303,419
Land	$8,150	.....	$350	$7,800
Buildings	$13,632	.....	$600	$13,032
Machinery, tools, and implements	$79,074	$25,175	$9,350	$44,549
Cash and sundries	$489,773	$236,495	$15,240	$238,038
Proprietors and firm members	25	8	6	11
Salaried officials, clerks, etc.:				
Total number	84	49	3	32
Total salaries	$80,808	$56,834	$1,669	$22,305
Officers of corporations—				
Number	9	4	.....	5
Salaries	$19,650	$13,250	.....	$6,400
General superintendents, managers, clerks, etc.—				
Total number	75	45	3	27
Total salaries	$61,158	$43,584	$1,669	$15,905
Men—				
Number	42	25	3	14
Salaries	$47,491	$33,697	$1,669	$12,125
Women—				
Number	33	20	.....	13
Salaries	$13,667	$9,887	.....	$3,780
Wage-earners, including pieceworkers, and total wages:				
Greatest number employed at any one time during the year	339	114	48	177
Least number employed at any one time during the year	299	112	39	148
Average number	318	105	43	170
Wages	$141,012	$48,395	$16,515	$76,102
Men, 16 years and over—				
Average number	241	94	27	120
Wages	$122,777	$44,620	$12,495	$65,662
Women, 16 years and over—				
Average number	66	10	15	41
Wages	$16,008	$3,550	$3,700	$8,758
Children, under 16 years—				
Average number	11	1	1	9
Wages	$2,227	$225	$320	$1,682
Average number of wage-earners, including pieceworkers, employed during each month:				
Men, 16 years and over—				
January	244	94	30	120
February	243	94	30	119
March	242	94	30	118
April	233	93	24	116
May	234	94	24	116
June	233	94	24	115
July	243	95	28	120
August	242	94	25	123
September	246	93	28	125
October	243	93	24	126
November	246	94	29	123
December	243	96	30	117
Women, 16 years and over—				
January	64	9	14	41
February	66	9	16	41
March	65	9	16	40
April	64	9	14	41
May	72	18	14	40
June	63	9	14	40
July	67	9	16	42
August	64	9	14	41
September	64	9	14	41
October	64	9	14	41
November	64	9	14	41
December	75	12	20	43
Children, under 16 years—				
January	12	1	2	9
February	12	1	2	9
March	12	1	2	9
April	11	1	1	9
May	12	1	1	10
June	11	[illegible]	1	9

[1] Includes establishments distributed as follows: Connecticut, 2; Indiana, 1; Iowa, 1; Massachusetts, 2; Pennsylvania, 2; Rhode Island, 1; Wisconsin, 1.

TABLE 9.—PENS, FOUNTAIN AND STYLOGRAPHIC: BY STATES: 1900—Continued.

	United States.	New York.	Ohio.	All other states.[1]
Average number of wage-earners, including pieceworkers, employed during each month—Continued.				
Children, under 16 years—Continued.				
July	11	1	1	9
August	12	1	2	9
September	11	1	1	9
October	11	1	1	9
November	11	1	1	9
December	6	1	1	4
Miscellaneous expenses:				
Total	$113,334	$72,371	$2,964	$37,999
Rent of works	$15,880	$11,620	$1,400	$2,860
Taxes, not including internal revenue	$936	$142	$37	$757
Rent of offices, insurance, interest, and all sundry expenses not hitherto included	$94,518	$58,609	$1,527	$34,382
Amount paid for contract work	$2,000	$2,000	.....	.....
Materials used:				
Total cost	$351,932	$235,550	$22,189	$94,193
Principal materials—				
Total cost	$314,153	$206,543	$20,109	$87,501
Purchased in raw state	$10,000	.....	.....	$10,000
Purchased in partially manufactured form	$304,153	$206,543	$20,109	$77,501
Fuel	$864	$146	$95	$623
Rent of power and heat	$3,224	$1,690	$320	$1,214
Mill supplies	$821	$76	$20	$725
All other materials	$32,227	$26,995	$1,357	$3,875
Freight	$643	$100	$288	$255
Products:				
Total value	$906,454	$524,079	$52,000	$330,375
Pens and pencils—				
Total value	$842,248	$502,363	$38,985	$300,900
Pens—				
Total gross	8,113	3,396	650	4,067
Total value	$832,748	$502,363	$38,985	$291,400
Fountain (complete)—				
Number of gross	5,836	1,806	165	3,865
Value	$707,023	$417,123	$12,000	$277,900
Gold—				
Number of gross	584	80	365	139
Value	$47,945	$18,000	$21,945	$8,000
Stylographic—				
Number of gross	1,686	1,510	120	56
Value	$77,280	$67,240	$5,040	$5,000
Other varieties—				
Number of gross	7	.....	.....	7
Value	$500	.....	.....	$500
Pencils—				
Total gross	582	.....	.....	582
Total value	$9,500	.....	.....	$9,500
Gold—				
Number of gross	5	.....	.....	5
Value	$200	.....	.....	$200
Plated—				
Number of gross	521	.....	.....	521
Value	$8,000	.....	.....	$8,000
Other varieties—				
Number of gross	56	.....	.....	56
Value	$1,300	.....	.....	$1,300
All other products	$64,206	$21,716	$13,015	$29,475
Comparison of products:				
Number of establishments reporting for both years	20	8	3	9
Value for census year	$893,154	$523,579	$51,200	$318,375
Value for preceding business year	$756,369	$435,619	$49,750	$271,000
Power:				
Number of establishments reporting	15	6	2	7
Total horsepower	406	20	7	379
Owned—				
Engines—				
Steam—				
Number	3	.....	.....	3
Horsepower	270	.....	.....	270
Rented—				
Electric, horsepower	31	20	2	9
Other kind, horsepower	105	.....	5	100
Horsepower furnished to other establishments	1	.....	.....	1
Establishments classified by number of persons employed, not including proprietors and firm members:				
Total number of establishments	23	9	4	10
No employees	3	.....	2	1
Under 5	4	2	.....	2
5 to 20	8	4	1	3
21 to 50	6	2	1	3
51 to 100	2	1	.....	1
101 to 250	.....	.....	.....	.....
251 to 500	.....	.....	.....	.....
501 to 1,000	.....	.....	.....	.....
Over 1,000	.....	.....	.....	.....

[1] Includes establishments distributed as follows: Connecticut, 2; Indiana, 1; Iowa, 1; Massachusetts, 2; Pennsylvania, 2; Rhode Island, 1; Wisconsin, 1.

GOLD PENS.

Although the manufacture of gold pens was carried on successfully as early as 1850, the census reports on this industry prior to 1880 were not sufficiently accurate to justify their use in comparisons with later censuses to show the growth of the industry. The census of 1850 reported the manufacture of pens under the general classification of pens and pencils, and, as there was but a small amount of pencils, and a very limited amount, if any, of steel, fountain, and stylographic pens produced in the United States at that time, a very large proportion of the value of the products reported for that year was obviously that of gold pens. In the census of 1860 the manufacture of gold pens was reported as a subdivision of jewelry, and the reports show that there were then 9 establishments engaged in the industry, with a capital of $32,500, employing 89 people at a cost of $32,228, and manufacturing products to the value of $113,600. The census of 1870 reported the industry in connection with the manufacture of gold pencils. The statistics for these combined industries in 1870 showed that there were 21 establishments engaged in the manufacture of gold pens and pencils, and that they had a capital of $268,250, and a product of $467,380. The growth of the gold pen industry since 1880 has been gradual but satisfactory, as is shown by the statistics presented in the following tables.

Table 10 is a comparative summary of the statistics of the manufacture of gold pens as returned at the censuses of 1880 to 1900, inclusive, with the percentage of increase for each decade.

TABLE 10.—PENS, GOLD: COMPARATIVE SUMMARY, 1880 TO 1900, WITH PER CENT OF INCREASE FOR EACH DECADE.

	DATE OF CENSUS.			PER CENT OF INCREASE.	
	1900	1890	1880	1890 to 1900	1880 to 1890
Number of establishments	22	18	16	22.2	12.5
Capital	$496,246	$473,964	$370,150	4.7	28.0
Salaried officials, clerks, etc., number	62	[1]62	(2)	.....	.....
Salaries	$67,522	[1]$75,124	(2)	[4]10.1	.....
Wage-earners, average number	378	301	264	25.6	14.0
Total wages	$229,679	$185,545	$172,207	23.8	7.7
Men, 16 years and over	337	277	226	21.7	22.6
Wages	$216,838	$178,489	(2)	21.5	.....
Women, 16 years and over	38	23	19	65.2	21.1
Wages	$12,541	$6,952	(2)	80.4	.....
Children, under 16 years	3	1	19	200.0	[4]94.7
Wages	$300	$104	(2)	188.5	.....
Miscellaneous expenses	$42,740	$82,753	(3)	[4]48.4	.....
Cost of materials used	$312,537	$235,628	$190,906	32.6	23.4
Value of products, including custom work and repairing	$799,078	$718,070	$533,061	11.3	34.7

[1] Includes proprietors and firm members, with their salaries; number only reported in 1900, but not included in this table. (See Table 16.)
[2] Not reported separately.
[3] Not reported.
[4] Decrease.

It appears from Table 10 that for the decade between 1880 and 1890 the increase in capital and value of products was comparatively large, and in number of establishments, comparatively small; while for the decade between 1890 and 1900 the increase in number of establishments was greater than in the preceding decade, yet the capital increased hardly at all, and the value of products little.

Table 11 presents, by states, the number of establishments actively engaged in the manufacture of gold pens in 1890 and 1900, with the increase for the decade.

TABLE 11.—PENS, GOLD: NUMBER OF ESTABLISHMENTS, BY STATES, 1890 AND 1900.

STATES.	1900	1890	Increase.
United States	22	18	4
California	1	1	.....
Illinois	2	.....	2
Maryland	1	.....	1
Massachusetts	1	1	.....
Michigan	1	1	.....
Nebraska	.....	1	[1]1
New York	14	12	2
Ohio	1	1	.....
Rhode Island	1	1	.....

[1] Decrease.

Two-thirds of the establishments, both in 1890 and 1900, were located in New York. During the decade there was a net increase of 4 establishments in the United States; Illinois and New York contributing 2 each, and Maryland 1. The only state showing a decrease was Nebraska, which reported 1 establishment in 1890 and none in 1900.

A comparative summary of capital in its several subdivisions for 1890 and 1900, giving percentages of increase between the two census years, and the proportion of each item to the total for those years, is presented in Table 12.

TABLE 12.—PENS, GOLD: CAPITAL, 1890 AND 1900.

	1900		1890		Per cent of increase.
	Amount.	Per cent of total.	Amount.	Per cent of total.	
Total	$496,246	100.0	$473,964	100.0	4.7
Land	33,000	6.6	12,000	2.5	175.0
Buildings	7,000	1.4	8,000	1.7	[1]12.5
Machinery, tools, and implements	129,775	26.2	129,120	27.3	0.5
Cash on hand, and sundries	326,471	65.8	324,844	68.5	0.5

[1] Decrease.

In this industry, as in the other industries reported in this bulletin, cash and sundries, including bills receivable, unsettled ledger accounts, etc., was the largest item reported in the table, but this item was only a little larger in 1900 than in 1890. The item for machinery, tools, and implements formed a considerable proportion of the total amount of capital for the years 1890 and 1900, indicating that machinery is extensively used in the industry, but from the very insignificant percentage of increase in this item during the decade, it is evident that very little new machinery has been added. The items of land and buildings each form but a small percentage of the total capital; the value of the land,

however, increased during the decade $21,000, while the value of the buildings decreased $1,000.

The cost of materials used in the manufacture of gold pens in 1900, and the cost of each item, with its percentage of the whole amount, are presented in Table 13.

TABLE 13.—PENS, GOLD: COST OF MATERIALS USED, 1900.

	Amount.	Per cent of total.
Total	$312,537	100.0
Principal materials[1]	308,545	98.7
Fuel	982	0.3
Rent of power and heat	3,010	1.0

[1] Includes items for mill supplies and all other materials, which are shown separately in Table 16.

By far the largest item shown in Table 13, covering almost the entire cost, is that reported for principal materials, which includes not only the materials purchased in partially manufactured form, but all materials that are used in the manufacture of gold pens. The largest part of this item consists of materials purchased in partially manufactured form. This item alone was $283,089, or 90.6 per cent of the total cost of materials. The materials used were principally gold bullion and iridium, but other metals were used to some extent.

Table 14 is a detailed statement, by states, of the quantity and value of gold pens manufactured during the census year by the establishments principally engaged in this industry, and the subsidiary products reported by them.

TABLE 14.—GOLD PENS: QUANTITY AND VALUE OF PRODUCTS, BY STATES, 1900.

STATES.	AGGREGATE VALUE.	PRODUCTS.									
		Total gross.	Total value.	Pens.							
				Total gross.	Total value.	Gold.		Fountain (complete).		Stylographic.	
						Gross.	Value.	Gross.	Value.	Gross.	Value.
Total	$799,078	11,737	$705,832	7,931	$567,755	6,120	$408,229	1,745	$156,586	66	$2,940
New York	657,693	9,975	577,857	6,658	458,255	5,099	344,848	1,507	111,419	52	1,988
All other states[1]	141,385	1,762	127,975	1,273	109,500	1,021	63,381	238	45,167	14	952

STATES.	PRODUCTS—continued.								
	Pencils.								All other.
	Total gross.	Total value.	Gold.		Silver.		Plate.		
			Gross.	Value.	Gross.	Value.	Gross.	Value.	Value.
Total	3,806	$138,077	26	$32,326	795	$68,022	2,985	$37,729	$93,246
New York	3,317	119,602	26	32,326	569	59,222	2,722	28,054	79,836
All other states[1]	489	18,475	.....	.....	226	8,800	263	9,675	13,410

[1] Includes establishments distributed as follows: Illinois, 1; Maryland, 1; Massachusetts, 1; Michigan, 1; Ohio, 1; Rhode Island, 1.

In this industry, as in the manufacture of fountain and stylographic pens, New York led, producing almost five times as much as all other states combined. The overlapping of the industries is more strikingly exemplified in this industry than in the manufacture of fountain and stylographic pens, the principal product of gold pen establishments making up only 52.1 per cent of the total number of gross produced, while in fountain and stylographic pen establishments the principal product furnished 86.5 per cent of the total.

The tables which have thus far been shown for this industry do not give complete statistics of the quantity and value of gold pens produced during the census year, because of the rule adopted of classifying establishments according to the predominating product. Table 15 shows the total quantity and value of gold pens produced during the census year as reported by establishments of any character.

TABLE 15.—PENS, GOLD: QUANTITY AND VALUE OF PRODUCTS, BY STATES, 1900.

STATES.	Gross.	Value.
United States	6,735	$458,876
New York	5,210	365,050
All other states[1]	1,525	93,826

[1] Includes establishments distributed as follows: Illinois, 2; Maryland, 1; Massachusetts, 2; Michigan, 1; Ohio, 2; Rhode Island, 1.

Table 15 includes the quantity and value of gold pens produced in establishments engaged primarily in this industry, and also the quantity and value reported as a subsidiary product of establishments engaged in the manufacture of fountain and stylographic pens and lead pencils. The values reported in Table 15 do not include the amounts reported as the value of any other products, therefore the totals given in this table do not agree with the totals elsewhere given with those of the general report on Manufactures, Parts I and II.

HISTORICAL AND DESCRIPTIVE.

The manufacture of gold pens was commenced in the United States in 1835 by a watchmaker of Detroit, Mich. Attempts had been made in England to make gold pens prior to that time, but they met with little success. Alloyed gold is too soft to make a durable point, and this circumstance made it necessary to protect the pen points with diamonds or rubies until John Isaac Hawkins, a citizen of the United States, but residing in England while the experiments in the manufacture of the gold pen were in progress there, accidentally discovered that the native alloy of iridium and osmium, one of the hardest and most refractory of all metallic alloys, could be used for protecting the points to much better advantage and more cheaply. Hawkins' rights were purchased by a clergyman of Detroit, Mich., who induced the watchmaker above mentioned to manufacture gold pens. The first pens made by him were very poor substitutes for the quill then in use. In 1840 his plant was taken to New York, where the business was enlarged. Quite an improvement was added to the plant by the machines, for the making and tempering of the pens, invented by John Rendell, one of the employees of the establishment. This establishment soon produced a gold pen so perfect that it combined the elasticity of the quill with the permanency of the metal. About 1850 it was discovered that by embedding the iridium points in the gold instead of soldering them on, the corrosive influence of the ink on the two metals, the solder and the gold, was avoided, and a firmer hold in the pen was given to the points.[1]

The gold pen has been brought to its present degree of perfection by the American manufacturer, and the industry from its inception has been characterized by the use of American methods. For the production of the gold pen a high degree of skill is necessary, and only experts are employed in the different plants.

The gold used in the making of the pens is obtained from the United States Assay Office. It is then melted and alloyed to about 16 carats fine, and rolled into a long narrow ribbon from which pen blanks or flat plates in the shape of a pen, but considerably thicker than the finished pen, are cut by means of a lever press or die and punch. The blunt nib of the blank is notched or recessed at the end to receive the iridium that forms the exceedingly hard point which all good gold pens possess. The iridium is coated with a cream of borax ground in water, and laid in the notch formed in the end of the blank. It is then secured by a process of sweating, which is nothing more nor less than melting the gold of which the pen is formed so that it unites solidly with the iridium. The blank is then passed between rollers of peculiar form to give a gradually diminishing thickness from the point backward. The rolls have a small cavity in which the extreme end of the iridium-pointed nib is placed, to prevent injury to the iridium. After rolling, the nib of every pen is stiffened and rendered spongy by hammering. This is the most important process in the manufacture of the pen, as the elasticity of the nib depends entirely upon this operation. The pen is then trimmed by a press similar to that which is used for cutting out the blanks, or by automatic machinery. When the blank has been trimmed, the name of the manufacturer and the number of the pen are stamped on it by means of a screw press. The pen is given its convex surface also by means of a screw press, the blank being pressed between a concave die beneath and a convex one above. Quite a little force is necessary to bring the pen to the required convexity, and when this operation is completed, two jaws approach the blank and press it up on the opposite edges, thus giving the pen its final shape. The next step is to cut the iridium into two points by holding it on the edge of a very thin copper disk, which is charged with fine emery and oil and revolves at a high speed. The nib is then slit by a machine and the slit cleared by means of a fine circular saw. After slitting, the nibs are brought together by hammering, and the pen burnished on the inside in a concave form and on the outside in a convex form. This is necessary in order to give the pen a uniform surface and greater elasticity. These nibs are then set by the fingers alone, after which operation the pen is ground by a lathe with a thin steel disk and a copper cylinder, both charged with fine emery and oil. The slit is then ground by a thin disk and the sides of the nibs and the points are ground upon the copper cylinder. After the grinding is done the pen is polished upon buff wheels, which completes the process of manufacture. Before the pen is placed upon the market, however, it is given a thorough inspection to see that it possesses the proper elasticity, fineness and weight, then passed to an inspector who tests it and weighs it.

Table 16 is a detailed statement of the statistics for the manufacture of gold pens, by states, 1900.

TABLE 16.—PENS, GOLD: BY STATES, 1900.

	United States.	New York.	All other states.[1]
Number of establishments	22	14	8
Character of organization:			
Individual	11	5	6
Firm and limited partnership	5	5	.....
Incorporated company	6	4	2
Capital:			
Total	$496,246	$307,734	$188,512
Land	$33,000	.....	$33,000
Buildings	$7,000	.....	$7,000
Machinery, tools, and implements	$129,775	$88,856	$40,919
Cash and sundries	$326,471	$218,878	$107,593
Proprietors and firm members	23	17	6
Salaried officials, clerks, etc.:			
Total number	62	39	23
Total salaries	$67,522	$45,672	$21,850
Officers of corporations—			
Number	8	6	2
Salaries	$15,860	$9,660	$6,200

[1] Includes establishments distributed as follows: California, 1; Illinois, 2; Maryland, 1; Massachusetts, 1; Michigan, 1; Ohio, 1; Rhode Island, 1.

[1] Universal Cyclopædia, vol. 9, page 198.

TABLE 16.—PENS, GOLD: BY STATES, 1900—Continued.

	United States.	New York.	All other states.[1]
Salaried officials, clerks, etc.—Continued.			
General superintendents, managers, clerks, etc.—			
Total number	54	33	21
Total salaries	$51,662	$36,012	$15,650
Men—			
Number	43	27	16
Salaries	$47,252	$33,212	$14,040
Women—			
Number	11	6	5
Salaries	$4,410	$2,800	$1,610
Wage-earners, including pieceworkers, and total wages:			
Greatest number employed at any one time during the year	431	340	91
Least number employed at any one time during the year	370	296	74
Average number	378	302	76
Wages	$229,679	$191,623	$38,056
Men, 16 years and over—			
Average number	337	274	63
Wages	$216,838	$181,517	$35,321
Women, 16 years and over—			
Average number	38	28	10
Wages	$12,541	$10,106	$2,435
Children, under 16 years—			
Average number	3	.....	3
Wages	$300	.....	$300
Average number of wage-earners, including pieceworkers, employed during each month:			
Men, 16 years and over—			
January	348	286	62
February	345	280	65
March	350	284	66
April	344	277	67
May	354	289	65
June	342	280	62
July	290	249	41
August	291	250	41
September	334	264	70
October	346	276	70
November	356	283	73
December	344	271	73
Women, 16 years and over—			
January	37	28	9
February	38	28	10
March	38	28	10
April	38	28	10
May	41	31	10
June	37	28	9
July	34	29	5
August	35	30	5
September	39	27	12
October	41	28	13
November	41	28	13
December	37	24	13
Children under 16 years—			
January	3	.....	3
February	3	.....	3
March	3	.....	3
April	3	.....	3
May	3	.....	3
June	3	.....	3
July	.....	.....	.....
August	.....	.....	.....
September	5	.....	5
October	5	.....	5
November	3	.....	3
December	5	.....	5
Miscellaneous expenses:			
Total	$42,740	$27,845	$14,895
Rent of works	$15,564	$12,574	$2,990
Taxes, not including internal revenue	$455	$271	$184
Miscellaneous expenses—Continued.			
Rent of offices, insurance, interest, and all sundry expenses, not hitherto included	$23,321	$11,600	$11,721
Amount paid for contract work	$3,400	$3,400	.....
Materials used:			
Total cost	$312,537	$264,138	$48,399
Principal materials—			
Total cost	$283,089	$248,838	$34,251
Purchased in raw state	.....	.....	.....
Purchased in partially manufactured form	$283,089	$248,838	$34,251
Fuel	$982	$473	$509
Rent of power and heat	$3,010	$2,540	$470
Mill supplies	$775	$625	$150
All other materials	$24,681	$11,662	$13,019
Freight	.....	.....	.....
Products:			
Total value	$799,078	$657,693	$141,385
Pens and pencils—			
Total value	$705,832	$577,857	$127,975
Pens—			
Total gross	7,933	6,658	1,273
Total value	$567,755	$458,255	$109,500
Gold—			
Gross	6,120	5,099	1,021
Value	$408,229	$344,848	$63,381
Fountain (complete)—			
Gross	1,745	1,507	238
Value	$156,586	$111,419	$45,167
Stylographic—			
Gross	66	52	14
Value	$2,940	$1,988	$952
Pencils—			
Total gross	3,806	3,317	489
Total value	$138,077	$119,602	$18,475
Gold—			
Gross	26	26	.....
Value	$32,326	$32,326	.....
Silver—			
Gross	795	569	226
Value	$68,022	$59,222	$8,800
Plated—			
Gross	2,985	2,722	263
Value	$37,729	$28,054	$9,675
All other products	$93,246	$79,836	$13,410
Comparison of products:			
Number of establishments reporting for both years	20	12	8
Value for census year	$761,553	$620,168	$141 385
Value for preceding business year	$719,000	$560,362	$158,638
Power:			
Number of establishments reporting	16	13	3
Total horsepower	121	66	55
Owned—			
Engines—			
Steam—			
Number	3	2	1
Horsepower	67	17	50
Rented—			
Electric, horsepower	28	23	5
Other kind, horsepower	26	26	.....
Establishments classified by number of employees, not including proprietors and firm members:			
Total number of establishments	22	14	8
No employees	4	.....	4
Under 5	.....	.....	.....
5 to 20	9	7	2
21 to 50	6	5	1
51 to 100	3	2	1
101 to 250	.....	.....	.....
251 to 500	.....	.....	.....
501 to 1,000	.....	.....	.....
Over 1,000	.....	.....	.....

[1] Includes establishments distributed as follows: California, 1; Illinois, 2; Maryland, 1; Massachusetts, 1; Michigan, 1; Ohio, 1; Rhode Island, 1.

STEEL PENS.

The steel pen manufacture was successfully established in the United States by 1860, but the statistics of the industry were not separately reported until the census of 1870. Its growth since that time, though slow, has been satisfactory, until to-day the home manufacturer not only supplies three-fourths of the home trade, but exports a considerable quantity.

The statistics for the manufacture of steel pens, as returned at the censuses of 1870 to 1900, inclusive, with the percentages of increase for each decade, are presented in Table 17.

TABLE 17.—PENS, STEEL: COMPARATIVE SUMMARY, 1870 TO 1900, WITH PER CENT OF INCREASE FOR EACH DECADE.

	DATE OF CENSUS.				PER CENT OF INCREASE.		
	1900	1890	1880	1870	1890 to 1900	1880 to 1890	1870 to 1880
Number of establishments	3	3	3	3	.....	.....	.....
Capital	$357,460	$399,182	$182,500	$175,000	[1]10.5	118.7	4.3
Salaried officials, clerks, etc., number	13	[2]15	(3)	(3)	[1]13.3	.....	.....
Salaries	$21,416	[2]$20,143	(3)	(3)	6.3	.....	.....
Wage-earners, average number	473	496	280	257	[1]4.6	77.1	8.9
Total wages	$138,433	$132,082	$88,500	$60,000	4.8	49.2	47.5
Men, 16 years and over	65	141	34	47	[1]53.9	314.7	[1]27.7
Wages	$26,684	$59,907	(3)	(3)	[1]55.5	.....	.....
Women, 16 years and over	371	322	230	195	15.2	40.0	17.9
Wages	$101,622	$66,876	(3)	(3)	52.0	.....	.....
Children, under 16 years	37	33	16	15	12.1	106.3	6.7
Wages	$10,127	$5,249	(3)	(3)	92.9	.....	.....
Miscellaneous expenses	$37,405	$6,295	(4)	(4)	494.2	.....	.....
Cost of materials used	$52,466	$56,630	$38,950	$49,943	[1]7.4	45.4	[1]22.0
Value of products, including custom work and repairing	$294,340	$268,259	$164,000	$180,000	9.7	63.6	[1]8.9

[1] Decrease.
[2] Includes proprietors and firm members with their salaries; number only reported in 1900, but not included in this table. (See Table 23.)
[3] Not reported separately.
[4] Not reported.

It appears from Table 17 that the period of the industry's greatest growth was from 1880 to 1890. By a singular coincidence the number of establishments engaged in the industry has been the same at the several censuses. This does not necessarily mean that the establishments reporting in 1900 are individually the same establishments that reported in 1870, 1880, and 1890, although it is more than probable that one or more of the establishments reported in 1900 was actively engaged in the business in previous census years. During the whole period between 1870 and 1900, the capital invested in the industry increased $182,460, and the products $114,340. Between 1890 and 1900 the value of the products increased very slightly, and the amount of capital showed a decrease of 10.5 per cent. The large number of women employed in the manufacture as compared with the number of men is to be expected in an industry using machinery that requires but little skill and strength to operate.

Table 18 presents, by states, the number of establishments actively engaged in the manufacture of steel pens in 1890 and 1900, with the increases and decreases for the decade.

TABLE 18.—PENS, STEEL: NUMBER OF ESTABLISHMENTS, BY STATES, 1890 AND 1900.

STATES.	1900	1890	Increase.
United States	3	3	.....
Connecticut	.....	1	[1]1
New Jersey	1	1	.....
Ohio	1	.....	1
Pennsylvania	1	1	.....

[1] Decrease.

During the decade 1 plant was established in Ohio, which in 1890 had none. Owing to the plan adopted by this census of classifying establishments in accordance with the predominating product, it is probable that the establishment engaged in this industry in Connecticut in 1890 was reported under some other classification in 1900. An examination of the returns for that state shows that steel pens were manufactured there during the census year, 1900, and the quantity and value of such product is included in Table 22.

In Table 19 is presented a comparative summary, for 1890 and 1900, of the capital in its several subdivisions, with the percentage that each item is of the total in the two census years, and percentages of increase for the decade.

TABLE 19.—PENS, STEEL: CAPITAL, 1890 AND 1900.

	1900		1890		Per cent of increase.
	Amount.	Per cent of total.	Amount.	Per cent of total.	
Total	$357,460	100.0	$399,182	100.0	[1]10.5
Land	20,000	5.6	36,000	9.0	[1]44.4
Buildings	43,000	12.0	52,672	13.2	[1]18.4
Machinery, tools, and implements	82,000	22.9	87,443	23.0	[1]6.2
Cash and sundries	212,460	59.5	223,067	59.4	[1]4.8

[1] Decrease.

The table shows a decrease of 10.5 per cent in the total capital for the industry during the decade, and decreases in each item making up the total. The most marked decreases are shown in the items of land and buildings; machinery, tools, and implements, and cash on hand, bills receivable, etc., formed a greater proportion of the total capital in 1900 than in 1890, yet each of these items showed a decrease for the decade. This industry reported a considerable amount for machinery, tools, and implements, thus indicating that machinery is extensively used in the manufacture of the steel pen.

The cost of materials used in the manufacture of steel pens in 1900, and the cost of each item, with its proportion to the whole amount, are presented in Table 20.

TABLE 20.—PENS, STEEL: COST OF MATERIALS, 1900.

	Amount.	Per cent of total.
Total	$52,466	100.0
Principal materials[1]	50,237	95.8
Fuel	2,090	4.0
Rent of power and heat	139	0.2

[1] Includes items mill supplies and all other materials which are shown separately in Table 23.

Of the item "principal materials," $39,168 was for materials purchased in partially manufactured form, while $10,491 was for all other materials used in the manufacture. Steel and aluminum, and one or two other metals constituted all that was purchased in partially manufactured form.

Table 21 is a statement of the quantity and value of steel pens manufactured during the census year as reported by establishments engaged primarily in the manufacture of steel pens.

TABLE 21.—PENS, STEEL: QUANTITY AND VALUE OF PRODUCTS, 1900.

	Aggregate value.	PRODUCTS—PENS.				All other products, value.
		Total gross.	Total value.	Steel.		
				Gross.	Value.	
All establishments[1]	$294,340	1,075,780	$289,340	1,075,780	$289,340	$5,000

[1] Distributed as follows: New Jersey, 1; Ohio, 1; Pennsylvania, 1.

This table does not give statistics of the industry by states, separately, as the number of establishments in each is too small to permit such presentation without disclosing the operations of individual concerns. The establishments reporting for this industry for 1900 were then engaged exclusively in the manufacture of steel pens and did not report any subsidiary product of other pens or of pencils. The above table, however, does not show the total quantity and value of steel pens manufactured in this country during the census year, as some of the establishments, engaged primarily in manufacturing other articles, reported steel pens as a subsidiary product.

Table 22 shows the total quantity and value of steel pens produced during the census year as reported by establishments of any character.

TABLE 22.—PENS, STEEL: QUANTITY AND VALUE, 1900.

	Gross.	Value.
All establishments[1]	1,764,079	$411,872

[1] Distributed as follows: Connecticut, 1; New Jersey, 1; New York, 1; Ohio, 1; Pennsylvania, 1.

The totals shown in Table 22 do not agree with the totals elsewhere shown in this report or with those of the general report on this industry as presented in Manufactures, Parts I and II, for reasons previously mentioned.

HISTORICAL AND DESCRIPTIVE.

The real inventor of the steel pen is unknown. France, England, and the United States each have claimants for the honor, and it is difficult to decide to whom it belongs. Arnoux, a French mechanic, made metallic pens with side slits in 1750. Samuel Harrison, an Englishman, made a steel pen for Dr. Priestly in 1780. Peregrine Williamson, a native of New York, while engaged as a jeweler in Baltimore, made steel pens in that city in 1800. He met with signal success and produced a very good article.[1]

The first manufacture of steel pens by mechanical appliances was in England during the third decade of the Nineteenth century, and the names associated with it were John Mitchell, Joseph Gillott, and Josiah Mason, each doing something toward perfecting the processes of manufacture by mechanical means. At the period when these men commenced operations the pens in use were very crude specimens, made from a piece of steel formed into a tube, and filed into the shape of a pen, by hand, the joint of the two edges forming the slit. By degrees a press was contrived to do the cutting, bending, and marking; and machinery was devised for cleaning and polishing. Experiments were made with the object of securing the best possible quality of steel, and by the year 1860, when the manufacture of steel pens was first begun in this country, the article had been brought to a considerable degree of perfection.

The pens in use half a century ago were mostly fine pointed, and while they gave satisfaction in certain lines of penmanship, some objections were made to them for business and rapid writing. Since that time there has been a gradual improvement in the material used and the process of manufacture, and the fine-pointed pens have given away to some extent to the stub and other blunt-pointed pens.

The first steel pens made in the United States by mechanical appliances were made at New York in 1858 by Harrison & Bradford. Two years later a factory was started at Camden, New Jersey, by Richard Esterbrook, sr., Richard Esterbrook, jr., and James Bromgrove. This firm met with success, and in 1866 the establishment was incorporated as the Esterbrook Steel Pen Company. Their enterprise was successful, and the growth of the plant has continued up to the present time.[2]

The many prefixes, such as Peruvian, Damascus, Amalgam, and Silver, used to describe the pen, are but fancy names and do not indicate the quality of the article. The material used for all kinds is cast steel of the best quality, imported from England or Sweden.

[1] Scientific American, Nov. 28, 1878.

[2] One Hundred Years of American Commerce, Vol. II, page 660.

The best variety is that made from Swedish iron, which has in its granular structure a peculiar density and compactness. Steel for the manufacture of the pen has not yet been successfully produced in the United States.

The steel used in the industry is received in sheets varying in length, width, and thickness. These sheets are cut by the manufacturer into strips of convenient width, and are packed in an oblong iron box, which is placed with the open top downward in another box of the same material, the interstices being then filled up with a composition in order to exclude the air. The boxes are placed in a furnace, gradually heated until they are dull red in appearance, and then gradually cooled. In this process the strips become covered with bits of small scale. To remove this roughness they are immersed in a bath of diluted sulphuric acid, which loosens the scales, and they are then placed in wooden barrels containing water and broken pebbles. These barrels are revolved until the whole of the scaly substance is removed and the strips are of a silver-gray appearance. The strips are then taken to the rolling mill, where they are passed between successive rolls until reduced to the required gauge, the more common thickness being the one-hundred and sixtieth part of an inch. This operation requires considerable care and skill, as the variation of one-thousandth part of an inch in the thickness of the strip would seriously affect the flexibility of the pens. The strips are now three times their original length and have a bright surface.

In these preliminary processes the labor is performed by men and boys, but the processes of forming and shaping the pen, that begin at this point, are carried on by women and girls, who are more adapted to the work. The cutting of the blanks is accomplished by a die and a punch. This die is set in a bolster and is perforated by a hole the exact shape of the blank; and a punch, also of the exact shape of the blank, is attached to the bottom of the screw bolt of a press. The operator with her left hand introduces one of the strips of steel at the back of the press and pulls the handle toward her with the right hand. This causes the screw to descend, driving the punch into the bed, thus perforating the strip of steel with a scissor-like cut, and making a blank which falls through the opening in the die into a drawer below. The operator then pulls the strip of steel toward her until it is stopped by a little projection called a guide, and the operation just described is repeated, and again repeated, until the whole of one side of the strip is perforated, when the strip is reversed and the other side treated in a similar way. In the operation of cutting, a small V-shaped indentation is formed in the blanks upon the upper edge of that part inserted in the holder, which may be found upon a careful examination, and which plays an important part in the succeeding processes, as it enables the operator to distinguish between the smooth and rough sides of the blank.

The next process, called marking, is done by a stamp. The precise mark required is cut upon a piece of steel, which is placed in the hammer of the stamp. The stamp is operated by foot power. The operator takes a handful of blanks with her left hand, and by a dexterous motion makes a little train of them between the thumb and finger, presenting the first in the most ready position to be passed to the other hand. By the right hand the blank is placed, with the point toward the worker, in a guide upon the bed of the stamp, where the hammer falls upon it and makes the impression of the name cut upon the punch. So skillful do operators become in this process that they can stamp 200 to 250 gross of pens a day. Should the impression to be made be unusually large, the marking process is deferred until later in the course of construction.

The next process in the manufacture is "piercing," which produces the elasticity desired and causes the ink to attach itself to the pen. The tools used in this operation are very delicate and must be made with great precision. A piercing punch and bed are fixed in a screw press, and an ingenious arrangement of guides is fastened thereto. The operator then places the blank in its proper position and so manipulates the machinery as to cause the screw to descend, driving the punch into the bed. In order to soften the blanks, so that they can be properly shaped, they are put through a process called annealing. In this process the blanks are freed from the dust and grease that has become attached to them, and are then carefully placed in round iron pots, which are again inclosed in larger ones, covered over with charcoal dust to prevent the entrance of gases and put into the furnace, where they are heated to a dull red, and then gradually cooled.

After this process is finished the blanks are soft and pliable and readily assume the various shapes into which they are made by the next process, called "raising." In this operation a punch and die are again brought into use. The punch is fitted into a contrivance fixed in the bottom of the screw of the press; the die, or bed, is placed in a bolster, a cylindrical piece of steel attached to the bottom of the press, with a groove cut for the reception of the die. Four pieces of steel, called guides, are fixed to the bolster in such a position that the operator is enabled to slide the blank into the bed, where it is held by the guides until the punch descends, forcing the blank into the bed, and giving the pen its shape. The blanks are then placed in thin layers in round pans with lids and go through the process called "hardening." In this operation the pans mentioned are placed in the furnace for a period varying from twenty to thirty minutes, at the end of which time they have come to a bright red heat. The pans are then taken from the furnace and their contents thrown into a large bucket immersed in a tank of oil. This bucket is perforated, and when lifted from the tank the oil drains off. The pens are then placed in a perforated

cylinder, which is set in motion and drains off the remainder of the oil. At this stage of the manufacture the pens are very greasy and as brittle as glass. To remove the grease adhering to them they are again placed in perforated buckets and immersed in a tank of boiling soda water.

The pens are then put into an iron cylinder, which is kept revolving over a charcoal fire until they are softened or tempered down to the degree required. This process is regulated according to the color shown by the pens, which indicates the varying temperature of the metal. After this operation the pens are black and rough at the point. To remedy these defects, the pens are subjected to the process known as "scouring," which consists in dipping the pens in a bath of diluted sulphuric acid, which removes all extraneous substances acquired in the hardening and tempering processes. Great care is exercised in this operation, as the acid is very likely to injure the steel. The pens are then placed in iron barrels with a quantity of water and a material composed of annealing pots broken and ground fine enough to pass through a fine riddle. The barrels are then set in motion, which is continued for a period varying from five to eight hours. At the end of this time they are placed in barrels with dry pot for about the same period, after which they are put into other barrels, together with a quantity of dry sawdust. They are then ground between the center pierce and the point. This is done by girls with the aid of a "bob," or "glazer," a circular piece of alder wood about 10½ inches in diameter and one-half an inch in width. Around this a piece of leather is stretched and dressed with emery. A spindle is driven through the center and the two ends placed in sockets. The mechanism thus arranged is set in motion by means of a leather band, and the operator, holding a pen firmly, grinds off, with a light touch, a portion of the surface.

The last and most important mechanical operation performed upon the pen is slitting. The tools used for this purpose are two oblong pieces of steel known as cutters, which are about 1½ inches long, three-eighths of an inch thick, and 1¼ inches wide. The edges of these cutters are equal in delicacy to the cutting edge of a razor. One of the cutters is fixed in a press with a pair of guides screwed on either side, and the other cutter is held by a bolster, having attached to it a small tool called a rest, or table. The operator places the pen upon the table, pushes the point up toward the guide, and, by operating the machine, makes the upper cutter descend and meet the lower one, thus slitting the pen.

At this stage in the process of manufacture the outer edge of each point is smooth, but the inside edges are sharp and rough. To remedy these defects the pens are again put in the iron barrels with pounded pot, and kept revolving for five or six hours, when they are removed and polished in sawdust. The pens are then colored by being placed in a copper or iron cylinder which revolves over a coke fire until the requisite tint is obtained. If the pens are to be lacquered they are placed in a solution of shellac dissolved in alcohol. This solution is afterwards drained off and the pens are placed in iron cylinders that are kept revolving until the pens are dry. The pens are then scattered upon iron trays and heated in an oven until the lacquer is diffused equally over the whole surface of the pens. The lacquer gives the pens a glossy appearance and prevents rust; and when the pens have cooled they are complete as far as manufacturing processes are concerned. Before they are offered to the public, however, they are given a very careful inspection, to see that no inferior ones are put on the market.

Table 23 presents a detailed statement of the statistics for the manufacture of steel pens, by states, 1900.

TABLE 23.—STATISTICS OF STEEL PENS, 1900.

	United States.[1]
Number of establishments	3
Character of organization:	
Individual	.....
Firm, and limited partnership	1
Incorporated companies	2
Capital:	
Total	$357,460
Land	$20,000
Buildings	$43,000
Machinery, tools, and implements	$82,000
Cash and sundries	$212,460
Proprietors and firm members	3
Salaried officials, clerks, etc.:	
Total number	13
Total salaries	$21,416
Officers of corporations—	
Number	3
Salaries	$10,000
General superintendents, managers, clerks, etc.—	
Total number	10
Total salaries	$11,416
Men—	
Number	10
Salaries	$11,416
Women—	
Number	.....
Salaries	.....
Wage-earners, including pieceworkers, and total wages:	
Greatest number employed at any one time during the year	473
Least number employed at any one time during the year	471
Average number	473
Wages	$138,433
Men, 16 years and over—	
Average number	65
Wages	$26,684
Women, 16 years and over—	
Average number	371
Wages	$101,622
Children, under 16 years—	
Average number	37
Wages	$10,127
Average number of wage-earners, including pieceworkers, employed during each month:	
Men, 16 years and over—	
January	65
February	65
March	65
April	65
May	65
June	65
July	65
August	65
September	65
October	65
November	66
December	64
Women, 16 years and over—	
January	371
February	371
March	371
April	371
May	371
June	371
July	371
August	371
September	371
October	371
November	371
December	371

[1] Includes establishments distributed as follows: New Jersey, 1; Ohio, 1; Pennsylvania, 1.

TABLE 23.—STATISTICS OF STEEL PENS, 1900—Continued.

	United States.[1]
Average number of wage-earners, including pieceworkers, employed during each month—Continued.	
Children, under 16 years—	
January	37
February	37
March	37
April	37
May	37
June	37
July	36
August	36
September	36
October	36
November	42
December	36
Miscellaneous expenses:	
Total	$37,405
Rent of works	$945
Taxes, not including internal revenue	$1,578
Rent of offices, insurance, interest, and all sundry expenses not hitherto included	$34,882
Amount paid for contract work	.....
Materials used:	
Total cost	$52,466
Principal materials—	
Total cost	$39,168
Purchased in raw state	.....
Purchased in partially manufactured form	$39,168
Fuel	$2,090
Rent of power and heat	$139
Mill supplies	$578
All other materials	$10,491
Freight	.....

	United States.[1]
Products:	
Total value	$294,340
Pens, steel—	
Gross	1,075,780
Value	$289,340
All other products	$5,000
Comparison of products:	
Number of establishments reporting for both years	3
Value for census year	$294,340
Value for preceding business year	$267,127
Power:	
Number of establishments reporting	3
Total horsepower	138
Owned—	
Engines—	
Steam—	
Number	1
Horsepower	125
Gas or gasoline—	
Number	1
Horsepower	10
Rented—	
Total horsepower	3
Establishments classified by number of persons employed, not including proprietors and firm members:	
Total number of establishments	3
No employees	.....
Under 5	.....
5 to 20	1
21 to 50	.....
51 to 100	1
101 to 250	.....
251 to 500	1
501 to 1,000	.....
Over 1,000	.....

[1] Includes establishments distributed as follows: New Jersey, 1; Ohio, 1; Pennsylvania, 1.

LEAD PENCILS.

The lead pencil industry was first reported separately at the census of 1860, as a subdivision of the general class of stationery. At the census of 1850 it was reported under the general classification of pens and pencils, when it was shown that there were four establishments engaged in the manufacture of pens and pencils, with a capital of $43,000 invested, employing 58 people at a cost of $14,028, and producing a product of $85,300. It is probable that the value of the products of the lead pencil industry was very small at that time, as it was only $20,400 in 1860. The growth of the lead pencil industry since 1860 has been constant, and in some periods remarkably great, as is shown by the statistics presented in the following tables.

Table 24 is a comparative summary of the statistics of the manufacture of lead pencils at the censuses of 1860 to 1900, inclusive, with the percentages of increase for each decade.

TABLE 24.—PENCILS, LEAD: COMPARATIVE SUMMARY, 1860 TO 1900, WITH PER CENT OF INCREASE FOR EACH DECADE.

	DATE OF CENSUS.					PER CENT OF INCREASE.			
	1900	1890	1880	1870	1860	1890 to 1900	1880 to 1890	1870 to 1880	1860 to 1870
Number of establishments	7	5	4	8	6	40.0	25.0	[1]50.0	33.3
Capital	$2,227,406	$3,100,836	$341,597	$261,150	$6,600	[1]28.2	807.7	30.8	3,856.8
Salaried officials, clerks, etc., number	81	[2]64	(3)	(3)	(3)	26.6	.....	.....	.....
Salaries	$111,890	[2]$130,300	(3)	(3)	(3)	[1]14.1	.....	.....	.....
Wage-earners, average number	2,162	1,388	399	160	24	55.8	247.9	149.4	566.7
Total wages	$683,281	$450,450	$102,233	$51,150	$7,920	51.7	340.6	99.9	545.8
Men, 16 years and over	758	483	116	65	18	56.9	316.4	78.5	261.1
Wages	$352,568	$264,481	(3)	(3)	(3)	33.3	.....	.....	.....
Women, 16 years and over	1,087	632	144	95	6	72.0	338.9	51.6	1,483.3
Wages	$263,118	$144,409	(3)	(3)	(3)	82.2	.....	.....	.....
Children, under 16 years	317	273	139	(3)	(3)	16.1	96.4	.....	.....
Wages	$67,600	$41,560	(3)	(3)	(3)	62.7	.....	.....	.....
Miscellaneous expenses	$278,176	$154,528	(4)	(4)	(4)	80.0	.....	.....	.....
Cost of materials used	$1,030,917	$796,378	$97,344	$57,510	$3,335	29.5	718.1	69.3	1,624.4
Value of products, including custom work and repairing	$2,222,276	$1,687,560	$279,427	$180,000	$20,400	31.7	503.9	55.2	782.4

[1] Decrease.
[2] Includes proprietors and firm members with their salaries; number only reported in 1900, but not included in this table. (See Table 30.)
[3] Not reported separately.
[4] Not reported.

In 1860 the 6 establishments engaged in this industry reported a capital of $6,600 and products valued at $20,400. From 1860 to 1870 the growth of the industry was nothing less than remarkable. Although the number of establishments was increased by 2 only, the increase in capital was $254,550, and in products, $159,600. This rapid growth was probably due to the establishment in New York of branches of the leading factories in Germany, where the process of manufacture had attained a high degree of perfection.

During the next decade the number of establishments decreased one-half, while the capital invested and the value of the products showed gratifying gains, indicating that the larger plants remaining were successful in the manufacture of the article. Although the number of establishments increased but one from 1880 to 1890, the increase in the amount of capital invested exceeded that for any decade, and the increase in the value of the products was correspondingly large. In comparing the capital as reported at different censuses, however, it should be borne in mind that until the census of 1890, no definite attempt was made to include live capital in the returns. During the past decade there has been a marked decrease in the amount of capital invested, but an increase in number of establishments and in value of products. Women wage-earners predominate in this industry, and for each decade except 1870 to 1880 their number increased in greater proportion than that of the men wage-earners.

The number of establishments actively engaged in the manufacture of lead pencils in 1890 and in 1900, with the increase or decrease, by states, is presented in Table 25.

TABLE 25.—PENCILS, LEAD: NUMBER OF ESTABLISHMENTS, 1890 AND 1900.

STATES.	1900	1890	Increase.
United States	7	5	2
Illinois	1	.....	1
Massachusetts	1	.....	1
New Jersey	2	1	1
New York	3	3	.....
Rhode Island	.....	1	[1]1

[1] Decrease.

It appears from Table 25 that the number of establishments increased 2, or 40 per cent, during the decade. Illinois, Massachusetts, and New Jersey each show a gain of 1 establishment, while Rhode Island reported 1 establishment in 1890 and none in 1900. The center of the industry in 1900 was in New York and New Jersey, and but 2 establishments are reported outside of those states.

Table 26 is a comparative summary of the capital for 1890 and 1900, in its several subdivisions, with percentages of increase for the decade and the per cent each item is of the total.

TABLE 26.—PENCILS, LEAD: CAPITAL, 1890 AND 1900.

	1900		1890		Per cent of increase.
	Amount.	Per cent of total.	Amount.	Per cent of total.	
Total	$2,227,406	100.0	$3,100,836	100.0	[1]28.2
Land	151,800	6.8	270,000	8.7	[1]43.8
Buildings	253,500	11.4	373,000	12.0	[1]32.0
Machinery, tools, and implements	244,725	11.0	293,000	9.5	[1]16.5
Cash and sundries	1,577,381	70.8	2,164,836	69.8	[1]27.1

[1] Decrease.

The total amount of capital invested showed a large decrease for the decade. The different items making up the total also showed decreases of varying proportions. The most marked decrease in the items is shown in the value of lands owned by the establishments. The item of machinery represented a greater percentage of the total capital in 1900 than in 1890, and showed the smallest percentage of decrease of any item reported in Table 26. The items of buildings owned and cash on hand, bills receivable, etc., represented very nearly the same percentage of the total for the year 1890 as in 1900.

The cost of materials used in the manufacture of lead pencils and the proportion of each item to the total for 1900 is shown in Table 27.

TABLE 27.—PENCILS, LEAD: COST OF MATERIALS, 1900.

	Amount.	Per cent of total.
Total	$1,030,917	100.0
Principal materials	1,002,710	97.3
Purchased in raw state	79,233	7.7
Purchased in partially manufactured form[1]	923,477	89.6
Fuel	13,757	1.3
Rent of power and heat	.....	.....
Freight	14,450	1.4

[1] Includes mill supplies and all other materials, which are shown separately in Table 30.

The largest item shown in Table 27 is that reported for principal materials, which is divided into those purchased in raw state, that is, materials upon which no manufacturing force has been expended, and those purchased in a partially manufactured form. Of the amount shown for materials purchased in a raw state, the cost of cedar logs made up the greatest proportion. In the amount reported for materials purchased in a partially manufactured form are included cost of "mill supplies" and "all other materials," the former being $32,566 and the latter $255,587. Some establishments were unable to separate the amount paid for freight from the cost of materials, and reported the two together. For this reason the $14,450 does not represent the entire cost of freight, and should be considered only in connection with the cost of material. Nothing was reported under the item "rent of power and heat."

A detailed statement, by states, of the number of gross and the value of the different varieties of lead pencils, and the subsidiary products, of plants engaged primarily in this industry, is presented in Table 28.

TABLE 28.—PENCILS, LEAD: QUANTITY AND VALUE OF PRODUCTS, 1900.

STATES.	Aggregate value.	PRODUCTS.									
		Pencil cases.									
		Total gross.	Total value.	Wood.		Silver.		Plate.		Other material.	
				Gross.	Value.	Gross.	Value.	Gross.	Value.	Gross	Value.
Total	$2,222,276	1,383,822	$1,705,065	1,381,329	$1,641,975	1,486	$43,496	482	$18,794	525	$800
New York	1,581,351	911,138	1,213,785	909,170	1,151,495	1,486	43,496	482	18,794		
All other states[1]	640,925	472,684	491,280	472,159	490,480					525	800

STATES.	PRODUCTS—continued.										ALL OTHER PRODUCTS.
	Pens.										
	Total gross.	Total value.	Fountain (complete).		Gold.		Steel.		Stylographic.		
			Gross.	Value.	Gross.	Value.	Gross.	Value.	Gross.	Value.	Value.
Total	432,759	$115,101	447	$39,125	31	$2,202	432,230	$71,318	51	$2,456	$402,110
New York	432,759	115,101	447	39,125	31	2,202	432,230	71,318	51	2,456	252,465
All other states[1]											149,645

[1] Includes establishments distributed as follows: Illinois, 1; Massachusetts, 1; New Jersey, 2.

It appears from Table 28 that New York led in the output of lead pencils in the census year, producing almost twice as many gross as all other states combined. To show to a better advantage the different varieties of lead pencils manufactured during the census year, it was decided to subdivide the product according to the case in which the lead was inclosed. In doing this 5 divisions (wood, gold, silver, plated, and other varieties) were made. Practically, all lead pencils manufactured are inclosed in wooden cases, as will be seen from Table 28. A considerable overlapping of the pen and pencil industries is shown in this table. Table 28 gives only an incomplete enumeration of the quantity of lead pencils produced during the census year, for the reason that many lead pencils were reported as a subsidiary product of the industries engaged primarily in the manufacture of pens and other articles. The total quantity and value of lead pencils produced by establishments of any character is shown in Table 29.

Of the total quantity of lead pencils manufactured during the census year, those incased in wood were 1,653,973 gross, valued at $2,053,484, and all other

TABLE 29.—PENCILS, LEAD: QUANTITY AND VALUE OF PRODUCTS, 1900.

STATES.	Total value.	CASES.									
		Wood.		Gold.		Silver.		Plated.		Other materials.	
		Gross.	Value.	Gross.	Value.	Gross.	Value.	Gross.	Value.	Gross.	Value.
United States	$2,264,151	1,653,973	$2,053,484	31	$32,526	2,281	$111,518	3,988	$64,523	581	$2,100
New York	1,333,387	909,170	1,151,495	26	32,326	2,055	102,718	3,204	46,848		
All other states[1]	930,764	744,803	901,989	5	200	226	8,800	784	17,675	581	2,100

[1] Includes establishments distributed as follows: Illinois, 1; Massachusetts, 1; New Jersey, 3, including 1 establishment which reported pencils as a by-product; Ohio, 1; Rhode Island, 2.

varieties were but 6,881 gross, valued at $210,677. There were produced in all during the census year 1,660,854 gross, or 239,162,976 lead pencils—more than three for each man, woman, and child then living in the United States. The totals shown in Table 29 do not agree with the totals elsewhere given in this report, or with those in the general report on this industry as presented in Manufactures, Parts I and II.

As the importations of pencils, "paper or wood filled with lead or other material, and pencils of lead," were but 85,119 gross, valued at $228,144, for the fiscal year ending June 30, 1900,[1] and as this was greatly in excess of the reports for the previous years, it will be seen that the American manufacturer practically supplies the home trade. It is to be regretted that no statistics are available as to the amount of lead pencils exported.

[1] Annual Report, United States Treasury Department, on Commerce and Navigation of the United States for 1900.

HISTORICAL AND DESCRIPTIVE.

The manufacture of lead pencils is a comparatively modern industry in the United States, dating from 1861, when the Fabers, pencil manufacturers in Germany, established a branch factory in New York. The use, however, of metallic lead for marking is very old. Pliny refers to lead as used for marking lines on papyrus; La Moine cites a document of 1387 ruled with it; Cortez found the Aztecs, in 1520, using crayons made of it.[1] The manufacture of lead into pencils, however, was not very general until after the discovery of the famous Barrowdale graphite mine in Cumberland, England, in 1564. The material from this mine was so highly desired and was so closely maintained as a monopoly that, in pursuance of an act of Parliament, the mouth of the mine was guarded by an armed force. To keep up the monopoly, the mine was worked only six weeks in a year, and its mouth was closed by flooding with water after the workmen left. The process of preparing the graphite mined here was the simple one of dividing it into slips. The most general method used to accomplish this purpose was that of compressing pulverized graphite with hydraulic presses into solid blocks, and then sawing it into bars. About 1850 the Barrowdale mines became exhausted, and since that time the lead for pencils has been prepared by a process invented by Conté, of Paris, at the close of the last century, or some adaptation of that process. Briefly, his method was to powder the graphite ore and mix it with a powdered clay. These materials, mixed in varying proportions, constitute the marking portion of the modern lead pencil. The grades of hardness and softness are secured by using more graphite and less clay to produce the softer grades, and more clay and less graphite for the harder grades. While Conté, a Frenchman, originated this process, it was left to the Germans to perfect it, which they accomplished so completely during the first part of the past century, that Germany can well be called the home of the modern graphite pencil.

Graphite or plumbago, the material now universally used for true surface writing, has been known for more than five hundred years. This material resembles lead no more than chalk does. Graphite is a nearly pure form of carbon and has many peculiar qualities. It is only one-fourth as heavy as lead; can not be fused; is one of the softest minerals dug from the earth; and if subjected to a very hot fire it will not melt nor be consumed, but it will gradually waste. This substance is found in its purest form at Ticonderoga, N. Y. The variety mined at this place contains 99.9 per cent carbon, while the best quality taken from the Ceylon mines is 99 per cent, and that found in the Barrowdale mine in England had but 87 per cent carbon. The inferior grades of graphite contain from 50 to 60 per cent of foreign matter. For the manufacture of pencils only the finer grades of graphite are used. In addition to the places mentioned, graphite is mined in Siberia, where an excellent quality is found; at Harnon, Sweden; at Passau, Bavaria; at Schwarzback, Germany; in the province of Nelson, New Zealand; and in Mexico. In the United States, impure grades are found at Raleigh and Asheville, N. C., and at Cumberland Hill and Cranston, R. I.[2] The clay used to mix with the graphite is a peculiar kind of pipe clay imported from Germany and Holland. The wood chiefly used for the holders is soft, straight-grained, red cedar, found in Florida, Georgia, Alabama, Mississippi, and Texas, and is used not only by American manufacturers but by all the pencil makers of the world.

Prior to the coming of the Fabers to the United States lead pencils were manufactured here, but to a very limited extent. The first step in starting the industry was made by William Monroe, of Concord, Mass., in 1812. At the commencement of the War of 1812 he was engaged as a cabinetmaker, but the nonintercourse, nonimportation, and embargo acts had so depressed business generally that he turned his attention to the making of pencils. The price for them was exceedingly high, owing to their scarcity, and success in making them meant large rewards. He procured a few lumps of black lead, pulverized them with a hammer, and separated the finer portions by suspension in a tumbler full of water. From the material thus prepared he made his first experimental mixture in a spoon, and out of it attempted to make a pencil. The result was so discouraging that he returned to his old occupation of making cabinets. He managed, however, to devote some time each day to his experiments, and after four months' work in this way he secured a better lead, which he incased in cedar-wood holders, thus producing the first American-made pencils. On the 2d day of July, 1812, he proceeded to Boston with a modest sample of about 30 pencils, which found a ready sale. The purchaser encouraged him to continue the manufacture. On his next trip to Boston he took with him 3 gross. The dealer then made a contract with him for all the pencils he could make within a certain time, at a certain price. All the mixing of the lead and putting it into pencils was done entirely by his own hands in a small room of his dwelling, thoroughly protected from curious eyes, no one but his wife being permitted to know anything of his methods. He continued his pencil manufacture for about eighteen months, when he was compelled to abandon it, owing to the difficulty of obtaining raw materials. At the close of the war he resumed the manufacture, but the imported article was found superior, and he made but little progress in the

[1] Knight's Mechanical Dictionary.

[2] The Universal Cyclopædia, vol. 5, page 250.

business. Until 1819 he carried on the manufacture as a subsidiary occupation with his cabinetmaking, but in that year, having met with better results, he devoted himself exclusively to the manufacture of lead pencils. After ten years of persistence and study directed toward the improvement of the quality of the pencils, his make grew into favor and supplied a part of the home demand.

It is said on reliable authority that Joseph Dixon attempted the manufacture of lead pencils at Salem, Mass., as early as 1830. Mr. Dixon's first consignment to a Boston firm was not enthusiastically received, but he was told that if he would place a foreign label on the pencils they would meet with ready sale. Rather than do this he had the pencils returned, and never again manufactured any. He gave his attention after that time to the manufacture of crucibles, and formed what is known as the Joseph Dixon Crucible Company. This firm began the manufacture of lead pencils in 1872, and met with exceptional success.

Prior to the manufacture of pencils by the Dixon company, 3 establishments of foreign origin were in operation in the United States. First, came representatives of the Faber plant in Germany, who began the manufacture of lead pencils in 1861. Next, in 1865, the Eagle Pencil Company was established in a similar way, and in the same year and in the same manner the American Lead Pencil Company was established. The above-named companies are now managed and owned by American citizens and have no connection with foreign plants.

After the industry had been established in the United States in the manner described, its progress and growth were very rapid. This was due mainly to the following causes: The existence in the United States of very rich graphite mines; the extraordinary facilities for securing this substance from mines elsewhere; the presence here of the greatest cedar forests of the world; and the introduction of labor-saving machines.

The process employed to-day in the manufacture of the American lead pencil is the Conté system, but the article produced by it has been so infinitely improved in workmanship and detail beyond the original product, that it would seem as if the pencil had almost reached its limit of perfection. As now followed, the process is a difficult, painstaking, and most elaborate one, and there is needed in the manufacture both a practical and theoretical knowledge of its chemistry and mechanics.

The raw material (graphite) used in many American-made lead pencils is mined at Ticonderoga, N. Y. This mine closely resembles an anthracite coal mine both in external and internal appearance. In it there are two formations of the graphite—a large vein of the crystallized variety, and the compact or granulated form of deposit, the latter being the only one used in pencils. This latter kind is found in small veins, or in what miners call "pockets." The graphite is taken, in the lump, direct from the mouth of the mine to the reducing mill, where it is pulverized by stamps under water, the particles floating off with the water through a series of tanks, in which they sink to the bottom, forming a sediment. The water being drained off and the sediment dried, the graphite is finally sent to the factory in barrels in the form of an impalpable powder—lusterless and of a dingy color. At this stage the graphite is finer and softer than flour, and is as evasive to the touch as quicksilver.

The particles are then separated further, according to fineness, by a process known as "floating." To effect this separation the graphite is mixed with sufficient water to run very freely, and then turned into a hopper from which the water runs slowly through a series of tubs so arranged that the top portion of each tub drains off into the tub placed next to it, but on a lower plane than the first. In this manner the coarsest and heaviest particles settle to the bottom of the first tub, the next coarsest and heaviest in the next, and so on, the movement of the water being made very gentle. On reaching the last tub, the powder, being twice as heavy as water, sinks in it, if undisturbed, and so far settles that the water discharges at the top nearly clear. When the flow is stopped and the powder has settled, the clear water is withdrawn by removing successively, beginning with the upper one, a number of plugs inserted in holes in the side of each tub, care being taken not to agitate the contents so as to disturb the deposited dust. The deposits are then removed through gates at the bottom of each tub. The deposit in the last tub is used for the finest grade of pencils, and those in the other tubs for the coarser grades.

The graphite is now ready for the clay, which is of a bluish-gray color, of great strength, and of a fatty appearance when wet. This clay is subjected to the floating process in the same way as the graphite, only the finest being used for mixing with the graphite in proportions varying according to the degree of hardness required. The more clay used, the harder the pencil; but for the medium grade the proportions are about seven parts of clay to ten of graphite, by weight. The graphite and clay are then mixed together with water to the consistency of thick cream, and the mixture is fed to the grinding mills, which consist of two flat stones about two feet in diameter, placed horizontally, only the upper one being in motion. The mass is ground between these stones many times in order to secure the most perfect strength, uniformity, and freedom from grit in the leads. The mass, when ground, is inclosed in stout canvas bags, and the clear water forced out of it by hydraulic pressure until it becomes a thick dough, when it is sent to a forming press. This is a small, vertical, iron cylinder, having a solid plunger or piston, driven by a screw. A plate is inserted in the bottom

having an opening of the shape and size of the lead desired, and through this hole the lead is forced something as a stream of water is forced from a syringe and coils itself round and round, like a coil of wire on a board set beneath the press. The coil is taken up, straightened, and broken off into lengths sufficient for 3 leads, which are then laid in order on a board, pressed flat by having a cover put over them, placed in a crucible, and baked in a kiln.

The material is now ready for the wooden cases, for which, in the cheaper pencils, pine is used, and in the better grades, cedar. At the sawmills the wood is cut into blocks about 7 inches long, and these are sawed into strips about 3½ inches wide and three-sixteenths of an inch thick. Each of these strips is sufficient to make the halves of 6 pencils. As the pencils are made six at a time, imperfect strips are put together so as to make a full strip out of the parts. These are packed closely in boxes and shipped to the factory. When they reach the factory they are passed in a continuous line under a cutter, which smooths their faces and cuts 6 little grooves—round or square—for the leads at the same stroke. The putting in of the leads is done by three operators. The first places the lead in the grooves and passes it to a second, who receives another strip with the grooves and surface coated with glue from the third operator, and puts them together. The united pairs are laid in rows, pressed together by a screw, and left to dry. The rough ends of the strips and the projecting leads are then ground smooth against a wheel covered with sandpaper. Next, the slips are fed one by one under a revolving cutter, which separates each into 6 rough pencil forms, and rounds these on one side by cutting away the superfluous wood. As they come from under the cutter they are turned over and passed under a second one, which rounds them on the other side, so that they fall in a continuous stream of finished pencils.

The planing machine in this process uses revolving knives, which make a succession of little gouges in the wood. These gouges, which would otherwise leave the surface very irregular, leave it smooth by following one another so closely that they become one long cut. So perfect is the operation of these revolving cutters, which make 9,000 strokes upon the wood a minute, that they leave the surface not only "true," but so smooth that the finest sandpaper would scratch it. The pencils are then counted, a gross at a time, by an operator, who simply arranges them by the handful in grooves, each large enough to contain 1 pencil. If the pencils are to be colored, they are immersed in dye and then sent to the varnishing machines. Here they are fed into a little hopper, from which they settle through sidewise and are seized between two wheels, which thrust them endwise, one at a time, through a hole in a tube wherein they are varnished. Each pencil, pushed on by its follower in the single-file movement, emerges from the tube and drops on a horizontal belt. It then moves slowly with the belt some 30 feet, drying as it goes, when the belt, reaching a pulley, releases the pencil and it drops into a receptacle. Pencils are varnished in this machine at the rate of 100 a minute. The other operations are of minor consequence, consisting in shaving a little from the end, sharpening certain styles on a wheel, stamping, and packing. Except for the lead makers and a few attendants, the labor is done by women, the machines being automatic, so that little strength and skill is necessary. The work is singularly cleanly and in no respect unhealthy, and the factory is peculiar in being permeated by the aromatic odor of the red cedar.

Table 30 presents in detail the statistics for the manufacture of lead pencils, by states, 1900.

TABLE 30.—PENCILS, LEAD: BY STATES, 1900.

	United States.	New York.	All other states.[1]
Number of establishments	7	3	4
Character of organization:			
Individual	4	1	3
Firm and limited partnership	.....	.....	.....
Incorporated company	3	2	1
Capital:			
Total	$2,227,406	$1,493,381	$734,025
Land	$151,800	$131,500	$20,300
Buildings	$253,500	$119,000	$134,500
Machinery, tools, and implements	$244,725	$126,000	$118,725
Cash and sundries	$1,577,381	$1,116,881	$460,500
Proprietors and firm members	4	1	3
Salaried officials, clerks, etc.:			
Total number	81	46	35
Total salaries	$111,890	$69,602	$42,288
Officers of corporations—			
Number	8	5	3
Salaries	$34,600	$25,000	$9,600
General superintendents, managers, clerks, etc.—			
Total number	73	41	32
Total salaries	$77,290	$44,602	$32,688
Men—			
Number	58	32	26
Salaries	$68,860	$39,960	$28,900
Women—			
Number	15	9	6
Salaries	$8,430	$4,642	$3,788
Wage-earners, including pieceworkers, and total wages:			
Greatest number employed at any one time during the year	2,261	1,472	789
Least number employed at any one time during the year	2,029	1,330	699
Average number	2,162	1,415	747
Wages	$683,281	$492,546	$190,735
Men, 16 years and over—			
Average number	758	523	235
Wages	$352,563	$291,032	$61,531
Women, 16 years and over—			
Average number	1,087	758	329
Wages	$263,118	$179,798	$83,320
Children, under 16 years—			
Average number	317	134	183
Wages	$67,600	$21,716	$45,884
Average number of wage-earners, including pieceworkers, employed during each month:			
Men, 16 years and over—			
January	752	519	233
February	769	528	241
March	768	533	235
April	753	535	218
May	777	536	241
June	721	493	228
July	756	522	234
August	770	521	249
September	762	527	235
October	767	524	243
November	756	518	238
December	745	516	229
Women, 16 years and over—			
January	1,086	738	348
February	1,093	755	338
March	1,097	766	331
April	1,114	788	326
May	1,099	790	309
June	1,053	744	309
July	1,084	756	328
August	1,087	760	327
September	1,087	758	329
October	1,086	751	335
November	1,079	746	333
December	1,079	745	334
Children, under 16 years—			
January	304	126	178
February	318	133	185
March	320	136	184
April	325	137	188
May	322	138	184
June	310	135	175
July	316	136	180
August	379	195	184
September	314	135	179
Average number of wage-earners, etc.—Con.			
Children, under 16 years—Continued.			
October	327	135	192
November	314	132	182
December	255	75	180
Miscellaneous expenses:			
Total	$278,176	$191,382	$86,794
Rent of works	$1,320	$720	$600
Taxes, not including internal revenue	$16,172	$13,289	$2,883
Rent of offices, insurance, interest, and all sundry expenses not hitherto included	$260,684	$177,373	$83,311
Materials used:			
Total cost	$1,030,917	$755,549	$275,368
Principal materials—			
Total cost	$714,557	$457,733	$256,824
Purchased in raw state	$79,233	$79,033	$200
Purchased in partially manufactured form	$635,324	$378,700	$256,624
Fuel	$13,757	$8,489	$5,268
Mill supplies	$32,566	$29,890	$2,676
All other materials	$255,587	$244,987	$10,600
Freight	$14,450	$14,450	.....
Products:			
Total value	$2,222,276	$1,581,351	$640,925
Pencils and pens—			
Total value	$1,820,166	$1,328,886	$491,280
Pencils—			
Total gross	1,383,822	911,138	472,684
Total value	$1,705,065	$1,213,785	$491,280
Lead (complete)—			
Number of gross	1,381,329	909,170	472,159
Value	$1,641,975	$1,151,495	$490,480
Silver—			
Number of gross	1,486	1,486	.....
Value	$43,496	$43,496	.....
Plated—			
Number of gross	482	482	.....
Value	$18,794	$18,794	.....
Other varieties—			
Number of gross	525	.....	525
Value	$800	.....	$800
Pens—			
Total gross	432,759	432,759	.....
Total value	$115,101	$115,101	.....
Fountain (complete)—			
Number of gross	447	447	.....
Value	$39,125	$39,125	.....
Gold—			
Number of gross	31	31	.....
Value	$2,202	$2,202	.....
Steel—			
Number of gross	432,230	432,230	.....
Value	$71,318	$71,318	.....
Stylographic—			
Number of gross	51	51	.....
Value	$2,456	$2,456	.....
Value of all other products	$402,110	$252,465	$149,645
Comparison of products:			
Number of establishments reporting for both years	6	3	3
Value for census year	$2,212,276	$1,581,351	$630,925
Value for preceding business year	$1,890,174	$1,408,854	$481,320
Power:			
Number of establishments reporting	4	2	2
Total horsepower	1,360	1,100	260
Owned—			
Engines—			
Steam—			
Number	4	2	2
Horsepower	1,360	1,100	260
Establishments classified by number of persons employed, not including proprietors and firm members:			
Total number of establishments	7	3	4
No employees	.....	.....	.....
Under 5	1	.....	1
5 to 20	3	1	2
21 to 50	.....	.....	.....
51 to 100	.....	.....	.....
101 to 250	.....	.....	.....
251 to 500	1	1	.....
501 to 1,000	1	.....	1
Over 1,000	1	1	.....

[1] Includes establishments distributed as follows: Illinois, 1; Massachusetts, 1; New Jersey, 2.

CHEMICALS.

CHEMICALS.

[See Appendix, page 831, Digest of Patents Relating to Chemical Industry.]

By CHARLES E. MUNROE and THOMAS M. CHATARD.

The publication of special reports relating to the manufacture of chemicals, which was begun in the Tenth Census, was a feature of the Eleventh Census, although, as stated in the report on "chemicals and allied products" of the latter census (Eleventh Census, Manufacturing Industries, Part III, page 275), "owing to changes in the form of inquiry and the inclusion of certain allied industries not reported as chemicals at the census of 1880, and the exclusion of others that were included under this head at the Tenth Census, a true comparison is impossible."

The same may be said of the report on chemicals and allied products for the Twelfth Census, now presented. Pharmaceutical preparations, included as chemicals by the Eleventh Census, have been excluded from the present report, while "bone, ivory, and lamp black," previously reported elsewhere, is here included. Still, the data for so many of the industries included in the classification are comparable that a fairly correct idea of the growth of the combined industries as a whole, during the past decade, may be obtained.

The total number of active establishments included in this inquiry, as set forth in this report, is 1,827. Thirty-six establishments were reported as idle, making the total number of establishments 1,863. The report on "chemicals and allied products" for 1890 covered 1,626 establishments, including those making pharmaceutical preparations as the principal product, but the latter are not considered in the present report. The Census Office classifies an establishment according to the nature of its principal product, this being determined by its value as compared with that of any other product which may be made therein. The special schedules for the various industries call for the main products of the industry with sufficient detail, while subordinate products are, in most cases, brought together under the caption "all other products." Hence, chemical products made by works belonging to other categories can not, in most cases, be ascertained from the returns and do not appear in this report except in a few specified instances. The amount so lost to this inquiry is, however, not so large as to materially affect these returns, and as the value of such products is included in the figures of the other categories, the final total value of all manufactures is not affected. Moreover, establishments whose products during the census year were valued at less than $500 are not included in the general tabulations, but are taken into consideration in this special report.

Owing to the hearty cooperation of most of the leading chemical works it is believed that the figures here presented are as nearly correct as the difficulties attending the collection of the information have permitted. In probably no branch of the census work is the need of a permanent, trained force more keenly felt than in this particular inquiry, the wide range of which is shown by the character of the "Special Schedule, No. 17," used in the collection of these returns. The products were classified under 19 groups, as follows: Group I, Acids; II, Sodas; III, Potashes; IV, Alums; V, Coal-Tar Products; VI, Cyanides; VII, Wood Distillation; VIII, Fertilizers; IX, Bleaching Materials; X, Chemicals produced by the aid of Electricity; XI, Dyestuffs; XII, Tanning Materials; XIII, Paints, Pigments, and Varnishes; XIV, Explosives; XV, Plastics; XVI, Essential Oils; XVII, Compressed and Liquefied Gases; XVIII, Fine Chemicals; and XIX, General Chemicals. In the course of the work it was found necessary to form a subgroup, XIX A, to classify certain establishments whose main products were not originally included in "chemicals." A final group named "miscellaneous" includes a number of products not chemical but made by works belonging to the category of "chemical industries." By bringing such products together their nature, quantity, and value are given and the figures may be used to supplement the returns elsewhere given for such substances so far as they may be separately reported.

Separate tabulations have been made of the data for Group VIII, Fertilizers; Groups XI and XII, Dyestuffs and Extracts; Group XIII, Paints; also Group XIII, Varnishes; Group XIV, Explosives; and Group XVI, Essential Oils. The data for the remainder of the groups are included in the general tabulation of "chemicals." There is also a tabulation of "bone, ivory, and lamp black," but as results showed that the product was exclusively hydrocarbon black or lampblack, the figures may be properly included in those for "paints," and are so treated in the special group report. These tabulations are continued from previous censuses and are necessary in order that the condition of the manufactures of states, cities, etc., may be promptly shown with sufficient detail, but for the proper presentation of the chemical industries of the United States a certain reclassification of products became needful. For example, a certain large establishment made paints, acids, and general chemicals, its paint product being the largest in value; the establishment was classified

under "paints," the other products being there reported as subproducts. In another instance a large fertilizer works, making its own acid, had such an extensive business in the manufacture of cottonseed products that, although it was really a chemical works of much importance, it could not be put in this category, but had to go elsewhere. So far as possible, the chemical products of this latter class of works have been taken into consideration in the special group reports, but separately noted, so that any duplication may be made evident.

In the special group reports, all of the products belonging to the group are brought together. When the main product of a works belongs to the group under consideration, the establishment is a "main" one and belongs to Class A. When the group product is a minor one for an establishment, this is counted in, but as a "sub" works and placed in Class B. The chemical product of an establishment not belonging to the category of "chemical industries," as noted above, is also taken into account, but the establishment and its chemical product are placed in a third class, C. By this system each group report can present its special operations and products in any desired detail; and while the figures of product may differ from and often exceed those of the general tabulations, no confusion can result if it is clearly understood that the purpose of the special group reports is to give as clear and complete a presentation of the American chemical industry as the available information may permit.

The following table gives, first, the totals for establishments, capital, labor, cost of materials, and value of products as shown in the tabulations, and second, for purposes of comparison, the total values for the same classes of products as shown by the reclassified figures of the group reports:

COMPARISON OF TABULATION VALUES WITH GROUP VALUES: 1900.

TABULATION.	Number of establishments.	Capital.	WAGE-EARNERS.		Materials, cost.	Products, value.	Reclassified products, value.
			Average number.	Total wages.			
Total	1,740	$238,529,641	46,766	$21,799,251	$124,043,837	$202,582,396	$221,217,217
Chemicals	459	89,091,430	19,054	9,401,467	34,564,187	62,676,730	[1] 78,414,840
Dyestuffs [2]	77	7,889,034	1,648	787,942	4,745,912	7,350,748	7,767,226
Essential oils	70	612,657	199	69,100	596,112	850,093	859,401
Explosives	97	19,465,846	4,502	2,383,756	10,334,974	17,125,418	[3] 16,950,976
Fertilizers	422	60,685,753	11,581	4,185,289	28,958,473	44,657,385	45,911,382
Paints and varnishes [4]	615	60,834,921	9,782	4,971,697	44,844,229	69,922,022	71,313,392

[1] Including miscellaneous, $4,175,656 from all tabulations.
[2] Including tanning materials.
[3] Excluding miscellaneous.
[4] Including bone, ivory, and lamp black.

Taking the table of "principal products, their quantity and value, 1890," given on page 275 of the abovementioned special report of the Eleventh Census, and comparing the returns for the same products as given by the figures of the Twelfth Census, the following results are shown:

COMPARISON OF THE QUANTITIES AND VALUES OF THE PRINCIPAL PRODUCTS REPORTED: 1890 AND 1900.

PRODUCTS.	1890		1900	
	Quantity.	Value.	Quantity.	Value.
Total		$163,547,685		$221,217,217
Alum, pounds	93,998,008	1,616,710	179,467,471	2,446,576
Coal-tar products		687,591		1,421,720
Dyeing and tanning extracts and sumac, pounds	187,906,911	8,857,084	169,525,536	7,767,226
Gunpowder and other explosives, pounds	125,645,912	10,993,131	215,590,719	16,950,976
Fertilizers, tons	1,898,806	35,519,841	3,091,717	45,911,382
Paints, colors, and varnishes		52,908,252		71,313,392
Potash and pearlash, pounds	5,106,939	197,507	3,864,766	178,180
Sodas, pounds	333,124,375	5,432,400	1,279,082,000	10,237,944
Sulphuric acid, 50°, pounds	1,009,863,407	4,307,067	1,906,878,903	7,965,832
Sulphuric acid, 60°, pounds	20,379,908	122,940	34,023,131	246,284
Sulphuric acid, 66°, pounds	354,533,657	3,249,466	764,558,455	6,035,069
Wood alcohol and acetate of lime		1,885,469		5,775,290
Chemicals (including all acids, bases, and salts not heretofore enumerated)		24,751,974		[1] 40,791,690
All other products		13,018,253		4,175,656

[1] Including essential oils, $859,401.

This table shows that while the chemical industries of the United States have greatly advanced in quantity of product, the value per unit of product has much decreased, a tendency of much importance to those industries which use these products as materials for their own operations.

Each of the groups into which products are classified represents a special form of establishment, sometimes two or more forms, even though a single establishment may, and often does, furnish products belonging to two or more groups. Hence it is practically impossible to construct for this special branch of inquiry a single schedule which, by the wording of the interrogatories and the indications as to the proper nature of the replies, will enable the Census Office to elicit the desired information from all alike. The difficulties experienced in collecting the statistics have, however, indicated improvements needed for future work, and, with a permanent Census Bureau, there is every reason to expect that at the next census the statistics of chemical manufactures will show results of much wider scope than it has been possible to present even at the census of 1900.

The willingness of the manufacturers, notably of the great combinations, to furnish information has been most gratifying, and when difficulties have occurred in most cases they have been due to the fact that the establishments did not have such records as would give the information desired. The absence of such records has generally been regretted by the manufacturers, who have recognized the value such information would have been to them in their business. In the few cases where information was at first refused on the ground of interference with private business, a courteous letter of explanation rarely failed to elicit a pleasant reply, giving everything desired so far as it could be furnished.

While the groups above mentioned cover most of the products usually recognized as chemicals, inspection of the index of any standard work on chemical technology will show that the subjects considered as belonging to this domain are far more numerous. The reason for this becomes evident when it is remembered that every form of industry must be either physical or chemical or a combination of both. The manufacture of pig iron or the tanning of a hide is a chemical process, while the rolling of a rail or the making of a shoe is a physical process, but many manufacturing processes in which chemical reactions occur can not be sharply classified, since, while the products are the results of chemical action, the practical success of the operations depends upon the correct arrangement of the mechanical plant, a good example of this being the ammonia-soda process. Modern industrial chemistry tends to develop itself more and more along engineering lines; hence the increasing demand for the chemical engineer—a mechanical engineer with a special equipment of chemical science and technology.

A list of the topics treated of in Wagner's Chemical Technology is here given as an example of what the term "chemical technology" as a rule embraces, to which is added a list of the special schedules and bulletins issued by the Census Office showing how far these topics are the subject of special inquiries and reports at the census of 1900, thus facilitating the obtaining of a comprehensive view of this industrial complex.

COMPARISON OF THE TOPICS OF CHEMICAL TECHNOLOGY WITH THE CLASSIFICATIONS OF THE CENSUS OF 1900.

TOPICS.	Special schedule number.
Fuel:	
Charcoal (chemical manufactures)	17
Coke	7
Gas, illuminating and fuel	(no number)
Oil, mineral (petroleum refining)	8
Paraffin, etc (petroleum refining)	8
Metallurgy:	
Iron and steel	21 and 23
Copper	24
Lead	25
Zinc	26
Other metals, general schedule	3

COMPARISON OF THE TOPICS OF CHEMICAL TECHNOLOGY WITH THE CLASSIFICATIONS OF THE CENSUS OF 1900—Continued.

TOPICS.	Special schedule number.
Chemical manufactures, inorganic:	
Common salt	9
Acids, bases and salts; Fertilizers; Explosives; Compressed gases; Electrolytic products; Paints and varnishes (chemical manufactures)	17
Chemical manufactures, organic:	
Alcohols and ethers; Organic acids; Organic coloring matters; Coal-tar products and colors (chemical manufactures)	17
Glass:	
Pottery and fire-clay products	6
Bricks	5
Cements and mortar, general schedule	.....
Food, beverages, etc.:	
Starch, general schedule	.....
Sugar, general schedule	.....
Fermentation	.....
Brewing, general schedule	.....
Wine making, general schedule	.....
Spirits, general schedule	.....
Flour and grist products	31
Meat products (slaughtering and meat packing)	33
Milk, butter, and cheese	32
Fibers:	
Preparing, bleaching, dyeing, printing, and finishing	12
Silk	16
Wool	14 and 15
Cotton	11
Hemp, flax, and jute	13
Paper	34
Miscellaneous:	
Tanning (leather, tanned and curried)	18
Glue, size, gelatine, general schedule	.....
Bone distillation—	
Bone charcoal, general schedule	.....
Bone oil	.....
Fats, oils, soaps, general schedule	.....
Stearin and glycerin, general schedule	.....
Resins, general schedule	.....
Essential oils (chemical manufactures)	17
Wood preservation, general schedule	.....

While some of these topics may at first appear to the laymen to have but a very slight connection with chemistry, as, for example, the manufacture of flour or bricks, yet flour and bricks, as well as all of the other chemical substances named, are chemical substances, and they have been the subject of extended chemical study by specialists, through which there has resulted great improvement in the quality and cheapness of the products. In such industrial chemical investigation Germany leads all other countries, and its present preeminence in the field of chemical manufacture has been deservedly won by its work, although it has been materially aided by the character of the patent laws of England and of the United States.

The German chemical manufacturer is far in advance of those of all other nations in recognizing the value of specialized chemical skill in the conduct of the works and in employing trained chemists in laboratory investigations. Thus McMurtrie[1] points out that the Fabriken der Actien-Gesellschaft Farbewerke Meister Lucius und Bruning in Höchst, who were in 1890 making between 1,700 and 1,800 different colors, numbered

[1] The Relations of the Industries to the Advancement of Chemical Science, by William McMurtrie, Proc. A. A. A. S., Vol. 44, page 79, 1895.

among their 3,000 employees 70 chemists and 12 engineers. Green[1] states that in 1900 the six largest coal-tar color firms in Germany employed about 500 chemists and 350 engineers and technical men, while Sir Henry Roscoe[2] states that at the German works which he had visited, highly trained chemists were employed in original researches with a view to new discoveries. "One employee, who received £1,000 a year, worked for several years without producing any results; but eventually he made a discovery which repaid the firm ten times over, and placed an entirely new branch of manufacture in their hands."

Owing to the extended discussions going on in England and America relative to the tremendous growth of the chemical industries of Germany during the past twenty years, in which many have attributed much of this growth to the extensive employment of doctors of philosophy in chemistry and other university-bred chemists in the German technical works, a census has been taken of the establishments in the United States which are the subject of this report, with the following result:

CHEMISTS EMPLOYED IN THE ESTABLISHMENTS TREATED OF IN THIS REPORT.

GROUP NUMBER.	Group name.	Number of chemists.
I	Acids	28
II	Sodas	9
III	Potashes	.....
IV	Alums	11
V	Coal-tar products	7
VI	Cyanides	8
VII	Wood distillation	3
VIII	Fertilizers	10
IX	Bleaching materials	4
X	Electro-chemicals	9
XI	Dyestuffs	13
XII	Tanning materials	7
XIII	Paints and varnishes	53
XIV	Explosives	32
XV	Plastics	5
XVI	Essential oils	2
XVII	Liquefied gases	9
XVIII	Fine chemicals	26
XIX	General chemicals	41
	Total	276

When, in German works, the results of the investigations of the expert chemists indicate commercial possibilities, practical working tests follow, and, in the end, one more patent is added to those which hamper the development of chemical industry in countries which, like the United States, give the foreigner the monopoly of a patent without requiring that the protected article shall be made where the patent is issued. The effect is that since it is often more profitable to make the higher grade chemicals abroad than in the United States, foreign labor and capital are protected to the injury of the labor and capital of this country. Hence, while the manufacture of acids, alkalies, fertilizers, and other heavy chemicals has greatly increased in the United States, this is mainly because of transportation costs. The tariff on alkalies has certainly added much in the development of this branch because it has been to the interest of the foreign patentees to establish alkali works here either by their own capital or by granting licenses to others. When, as in the case of dyestuffs and other high-grade chemicals, the transportation cost is a minor consideration, the tariff has little effect in inducing the domestic manufacture of a foreign article protected by a local patent. So long as the demand for his article insures a sufficient price, the foreign patentee can make it abroad and ship it here, paying whatever duty may be demanded; by simply refusing to grant a license for manufacture here, he is secured from all competition. Other countries may have refused to grant him a patent, which may even have become void in the original country, and the article be made by others; yet under our laws, he, and he alone, may vend the article here. The English, who are suffering from a similar condition of their patent laws, are bestirring themselves to have the situation ameliorated, and a special committee of the Society of Chemical Industry has lately made a report upon this subject.[3] The effects of granting British patents to foreigners without requiring domestic operation are thus stated:

1. We foster foreign labor and assist in the development of foreign industries.
2. As the introduction of a new article generally replaces another article hitherto in use, we throw out of employment a certain number of our own workpeople.
3. Very frequently the foreign patentee has either not succeeded in getting a patent in his own country or such patent has already run its course there, whilst his British monopoly remains in full force. The result is that we stifle invention and increase the prices of a number of articles by closing the doors to our own inventors and manufacturers, whilst our foreign competitors may make and vend abroad the patented article without any restriction or payment of royalty.

Several examples are given of the practical working of the English patent laws. Artificial alizarine was invented in Germany but no patent was granted there. English patents were, however, granted, with the result that the patentees, having the monopoly of the English market anyhow, simply made it in Germany, as being cheaper so to do, and built up an enormous trade which was the foundation of Germany's present supremacy in the manufacture of coal-tar dyestuffs. Again, the production of artificial indigo is destroying the natural indigo industry of India and producing much distress there. England, which is thus a heavy loser, can do nothing to offset this loss, because the patent monopoly granted to the foreigner enables him to supply the English market on his own terms.

Every country, save England and the United States, has a provision in its patent laws that a patent can be revoked if not worked in the country granting the patent. Moreover, the French patent law has, in addi-

[1] The Coal-tar Industry, by A. G. Green, Science, Vol. 14, page 663; 1901.

[2] J. Soc. Chem. Ind., Vol. 16, page 570, 1897.

[3] J. Soc. Chem. Ind., 1902, pages 212 to 301.

tion, the following provision, article 32, section 3, "The patent shall be revoked if the patentee has introduced into France articles of manufacture made abroad and similar to those which are protected by the patent." In this way France provides that, in giving to anyone the protection of her patent laws, her domestic industry shall be fostered, and not, as in England and the United States, often injured and sometimes destroyed. Instances have occurred in this country where chemical substances once made here are no longer produced, because the foreign manufacturer, protected by his American patent, has been able to make the domestic manufacture unprofitable.

The report under consideration states that "There is but one remedy for this vexed question which is both simple and efficacious, viz, to enact that 'A patent may be revoked if it be proved that an article patented is worked abroad and not in the United Kingdom, the onus of proof that the patent is worked, bona fide, in this country, resting with the patentee or licensee.'" Some such provision as this in the laws of the United States would materially aid the development of our American chemical industry.

In order to bring out the relations existing between the growth of the chemical industry and of the patents which have been granted in this country covering inventions in this industry, an abstract has been made of all chemical patents issued from the founding of the United States Patent Office up to the year 1900, and this Digest of Chemical Patents is given as an appendix to this report. It was prepared by Mr. Story B. Ladd, M. E., whose experience as a patent attorney especially fitted him for this duty, and he elsewhere shows the effect which the granting of these monopolies has produced on the industries of the United States.

The Nineteenth century, the closing year of which is marked by the taking of the Twelfth Census, will always be a notable one in the history of chemical manufacture, since practically all of its present working processes have had their origin and development during this period. Indeed, chemical manufacture, as such, can hardly be said to have existed until the continuously working chamber process for sulphuric acid was introduced, about 1810, while the Leblanc soda process, although discovered by him in 1789, failed to get a footing until 1814, when it was introduced into England by Losh. Thereafter the development of chemical technology proceeded rapidly, and now, at the end of the century, we find that the great Leblanc process is approaching extinction through the inroads of the later ammonia-soda process and the electrolytic chlorine process, while the chamber process for sulphuric acid appears to be about to meet a formidable competitor in the recently developed contact process.

As the nature and working conditions of this process have been only lately made public, and as its general introduction will have such a profound effect upon industrial chemistry, especial attention is given to it in the next section. Moreover, contact action or catalysis continually occurs in chemical operations, has already numerous applications, and the number is continually increasing.

By catalysis in meant that peculiar action of a substance by which it can, when in contact with two or more substances capable of reacting upon each other, either cause the reaction, or, if the reaction is already occurring, greatly diminish the time required for its completion. At the same time, the catalytic substance, so far as respects the nature of the ultimate products, appears to have undergone no change. Hence, Ostwald's definition, "A catalytic agent is such material as affects the velocity of a chemical reaction without itself appearing in the final product." A very familiar example of catalytic action is the effect of adding manganese peroxide to potassium chlorate when making oxygen. Either of the substances gives off oxygen when heated to a temperature sufficiently high, but when mixed the reaction is effected at a much lower temperature and with much less danger of explosion. When the reaction is completed, examination of the residue shows that only the chlorate has lost its oxygen, becoming chloride, the peroxide being apparently unchanged. It is probable that the latter has taken full part in the reaction, giving off oxygen and taking it up again, but, looking only at the final result, it appears to have been effective merely by its presence.

The action of the niter gas in the sulphuric acid chamber is also catalytic. The union of sulphur dioxide and atmospheric oxygen can and does take place without the help of the niter gases, but the unassisted reaction is very slow and incomplete. The niter gases are oxygen carriers; the oxygen which they contain is in a much more active condition than that of the air, so that they oxidize the sulphur dioxide but replace the loss by taking up oxygen from the accompanying air. As water, in the form of steam, is always present in this reaction, the final product is sulphuric acid, which, in theory at least, is free from oxides of nitrogen, the niter gas remaining in its original active condition. In practice, however, a certain amount of this gas is reduced to inactive forms and this loss must be made up by addition of fresh gas, so that for every hundred parts of acid produced, a certain quantity of niter is used up, but this quantity, being theoretically nothing, depends upon the care of the management and other conditions.

Other applications of catalysis are met with in the Deacon chlorine process, the manufacture of chlorates, aldehydes (the formaldehyde lamp for disinfection being an example), acetone, carbon tetrachloride, and many other organic products, the entire subject being one of great and increasing importance.

Group I.—Acids.

Sulphuric Acid.—The manufacture of sulphuric acid has practically doubled during the past decade, the increase of product resulting more from the expansion of

works than from an increase in their number. The following table gives a comparison between the output for the census year of 1900 and that for 1890. The figures for quantity and value of 50° acid include acid made and consumed in the works in the production of fertilizers and other products.

COMPARISON OF SULPHURIC ACID PRODUCED IN 1890 AND 1900.

STRENGTH, BAUMÉ.	1900—127 ESTABLISHMENTS.			1890—105 ESTABLISHMENTS.		
	Acid produced.			Acid produced.		
	Pounds.	Value.	Value per ton.	Pounds.	Value.	Value per ton.
Total	2,705,460,489	$14,247,185	.....	1,384,776,972	$7,679,473	.....
50°	1,906,878,903	7,965,832	$8.35	1,009,863,407	4,307,067	$8.53
60°	34,023,131	246,284	14.47	20,379,908	122,940	12.06
66°	764,558,455	6,035,069	15.78	354,533,657	3,249,466	18.33

The figures of quantity and value of the 50° acid for both periods include the amount of this acid made at certain works and consumed there in the manufacture of fertilizers. In addition there is given the quantity and value of the acid consumed at works in 1900 for making mixed acids for explosives and for other purposes. The acid used for fertilizers was really 50° or chamber acid. The rest of the acid included for 1900 was of various strengths, but for purposes of comparison these have been reduced to 50°. In reducing 66° acid to 50°, the quantity is multiplied by 1.50, and for 60° acid, multiplied by 1.25, these factors being closely approximate to the usual strengths.

	1900.		1890.	
	Pounds.	Value.	Pounds.	Value.
Total	2,097,268,570	$8,819,526	581,536,200	$2,480,495
Fertilizers	1,578,718,000	6,591,147	581,536,200	2,480,495
Other purposes	518,550,570	2,228,379	(1)	(1)

[1] Not given.

The census report for 1890 also gave the total acid production reduced to a uniform strength of 50°. Doing this for the acid production of the present census gives the following comparison:

Total acid as 50°:	
1900	3,096,245,498
1890	1,567,138,777
Gain, 97.6 per cent	1,529,106,721

The census of 1870 was the first at which separate figures were given for sulphuric acid, but only the number of establishments and the total value of product were given. In 1880 the total quantity in pounds was given, but no separation into the various strengths was made, so that the returns are not strictly comparable. Even with these restrictions a comparison is interesting as showing the growth of this branch of manufacture.

YEAR.	Number of works.	Quantity of products.	Value of products.
1870	4	(1)	$212,150
1880	49	308,765,432	3,661,876
1890	105	1,384,776,972	7,679,473
1900	127	2,705,460,489	14,247,185

[1] Not given.

The first manufacturer of sulphuric acid in the United States appears to have been Mr. John Harrison, of Philadelphia, who in 1793 had a lead chamber capable of producing 300 carboys of acid per annum.[1] The business proving very remunerative, he built, in 1807, a lead chamber 50 feet long, 18 feet wide, and 18 feet high. This was a large chamber for the time, and was capable of making nearly half a million pounds of sulphuric acid annually, the price of the acid being then as high as 15 cents a pound. Mr. Harrison was also the first person in the United States to use a platinum still for the concentration of the acid, this having been up to then done in glass, a very precarious and dangerous operation. This first still was made in 1814 by Dr. Eric Bollman, and was at once put in use. It weighed 700 ounces, had a capacity of 25 gallons, and was in continuous use for fifteen years.

Powers & Weightman, of Philadelphia, report that they began the manufacture of sulphuric acid in 1825, while a letter from Mr. Nicholas Lennig, containing much valuable information, states that about 1829 his father, the late Mr. Charles Lennig, erected a sulphuric-acid plant which "was so successful that the then existing New York Chemical Company went into liquidation, and put the funds realized therefrom into a banking company now well known as the Chemical National Bank."

It also appears that, in 1829, the manufacture of sulphuric acid was begun in Baltimore by two companies, the Maryland Chemical Works and the Baltimore Chemical Manufactory. The industry extended, and the figures given at the census of 1870 of 4 works, with a total product of the value of $212,150, are undoubtedly erroneous. Of the works reporting acids as principal products at the census of 1900, 16 reported starting in business prior to 1870, while some of the fertilizer factories were making acid prior to that time. While nothing positive can now be said on this subject, it is not unlikely that in 1870 there were at least 25 sulphuric acid works in operation, with a product of over a million dollars in value. Such a supposition is certainly more reasonable when compared, as above, with the figures of subsequent censuses, since everyone, at all conversant with this subject, is well aware that between 1870 and 1880 there was no such outburst of energy in this branch of industry, as would be indicated by the

[1] Catalogue, Harrison Brothers & Company, Incorporated, Philadelphia, 1902.

figures of the respective years. Moreover, the figures of value for the total chemical industry, so far as they can be compared, were, for 1870, $60,998,214, and for 1880, $89,388,172; while the figures for 1890 were $161,067,190. The comparatively small increase of the figures of total value of product for 1880 over those for 1870 is what would be expected in the slow uphill course of business between 1873 and 1880, while the next decade opened with a revival which, with occasional backsets, held good until 1893.

The total number of sulphuric-acid works reporting at the census of 1900 was 127. Of these, 31 burned brimstone only, 79 burned pyrites only, while 17 reported that they used both brimstone and pyrites.

Brimstone Plants.—Seven brimstone-burning plants made 66° acid, burning 18,042,072 pounds of brimstone and producing 51,204,775 pounds of 66° acid, or an average of 279 parts of 66° acid (equivalent to 419 parts of 50° acid) to 100 brimstone, the figures for each plant running from 308 to 260 parts of acid. Thirteen brimstone plants, making 50° acid only, used 35,955,680 pounds of brimstone and produced 140,534,027 pounds of 50° acid, an average of 391 parts of acid to 100 parts of brimstone, the figures running from 446 to 321 parts of acid for 100 parts of brimstone. Two works reporting, respectively, a yield of 321 and 334 parts, stated that they were using a very low grade of brimstone, which was obtained under advantageous conditions. Taking the 20 works together and the whole product as 50° acid, it is found that the grand average is 402 parts of acid for each 100 parts of brimstone.

Pyrites Plants.—Nine pyrites plants, making 66° acid only, consumed 248,026,399 pounds of pyrites and produced 311,924,674 pounds of 66° acid, an average of 133.8 parts of acid (equivalent to 200.7 parts of 50° acid), for 100 parts pyrites. Thirty pyrites plants, making 50° acid only, consumed 425,050,296 pounds of pyrites and produced 889,222,560 pounds of 50° acid, an average of 209 acid to 100 pyrites, the figures running from 234 to 160 parts. The grand average for the 39 works is 206 acid to 100 pyrites.

The figure 160 is given by 3 works burning low grade domestic pyrites, while the highest figure, 234 parts acid, is furnished by a new model plant burning pyrites with an average content of 50.05 per cent of sulphur and using 1.26 parts of nitrate of soda to every 100 parts of pyrites. Other works give, per 100 pyrites, 224 acid, 1.66 niter; 213.4 acid, 2.13 niter, while a large combination reports that it allows 2.5 parts of niter and expects a yield of 225 parts of 50° acid. The brimstone works show approximately a consumption of 4.29 parts of niter per 100 brimstone. In considering these figures, it must be remembered that the 66° acid does not average more than 93 per cent of H_2SO_4, corresponding to 65.6° B. Similarly, the 50° acid runs from 52° to 48° B., and even lower, and the chamber acid made and used in fertilizer works is usually under 50°. The continued use of brimstone in this industry in the United States is remarkable, as practically no brimstone acid is now made in England or on the continent of Europe.

The Contact Process.—In 1900, at the meeting of the German Technical Chemists at Hanover, Clemens Winkler, the founder of the contact process, as we now have it, delivered an address entitled "The Development of the Sulphuric Acid Industry During the Nineteenth Century." In this paper, published in Zeitschrift fur Angewandte Chemie, 1900, page 731, he gives a short review of the history and present status of the chamber process, and then shows the lines he followed in his celebrated research upon contact action in the production of sulphur trioxide, which he made public in 1875. He then speaks of the subsequent development of this process, and concludes by impressively stating that the contact process has already demonstrated its ability to compete with and finally to supersede the chamber process. The subject is so important that a summary of this paper is given here, and, following it, an abstract of the very valuable paper by Knietsch upon the development of the contact process in the works of the Badische Anilin und Soda Fabrik to which Winkler calls attention. This paper is very recent, having been published in the "Berichte der Deutschen Chemischen Gesellschaft" for December, 1901, and is so full of valuable information that its presentation here, in abstract, seems appropriate.

Winkler stated that the only acid known to the ancients was vinegar, and that the first indication of the recognition of any other acid is when Geber, in the Eighth century, speaks of the "spirit" which can be expelled from alum and which possesses solvent powers. Albertus Magnus, Thirteenth century, speaks of a "spiritus vitrioli Romani" which can only have been sulphuric acid, while Basilius Valentinus, Fifteenth century, describes its preparation not only from copperas, but also by burning together sulphur and saltpeter, pointing out very distinctly not only that sulphur, in burning, produced some sulphuric acid, but also that the yield is much increased if saltpeter is added.

Dornaeus, in 1570, described its properties accurately; Libavius, 1595, recognized the identity of the acids from different processes of preparation; Angelus Sala, 1613, pointed out the fact, which had sunk into oblivion since Basilius, that sulphuric acid can be made by burning sulphur in moist vessels; after that time it was prepared by the apothecaries in that way.[1]

The addition of saltpeter was introduced by Lefevre and Lemery, 1666, and Ward, in London, 1740, began to make sulphuric acid on a large scale in glass vessels. The lead chamber was first used by Roebuck, of Birmingham, who, in 1746, erected such a chamber 6 feet square. The first chamber erected in France was at Rouen, in 1766. At this place, in 1774, De la Follie introduced the important improvement of the intro-

[1] Lunge: Sulphuric Acid and Alkali, 1891, Vol. I, page 7.

duction of steam into the chambers during the combustion of the brimstone. In 1793 Clement and Desormes showed that the chambers could be fed by a continuous current of air, by which much saltpeter could be saved. By this time the general principles of sulphuric-acid making were established, and by the end of the century there were already six or eight works in Glasgow alone, while the price of a kilogram (2.2 pounds), which, in 1740, in Germany, was about $1.12, sank in 1799 to 22 cents, and is now (1900) about three-fourths of a cent.

Lampadius (Grundriss d. tech. Chemie, Freiberg, 1815, p. 3) has given a description of a sulphuric-acid works and the manner of operation at the beginning of the Nineteenth century. From this it is learned that a mixture of five parts of sulphur and one part of niter was burned in successive charges in the lead chamber, steam being admitted at the same time and air being let in when deemed necessary. The acid obtained was weak and had to be concentrated in glass retorts up to about 1.80 sp. gr., while the yield was less than half of what would be obtained at present.

The proper construction of lead chambers involved great difficulties, it being almost impossible to make them gas-tight, until Debassyns de Richemont invented autogenic soldering. The chamber described by Lampadius contained about 300 cubic meters (10,594 cubic feet), but the dimensions have been increased until now the biggest chambers contain 4,000 to 5,000 cubic meters (140,000 to 176,000 cubic feet). The last figures appear to be too large, and the present practice is not to increase the chamber space, but to supplement the surface by means of other devices, such as the Lunge-Rohrmann plates.

Finally, in the earlier years of the Nineteenth century, the chamber process became a continuously working one, and thus was enabled to be what it now is, the foundation of the chemical industry and the measure of its extent. Improvements rapidly followed. The investigations of Gay-Lussac, on the recovery of the nitrogen oxides from the escaping gases, have given us the tower which bears his name, while the form of tower invented by Glover furnishes an efficient denitrator for the acid flowing from the Gay-Lussac tower. The simultaneous use of these two towers is a necessity in any modern, rationally managed establishment.

The use of pyrites, in place of brimstone, was first introduced in 1836, on a manufacturing scale, by Wehrle, in Nussbaum, near Vienna, and by Brem, in Bohemia. In 1862, Spanish pyrites began to be used in England, and by 1868 the use of brimstone in English works had almost entirely ceased, and now very little brimstone is used in any country of Europe for the manufacture of sulphuric acid, while the consumption in the United States for this purpose is still quite large, amounting, in the census year 1900, to 128,427,000 pounds, or about one-tenth of the total weight of the pyrites so used.

Attempts to use the roaster gases from smelting works were made in 1856–1858, and in 1859 a set of chambers using such gases was started at Oker. At present the smelting works in Germany produce (1899) 186,000 tons of H_2SO_4, about 22 per cent of the total production. As elsewhere, the principal use of this acid is in the manufacture of superphosphate, of which 500,000 tons were made in Germany in 1899.

The methods of concentration of the weaker acids have been greatly improved, the increasing cost of platinum making it necessary to exercise the greatest economy. Platinum, which in 1870 cost about $150 per kilogram, cost in 1900 over $700 per kilogram, and the price is now little less than that of gold. Heræus, in 1891, introduced the use of gold-plated platinum stills, which were found to be a great improvement.

Fuming sulphuric acid, or Nordhausen acid, as it is also called, is a mixture of sulphur trioxide (or sulphuric anhydride), with a varying proportion of monohydrated sulphuric acid. When the relation is about one part of SO_3, to one part of H_2SO_4, it is solid at ordinary temperatures, melting at 35° C., and is the "solid sulphuric acid" of the trade. As it is obtained by heating copperas, alum, or other metallic sulphates, it was the first form of sulphuric acid known, and the Pilsen acid works are already mentioned in 1526. This industry was destroyed during the Thirty Years War, but was revived at Nordhausen. In 1778 Starck reestablished the industry in Bohemia, where, on account of the cheapness of labor and of the necessary vitriol stone, his successors enjoyed a practical monopoly of this substance, until the increasing demand for it, in the manufacture of alizarin, and for many other purposes, led to researches which have given methods by which it can be made far more cheaply than by the distillation of vitriol stone, since when this is used only small charges can be worked, because the larger the charge, the higher the heat required, and the greater the loss of acid through the consequent splitting up of sulphur trioxide into sulphur dioxide and oxygen.

That these two gases could be made to recombine by the contact action of platinum and other substances, had long been known and methods of utilization proposed, but nothing of importance had been accomplished until Clemens Winkler published, in 1875, the results of his researches. In the beginning of his work, Winkler heated the vitriol stone in much larger quantities, without regard to the decomposition of the trioxides, passed the gases over platinized asbestos, thus recombining the SO_2 and O, and then absorbed the trioxide in strong sulphuric acid. The results were very satisfactory, but it was necessary to find a material cheaper than the vitriol stone. As the course of the work indicated that, for the best results, the SO_2 and O should be in stochiometrical proportions, sulphuric acid was used, because when heated sufficiently high it breaks up thus:

$$H_2SO_4 = SO_2 + O + H_2O.$$

The water vapor was easily removed and the residual gases remained in the exact proportion needed.

The need of a still cheaper material than sulphuric acid becoming manifest, Winkler began to experiment with the roaster gases of the Freiberg Smelting Works, and in time it was found that in this way two-thirds up to three-fourths of the SO_2 in these gases could be converted into SO_3. Still there were many difficulties in the way of commercial success, such as purification of the gases, etc., so that Winkler was unable to publish his further results for many years.

In the meantime the matter was taken up by the Badische Anilin und Soda Fabrik at Ludwigshafen on the Rhine, and after years of unwearied scientific investigation, in which no expense was spared, this great corporation has succeeded in solving the problem and has reaped a rich pecuniary reward.

What the commercial success of the contact process means for the future of industrial chemistry may best be expressed in the words of Winkler, who, having stated that at Ludwigshafen the new process can compete with the lead-chamber acid, goes on to say: "Therefore we can anticipate that, in no distant time, the lead chambers of to-day will be dispensed with, a condition amounting to a complete revolution in the domain of sulphuric-acid manufacture." Such a statement from so authoritative a source is a sufficient warrant for the presentation in this place of the following abstract of Knietsch's paper:

THE CONTACT PROCESS FOR THE MANUFACTURE OF SULPHURIC ACID.[1]

I. *Historical.*—The production of sulphuric acid is a matter of the greatest importance, as it is not only the foundation of the inorganic heavy-chemical industry and is used for many other purposes, but also has lately become a most important material in the organic dye-stuff industry, especially in the production of alizarine colors and of synthetic indigo. The contact process is causing a complete revolution in the methods of manufacture of sulphuric acid; hence an account of its historical development and present status should be of great interest. The historical development of this process may be divided into four periods.

First period: Phillips, in 1831, discovered the catalytic action of platinum in hastening the union of SO_2 and O to form SO_3.

Second period: Wohler and Mahla, in 1852, showed that many other substances besides platinum possess catalytic properties, and explained the character and course of the reaction.

Third period: Winkler used definite gas mixtures for the production of sulphuric anhydride, as it was then considered that only in this way could good quantitative yields be obtained.

Fourth period, the present one, is noted by the successful use of the furnace gases directly.

[1] R. Knietsch, Ber. d. d. Gesell, 1901, page 4069.

The investigations of the third period were directed toward the production of fuming sulphuric acid, which was then very expensive, while the investigations of the first and second periods had the same end as the work of the present time, that is, the replacement of the chamber process by improved methods.

The catalytic action of platinum was discovered by Humphry Davy in January, 1818, who showed that platinum wire, when warmed and then introduced into a mixture of oxygen (or air) with H, CO, ethylene, or cyanogen, became incandescent, and that the gas mixture oxidized, usually gradually, but often rapidly.

Edmund Davy, in 1820, discovered that finely divided precipitated platinum, when moistened with alcohol and exposed to the air, becomes incandescent and the alcohol burns.

Doebereiner, in 1822, found that finely divided platinum, obtained by heating ammonio-platinic chloride, acted in the same manner, and, in 1824, that such platinum could ignite a stream of hydrogen, when this impinged upon it in contact with air, and utilized this discovery in his celebrated "lighting machine."

The honor of having first utilized this catalytic action, for the production of sulphur trioxide, is due to Peregrine Phillips of Bristol, England, who, in 1831, took out an English patent for his discovery, and, in 1832, Doebereiner and Magnus each confirmed the observations of Phillips. Although this discovery attracted much attention, nothing practical followed until 1848, when Schneider exhibited a working model of an apparatus, which produced sulphuric acid through the contact action of a specially prepared pumice. This alleged discovery was presented with great claims, but never was able to show a success, although wonderful results were confidently predicted. The same may be said of the method of Richard Laming, who also used a contact mass of pumice, prepared by boiling it in concentrated sulphuric acid, washing it in ammoniacal water, drying, and then impregnating it with about 1 per cent of manganese dioxide, finishing by heating the mass in a retort to 600° and allowing it to cool out of contact with the air. Here we note for the first time, the use of another contact substance which, like platinum, can exist in various grades of oxidation, namely, manganese.

Especially noteworthy in this connection is the English patent of Jullion, 1846, because here, for the first time, the use of platinized asbestos as a contact mass is claimed. In 1849, Blondeau passed a current of a mixture of sulphur dioxide, steam, and air through a highly heated tube containing ferruginous, argillaceous sand and obtained sulphuric acid, while, in 1852, Wohler and Mahla found that oxides of iron, copper, and chrome also work catalytically upon a mixture of SO_2 and O, a mixture of cupric and chromic oxides being especially efficacious. These investigators gave, moreover, a correct explanation of this catalytic action; they found, namely, that cupric and ferric oxide, when heated in a current of sulphur dioxide free from oxygen, became

reduced to cuprous and ferroso-ferric oxides with simultaneous formation of sulphuric acid which, however, ceased as soon as the reduction of the oxides was completed. On the other hand, chromic oxide, under similar conditions, remained entirely unaltered and no sulphuric acid was produced, while metallic copper, in spongy form, exerts no action upon a mixture of 2 vol. SO_2 + 1 vol. O at ordinary temperatures, but, when heated, cupric oxide is first formed, and then sulphuric acid.

They also call attention to the fact that this union of SO_2 and O can take place in the complete absence of H_2O.

Upon these important discoveries are based the later researches of Lunge and others upon the catalytic action of pyrites cinder in causing the formation of SO_3. Quartz has also been recommended for this purpose, as have also platinized asbestus, platinized pumice, and even platinized clay.

Hundt, 1854, passed the hot roaster gas through a flue, filled with quartz fragments and heated by the gas, expecting to convert the greater part of the SO_2 into sulphuric acid with further treatment of the residue. The work of Schmersahl and Bouk, 1855, followed the same lines, as did also the method of Henry Deacon, which was patented in 1871, and may be considered as closing the second period.

So far, not only had all attempts to supersede the chamber process failed, but also no practical method for the production of fuming sulphuric acid had been devised. In 1875, Clemens Winkler published his celebrated researches upon the formation of sulphuric anhydride, for which industrial chemistry must always be greatly indebted to him, as originating successful methods for the economical production of the fuming sulphuric acid for which, as it has become cheaper, many new uses have been discovered.

Winkler concluded, as a result of his experiments, that the SO_2 and O should always be present in the molecular proportion of 2:1, any excess of either gas having a deleterious influence upon the completeness of the reaction, and he obtained this desired proportion by simply breaking up ordinary hydrated sulphuric acid into H_2O, SO_2, and O, removing the H_2O, and then recombining the SO_2 and O by means of appropriate contact substances, the preparation of which he greatly improved by utilizing the reducing action of formic acid. All subsequent work in this branch continued to follow the lines laid down by Winkler; hence, while little progress was made toward superseding the lead chamber, the manufacture of fuming sulphuric acid became highly developed.

II. *Knietsch's Work—Purification of the Gas.*—This work was undertaken by the Badische Anilin und Soda-Fabrik to determine if a complete conversion of the SO_2 in roaster gas was as practically feasible as it is theoretically possible.

It is well known that the outgoing gases of the chamber process still contain 6 volume per cent of oxygen, and that the roaster gas employed in the contact work contained a similar excess. Hence it was difficult to understand why, in the latter process, the yields were not nearer that of the former.

Experiments showed that when pure SO_2 was used the yield was close to the theoretical, even when a very large excess of O was present, which was contrary to the accepted views of Winkler.

When roaster gas was used in laboratory experiments, it was found that when this was carefully cooled, washed with sulphuric acid, and completely purified before it was allowed to enter the catalytic tube, the results were very satisfactory, nor could any diminution of the efficiency of the contact mass be noted even after several days' use. It was therefore supposed that the problem had been solved, and arrangements were made to carry on the process on full working scale.

It was, however, soon found that in practice the contact mass gradually lost all of its efficiency, no matter how carefully the gases were cooled and purified. Extended laboratory investigations were undertaken to determine the cause of this inefficiency, and it was ultimately discovered that there are substances which, when present in the gas, even in excessively small quantities, injure the catalytic properties of platinum to an extraordinary degree. Of all of the substances which may be found in roaster gas, arsenic is by far the most deleterious, next mercury, while Sb, Bi, Pb, Fe, Zn, etc., are injurious only so far as they may coat the contact mass.

It was also found that as the white cloud of sulphuric acid which was present in the gas contained arsenic, the complete removal of this was necessary, although such removal had always been considered an impossibility. This was, however, finally accomplished after an enormous expenditure of time, labor, and money, so that, in the end, by extended washing and filtration, the gases were obtained in a condition absolutely free from all impurities. (D. R. P. 113933, July 22, 1898.)

Slow cooling of the gas was found to be absolutely necessary as a preliminary to its purification. It is a fact, the cause of which is not yet clearly known, that the removal of the white cloud is rendered far more difficult if the gas is rapidly cooled.

To insure slow cooling, a system of iron tubes was used because it was supposed that, as the sulphuric acid in the gas was in a so highly concentrated condition, any action upon the metal would yield SO_2 only. It was now found that although the contact mass remained active for a much longer period, it still gradually lost its power, no matter how carefully the gas was purified. The cause of this was ultimately found to be a gas containing arsenic, probably hydrogen arsenide, produced by the action of the acid upon the iron by which hydrogen was evolved, although the formation of this gas

under such conditions had always been considered impossible. As soon as the cooling apparatus was so arranged that no condensed acid could attack the iron, the trouble from this source entirely ceased.

A final difficulty occurred in the occasional formation of a faint cloud of unburnt sulphur which contained arsenic. The cure for this was found to be a proper mixing of the hot gases, thus insuring complete combustion, and this mixing was effected by means of steam, which is also beneficial, by diluting the strong sulphuric acid present in the gas, so that it did not condense in the iron pipes of the first portion of the cooling apparatus, and attack them; when condensing in the lead pipes of the remainder of the apparatus, the acid was too weak to injure the lead. The use of steam also prevented the formation of hard dust crusts, which tend to stop up the pipes.

III. *Cooling of the Gases.*—The next important element in the successful carrying out of the contact process is the effective and economical utilization of the heat developed by the reaction which is exothermic.

$$SO_2+O=SO_3+22600 \text{ cal.}$$

The utilization of this heat had been suggested by Lunge, but only in the case of the use of a mixture of pure SO_2 and air, containing about 25 per cent of the former. On the other hand, it was universally considered that it was necessary to employ extra heat when the much weaker roaster gases are to be treated. Hence the apparatus used in this work was furnished with special heating arrangements so that the tubes could be kept at red heat, the tubes being arranged vertically like those of an upright boiler. Small, vertical tubes are much superior to the larger, horizontal ones, originally employed, as economizing the expensive platinized asbestus and insuring a more certain contact of the gases with the mass. The proper filling of the tubes with the asbestos is a matter of importance; it must be so done that no portion of the gas can pass through a tube without coming in contact with the mass, while the mass must not offer much resistance to the passage of the gas. Owing to the nature of the asbestus, this latter difficulty is likely to occur, but can be avoided by the simple device of packing the asbestus in successive layers, separated by perforated diaphragms sliding upon a central rod, but kept apart at regular intervals. In this way all of the tubes can be similarly and evenly packed.

As soon as this apparatus was started in the ordinary way at low red heat, the surprising discovery was made that not only was the output of acid increased, but that the strength of the gas current could be made greater when the tubes, instead of being heated artificially, were, on the contrary, cooled by the admission of cold air. This discovery, a contradiction of what had been considered correct practice, gave a rational method of work; i. e., the apparatus must be systematically cooled to obtain the maximum effect and production. As now operated, the tubes are cooled by the cold, purified gases, which thus become heated to the proper temperature for the reaction. In this way the following advantages are gained:

First. Overheating of the apparatus is avoided, and thus a yield of 96 per cent—98 per cent of the theoretical—is obtained.

Second. The iron parts of the apparatus are protected by this cooler working, and are therefore more durable.

Third. The contact mass does not become overheated and its efficiency remains unimpaired.

Fourth. The absolute efficiency of the contact mass, and of the entire apparatus, is greatly increased because the rapidity of the gas stream can be increased, and the contact mass be maintained at the most efficient temperature.

Another important discovery is that the reaction proceeds at atmospheric pressure, since it was formerly supposed that compression of the gases was necessary to overcome the hindrance of the indifferent gases present. In fact, if the other conditions are right the reaction proceeds almost quantitatively at atmospheric pressure. This is very important since, if this method is to compete with the chamber process, every unnecessary expense must be avoided.

IV. *Absorption of the Produced Anhydride.*—The affinity of sulphuric anhydride for water is greater than for concentrated sulphuric acid, as shown by the relative amount of heat developed during the absorption; hence it might be expected that the easiest and most complete absorption of anhydride from the contact process would be effected by the use of water. It is found, however, that oil of vitriol containing 97–99 per cent of H_2SO_4 is much more effective than either water or sulphuric acid of any other strength. The absorbing power of the acid at this degree of concentration is so great that a single absorption vessel is sufficient for the removal of the SO_3 from a very rapid current of gas, provided that the strength of the acid be kept uniformly between the above limits by a steady inflow of water or weak acid, and a proportional outflow of the excess of strong acid thus produced.

Sulphuric acid, at this particular degree of concentration, possesses certain marked qualities. Its boiling point is a maximum, so that if a weaker acid is evaporated, it loses water or weak acid until the residue attains a strength of 98.33 per cent H_2SO_4, at which point it distills without further change at a constant temperature of about 330°. Similarly, a stronger acid gives off anhydride until this constant strength is reached. Again, at this particular degree, the vapor pressure is at its minimum, the specific gravity is at the maximum, the electrical resistance suddenly rises, while the action on iron decreases considerably.

When fuming sulphuric acid is to be made, one or more absorption cells must precede the regular appa-

ratus. For these, cast iron, which is quite suitable as the material for the other vessels, becomes unavailable, because, although it is only slowly attacked, it, what is worse, becomes fragile and even explodes. This appears to be due to the fuming acid diffusing into the iron and then breaking up into SO_2 and H_2S, thus causing a condition of internal stress. Wrought iron is attacked by fuming acid containing less than 27 per cent of SO_3, but when the contents of anhydride exceeds this, the acid has practically no action upon wrought iron, and vessels of this material can be used for years without sensible corrosion.

V. *Theory of the Contact Process.*—The results of many experiments showing the influence upon the reaction of variations in the temperature, the composition of the gases, the rate of flow (or the proportion of contact substance over which the gas passes) are given in the form of curves, and discussed, yielding the following results:

1. Complete conversion of the SO_2 into SO_3 occurs only when there is at least twice as much oxygen present as the reaction formula indicates. When using the gas obtained from the roasting of pyrites, and which contains about 7 vol. per cent of SO_2, 10 vol. per cent of O, and 83 vol. per cent of nitrogen, the nitrogen is absolutely without influence upon the reaction, except as diluting the gas and reducing the output.

2. The completeness of the reaction depends solely upon the temperature and not upon the nature of the contact substance. The reaction begins at about 200°. As the temperature rises, so does the degree of conversion, until, at about 400°, a nearly complete (98 to 99 per cent) conversion of the SO_2 is feasible. Any further rise in temperature is injurious, the degree of conversion falling so that at about 700° only about 60 per cent can be converted, while at about 900° the reaction ceases entirely.

3. The nature of the contact substance has no influence upon the completeness of the reaction, but, for practical results, a substance must be employed which shows a high degree of efficiency at the proper temperature of 400°. Substances, which require a higher temperature to develop their greatest efficiency, are evidently unsuited, since, as shown above, the degree of conversion falls with the rise in temperature. Up to the present time only one substance fulfilling the necessary conditions is known, and that is platinum. None of the other metals of the platinum group approaches it in efficiency.

This valuable paper concludes with a series of tables, giving the results of exhaustive sets of determinations of the following properties of sulphuric acid, and of fuming sulphuric acid of various strengths from 1 to 100 per cent of SO_3:

1. Melting point. 2. Specific gravity. 3. Specific heat. 4. Heat of solution. 5. Electrical resistance. 6. Action upon iron. 7. Boiling point. 8. Vapor pressure. 9. Viscosity. 10. Capillarity. 11. Table giving the percentage of free SO_3 in a fuming sulphuric acid when the total contents of SO_3 is known.

Production of Sulphur Trioxide.—The growth and present magnitude of the operations of this process in the works of the Badische Anilin-und-Soda-Fabrik are shown by the following figures:

Sulphur trioxide produced in—	Tons.
1888	18,500
1894	39,000
1899	89,000
1900	116,000

It will be seen from the foregoing, that this process has long passed the experimental stage, and now that the general conditions of successful operation are known, its speedy adoption in this country is to be expected. The advantages are many: First, no expense of construction and maintenance of the entire chamber system, including the Gay-Lussac and Glover towers and the steam and niter plant. Second, no expense for niter and for the sulphuric acid used therewith; although the resulting niter cake can be utilized, it is rarely a desirable product. Third, the acid produced is pure, strong oil of vitriol, requiring no concentration for sale or use. Concentration of chamber acid to high strengths requires the use of platinum stills, which thereby lose in weight, the dissolved platinum being irrevocably lost. The rate of loss is much reduced by previous purification of the acid, but is always a considerable item of cost. Fourth, the contact acid is also free from arsenic, lead, or iron salts. The fundamental difference in the character of the reactions in the chamber process and of those in the contact method indicates the possibility of substantial improvements in the methods of roasting. Fifth, although the 50 degree acid, as it comes from the chambers, is desirable for many purposes—for example, in making superphosphates—it is held by some authorities that it can be made more cheaply by diluting the strong acid with the needed proportion of cold water, than by introducing this water into the chambers in the form of steam. This, however, is denied by others, and it is probable that the chamber process will continue to exist, though in a more restricted field.

On the other hand, this new process appears to require a well planned and carefully managed system of purification for the roaster gases, and will need, for its successful operation, a higher order of chemical engineering skill than has usually been deemed necessary for the operation of an acid plant. This, however, should hardly be considered an obstacle in this country, where all other branches of engineering manufacture have reached such a height, mainly because the works have demanded and made liberal use of the highest order of trained ability, and have not hesitated to "scrap" expensive plant where it failed to give satisfactory results. In this connection the Badische Anilin-und-Soda-Fabrik is an instructive example. Its chemical

force numbers over 100 men, many of whom are engaged solely upon researches, the results of which, when promising, are at once put into operation on a sufficiently large scale to determine their practical value. That such a course pays in a strict business sense is shown by the enormous dividends paid by this company, and by the practical monopoly which it has long maintained in certain lines, simply because it has been a little ahead of its competitors in knowing just how a given thing should be done, and then at once protecting the discovery by patents.

In addition to sulphuric acid, reports have been received regarding the production of the acids enumerated in the following table:

ACIDS, OTHER THAN SULPHURIC, BY KIND, QUANTITY, AND VALUE: 1900.

KIND.	Number of establishments.	Quantity (pounds).	Value.
Nitric	34	30,961,501	$1,454,909
Mixed	9	42,368,819	1,111,158
Muriatic	31	116,848,001	1,020,574
Boric	3	2,384,935	198,212
Acetic	12	26,660,565	426,892
Lactic and citric	3	3,886,382	335,297
Tartaric	4	2,677,004	781,603
Tannic	5	282,515	135,662
Gallic	3	141,291	20,275
Other acids[1]	10	.....	360,232

[1] Hydrofluoric, oleic, phosphoric, salicylic, and stearic.

It is to be understood that the quantities and values given in this table represent only the acids sold as such, or produced for sale in the establishments, for the actual production, in many cases, is much greater than that given above. Thus the first item on the list, nitric acid, is used in the making of the "mixed acids," which is the second item on the list. This mixed acid is not only manufactured in the acid factories and sold to explosive works, to manufacturers of pyroxylin for use in the making of plastics and of varnishes, and to other manufacturers, but many of the larger works now make the nitric acid which they consume in this manner. There is thus made and consumed more nitric acid than is sold as such, the production as reported amounting to 62,473,295 pounds, which is probably less than the total amount actually made for use and sale. Theoretically, 74.13 parts of nitric acid monohydrate can be made from 100 parts of pure sodium nitrate, but in practice, only 95 per cent of this is condensed, while 5 per cent passes to the towers. From this, then, there would be required 43,841 tons of nitrate of soda and 47,348 tons of sulphuric acid to produce the above-given quantity of nitric acid, and there would result as a by-product 52,609 tons of niter cake. It is to be borne in mind that nitric acids of various degrees of strength, ranging from single aquafortis of specific gravity 1.22, and double aquafortis of specific gravity 1.36, to the strongest nitric of 1.50 specific gravity, and red fuming of 1.60 specific gravity are to be found in the market, and that no attempt has been made to separate them as to quantity, or to reduce them to a common basis, so that the data must be regarded as of average value.

Nitric acid was manufactured at Philadelphia in 1834 by Carter & Scattergood. The most notable recent advance made in its manufacture is in the form of apparatus employed, which is due to Edward Hart and Oscar Guttman. It is used in the manufacture of nitrates like silver nitrate, or nitrites like sodium nitrite; in making "mixed acids" and aqua regia; in making nitrosubstitution compounds, like nitrobenzene, nitronaphthalene, and picric acid; organic nitrates, such as gun cotton and nitroglycerin; as an oxidizing agent in many chemical processes; and for the etching of metals.

By "mixed acids" is meant mixtures of nitric and sulphuric acids which are employed in "nitrating" organic substances such as glycerin, cellulose, and carbolic acid. The commercial use of such a mixture began with the manufacture of nitrobenzene and picric acid, but it received its greatest impetus about 1862 when the commercial manufacture of nitroglycerin began. Originally the users of this mixed acid purchased the sulphuric and nitric acids and mixed them in the desired proportions for use, the acids being transported in separate carboys of glass. These not infrequently became broken during transportation, and as the nitric acid rapidly reacts with and "fires" such organic matter as is used as packing for carboys, its transportation gave rise to many serious accidents, which led to restrictive legislation. It is not known to whom the credit is due for the discovery that mixed acids of the highest concentration did not act upon iron, but for upward of twenty years manufacturers have been making the desired mixtures at the acid works and shipping them in iron drums, old glycerin drums having been first employed. With the increase in the production in works, attention has naturally been given by chemists to the utilization of the residues, and large economies have resulted from the regaining of the "spent acids" by which the sulphuric acid has been obtained of a strength sufficient for reuse in the ordinary course of manufacture, and the nitric acid, though recovered in a weak state, has been of value in other arts.

Owing to the necessity of having concentrated nitric acid to mix with this regained sulphuric acid, and to the fact that the transportation charges on nitric acid are very high, and the necessary regulations governing its transportation are vexatious to the consumers, many of the larger establishments have erected nitric-acid plants. In considering the magnitude of this industry there is to be noted not only the mixed acid sold as such, 42,368,819 pounds, the mixed acid produced and consumed in chemical works, 8,902,371 pounds, and the mixed acid reported produced and consumed in explosive works, 12,000,000 pounds, making in all 63,271,190 pounds, but there is also to be taken into account this repeated reuse of the acid. From the products reported of all kinds, nitroglycerin and dynamite; gun-

cotton; pyroxylin for varnishes, for smokeless powder, for plastics, and for photography; and the nitro-substitution compounds, it is safe to say that 65,000 tons of mixed acids were employed during the year 1899–1900.

Hydrochloric acid, commercially known as muriatic acid, is made by acting on common salt with sulphuric acid. The ordinary muriatic acid of commerce is an aqueous solution containing about 40 per cent by weight of dry hydrogen chloride. For the amount of hydrochloric acid reported on this standard there would be required for its production 37,000 tons of common salt and 39,000 tons of sulphuric acid of 60° Baumé, and there would be obtained in addition to the muriatic acid 47,000 tons of salt cake, which consists of sodium sulphate, together with some undecomposed common salt, and an excess of sulphuric acid. A new development in this trade is in the use of wooden barrels as containers in place of the glass carboys in which it was formerly transported.

Carter & Scattergood manufactured muriatic acid in Philadelphia in 1834, and Charles Lennig began its manufacture by modern methods in Philadelphia in 1869. Hydrochloric acid is used in the preparation of many organic and inorganic chlorides. Mixed with nitric acid it forms aqua regia, which is used in dissolving the precious metals. It has largely been used as a source of chlorine in the manufacture of bleaching powder and potassium chlorate. It is used in the manufacture of acetic acid and gelatin, in the manufacture of soda, and in a multitude of minor arts. The salt cake is used in the Le Blanc process for the manufacture of soda, for glass making, for ultramarine, in dyeing and coloring, and for the production of Glauber's salts.

Acetic acid as treated of under "chemicals" does not include vinegar, which is a very dilute acetic acid made largely by fermentation, but it covers such acid as is produced by chemical action from acetates, principally the calcium and sodium acetates. Calcium acetate is obtained in the destructive distillation of wood. The acetic acid is obtained from it by treatment with hydrochloric acid and distillation. This may be purified by rectification with potassium dichromate. A better product is obtained by converting the acid into a sodium salt and evaporating to dryness to destroy tarry matters and then distilling with hydrochloric or sulphuric acids. Acetic acid, varying in strength from 28 per cent to 90 per cent, is sent to the market in barrels holding on an average 425 pounds. Acetic acid is used in the preparation of metallic acetates, which are extensively used in dyeing and printing; or of organic acetates, such as ethyl and amyl acetates, which are used as solvents and flavors; in the manufacture of white lead; and the preparation of organic compounds. As an example of its use Lachman[1] states that in the preparation of the chloracetic acid used by the Badische Anilin-und Soda-Fabrik in the manufacture of synthetic indigo in 1900 there were used 4,500,000 pounds of glacial acetic acid, requiring 26,000 cords of wood for its production.

Lactic acid, citric acid, and tartaric acids are used in dyeing and in calico printing. Lactic acid is prepared by fermenting a sugar solution by means of certain bacteria, neutralizing the acid with calcium carbonate, and decomposing the calcium lactate thus formed with sulphuric acid. Lactic acid was manufactured by the Avery Chemical Company at Littleton, Mass., in 1882.

Citric acid occurs in the free state in the juices of all the plants of the genus *Citrus*, such as limes, lemons, and sour oranges. Good lemons yield about 5½ per cent of the crystallized acid. It is obtained by neutralizing the juice of the fruit with chalk and decomposing the resulting calcium citrate with an equivalent amount of sulphuric acid. This acid was manufactured by Carter & Scattergood at Philadelphia in 1834.

Tartaric acid occurs free or combined in many plants, but the only source from which it is commercially obtained is the grape. During the fermentation of grape juice, as the alcohol increases in quantity the calcium and potassium tartrates present in the juice are precipitated out, together with a quantity of organic coloring matter, forming what is known as argols. After purification it is treated with chalk and calcium sulphate to convert it into calcium tartrate, and this when decomposed with sulphuric acid yields free tartaric acid. This acid was manufactured by Carter & Scattergood in Philadelphia in 1834.

The foreign commerce in acids is exhibited in the following tables, compiled from the publications of the Bureau of Statistics, of the United States Treasury Department:

[1] J. Am. Chem. Soc., vol. 23, page 912: 1901.

IMPORTS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1891–1900.

YEAR.	[1]SULPHURIC ACID OR OIL OF VITRIOL (N. E. S.).		[1]SULPHURIC ACID.		BORACIC ACID.						CHROMIC ACID.		CHROMIC AND LACTIC ACID.	
					Commercial.		Pure.		All kinds.					
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1891	15,377	$836	.....	.....	152,093	$7,975	39,394	$2,906	475,378	$30,138	..... / 506	$1,587 / 155	.....	.....
1892	8,277	478	8,735	$339	.....	.....	.....	.....	701,625	39,418	426	156	.....	.....
1893	634	43	8,735	1,033	.....	.....	.....	.....	771,775	40,568	3,318	609	.....	.....
1894	17,053	405	400	32	.....	.....	.....	.....	292,990	19,282	5,048	824	.....	.....
1895	12,574	186	7,459	461	.....	.....	.....	.....	925,154	42,056	4,461	707	.....	.....
1896	36,798	475	48,759	1,606	.....	.....	.....	.....	555,769	21,899	2,440	409	.....	.....
1897	3,200	43	59,729	4,074	.....	.....	.....	.....	548,603	19,494	2,708	430	.....	.....
1898	25,350	786	2,725	40	134,707	4,053	244,073	7,994	.....	45,265	6,720	906	64,066	$4,917
1899	40,175	1,874	.....	.....	.....	.....	436,958	14,303	.....	56,428	.....	.....	23,969	4,843
1900	34,944	972	.....	.....	.....	.....	466,879	17,467	.....	53,625	.....	.....	34,741	6,044

YEAR.	CITRIC ACID.		TARTARIC ACID.		OXALIC ACID.		SALICYLIC ACID.		ACID, TANNIC OR TANNIN.		ALL OTHER ACIDS.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1891	45,197	$15,482	1,511	$468	2,743,222	$200,595	.....	.....	659	$239	1,350,710	$380,054
1892	80,034	27,461	10	5	2,209,940	150,529	.....	.....	564	216	1,024,580	347,510
1893	13,315	4,633	130	39	2,464,443	143,194	260,027	$254,022	1,443	597	685,677	175,637
1894	5,502	1,810	113	32	2,783,876	159,026	252,332	231,946	794	287	835,215	134,665
1895	8,895	2,480	355	88	2,889,513	189,506	193,974	140,197	1,500	597	1,798,417	228,430
1896	39,671	12,521	212	66	3,164,969	219,630	335,354	138,013	1,745	681	1,027,235	240,522
1897	73,133	18,158	225	71	3,602,124	246,200	616,187	201,980	3,144	1,296	3,040,325	223,458
1898	4,323	1,108	456	128	3,747,041	242,276	92,943	28,688	2,335	927	.....	45,265
1899	65,190	16,659	23,298	5,737	3,981,768	246,027	185,358	57,192	3,697	1,371	.....	56,428
1900	60,354	14,213	954	252	4,990,123	275,747	240,687	89,175	1,415	671	.....	53,625

[1] From the value given this would appear to be fuming sulphuric acid.

Group II.—Soda Products.

The great increase in this branch noted in the Census report for 1890 has continued during the past decade. The number of establishments making soda products as the main part or as a subsidiary of their business has increased from 32 to 50, while the products have increased as shown in the following table. To these figures for 1900 must be added "other soda products," not otherwise specified, produced by these works and valued at $143,432, and also 11,756,000 pounds of borax, valued at $541,160, made by seven borax works. These items were not included in the report for 1890 and are therefore not taken into the comparison. Where the figures of this table show an increase over the figures for the same items in other tables of this census, the difference is due to the inclusion here of all such products made by works belonging to other groups, for example, the caustic soda produced by electrolysis, which is included in the products of that group and not separately reported. This table shows the total actual production of the United States for the census year from all sources; and while the figures differ, there is no discrepancy.

SODA PRODUCTS, BY QUANTITY AND VALUE, 1890 AND 1900.

	1900		1890	
	Pounds.	Value.	Pounds.	Value.
Total	1,279,082,000	$10,237,944	333,124,375	$5,432,400
Soda ash	781,306,000	4,859,656	94,801,200	1,179,720
Sal soda	126,498,000	875,243	144,641,705	1,581,766
Bicarbonate of soda	137,712,000	1 332,765	60,678,750	2,009,800
Caustic soda	233,566,000	3,170,280	33,002,720	661,114

The decrease in the production of sal soda is noteworthy and is due to the increasing use of soap powders and other specially prepared washing materials. A comparison of these totals with the corresponding figures for 1880 is interesting.

SODA PRODUCTS, BY DECADES, 1880 TO 1900, WITH PERCENTAGES.

YEAR.	Number of establishments.	TOTAL PRODUCT.		PER CENT OF INCREASE.	
		Pounds.	Value.	Quantity.	Value.
1880	3	40,259,938	$866,560	.....	.....
1890	32	333,124,375	5,432,400	727.4	526.9
1900	50	1,279,082,000	10,237,944	284.0	88.5

There are no figures for soda products anterior to 1880, except that at the census of 1860, 11 establishments were reported manufacturing saleratus, with a total value of $1,176,000, while at the census of 1870, only 4 were reported, with a value of products of $231,647, a decrease which is remarkable in view of the general development of other industries during that decade.

Although the production has almost quadrupled during the past decade, the value per unit has fallen greatly. Taking the customary unit of 100 pounds, we find the following decrease of values:

YEAR.	Soda ash.	Sal soda.	Bicarbonate of soda.	Caustic soda.
1890	$1.24	$1.09	$3.31	$2.00
1900	.62	.77	.97	1.35
Decrease	.62	.32	2.34	.65
Percentage	50.00	29.35	70.69	32.50

This great increase in domestic production has resulted in a corresponding diminution of importations. The Treasury report of importations for 1890 gives soda ash and sal soda together as 332,733,952 pounds, valued at $3,493,288; caustic soda, 80,125,732 pounds, valued at $1,470,335; and bicarbonate of soda, 917,034 pounds, valued at $16,319; while the same report for 1900 gives soda ash, 78,571,870 pounds, valued at $648,450; sal soda, 6,624,194 pounds, valued at $31,072; and caustic soda, 11,429,989 pounds, valued at $177,857; but does not report bicarbonate separately. A comparison of these quantities shows what progress has been made toward supplying the home market.

YEAR.	Soda ash and sal soda, pounds.	Caustic soda, pounds.
1890	332,733,952	80,125,732
1900	85,196,064	11,429,989
Decrease	247,537,888	68,695,743
Percentage	74.39	85.73

The ratios of quantities of these materials imported to the domestic production are as follows:

YEAR.	SAL SODA AND SODA ASH.		CAUSTIC SODA.	
	Foreign.	Domestic.	Foreign.	Domestic.
1890	100	72	100	41
1900	100	1,075	100	1,979

Some of the imported soda ash and caustic has undoubtedly been used to make a part of the soda products reported at the census of 1900, but the quantity so used can not be ascertained and is in any case not large. The remainder, so far as concerns works making soda products from purchased soda ash, etc., was drawn from domestic sources, hence to this extent there is a duplication of quantities and values. This duplication is unavoidable. Had there been no imported stock on hand at the beginning of the census year and no importations during it, there would have been no difficulty in making any deductions needed to make the totals of quantities and values given in the table of soda products by quantity and value, 1890 and 1900, quite accurate. The returns for 1900 have been sufficiently studied to show that this duplication is proportionally small, that the totals given above are fairly correct, and that the real growth and present condition of the industry is substantially as shown. Most of the soda ash and bicarbonate reported are products of the ammonia-soda process; the cryolite process being limited by the supply of the mineral, and the natural soda industry restricted by cost of transportation to markets.

Natural Soda.—The manufacture of soda products from the natural soda of the West has increased from 10,964,390 pounds, valued at $124,783, in 1890, to 20,420,000 pounds, valued at $106,600, in 1900. This increase is very small, because, although the raw material is available in inexhaustible quantities (and with a well-arranged plant, soda ash can be delivered f. o. b. cars at the works at a cost less than one-half of that of ash at any ammonia-soda works in this or any other country), the distance from large eastern markets and consequent high freight rates have precluded successful commercial competition, especially in the face of steadily falling prices of the product. Of late the economic conditions have materially changed and will continue to improve. The past two years have seen great enlargements in the industries and commerce of the Pacific states, while the recent political occurrences in the Pacific and in Asiatic countries have profoundly altered trade conditions and indicate an enormous increase in our Pacific commerce in the near future. In supplying the demands of this commerce our natural soda deposits, when properly developed, can distance all rivals.

Although the operations so far carried on have been on a comparatively small scale, the subject has been carefully studied and much valuable information obtained. For example, at Owens Lake, California, the cost of making a ton of soda ash under local conditions is fairly well ascertained, and the lines to be followed to reduce manufacturing cost clearly indicated. Again, the extent of land suitable for evaporating vats is, in this locality, the measure of the possible development of the industry, and this is known. Many other important data have thus been secured, and as a general conclusion it may be safely stated that at Owens Lake alone there is space for works large enough for a production of soda ash more than equivalent to the entire demand of this country for soda products. All this is unquestioned by anyone having a practical acquaintance with the matter, and only the limited radius of profitable marketing has retarded the development of this locality. This industry is therefore not a hypothetical one, but based on solid fact and experience, and because of this and the prospects for the future, it has been deemed advisable to devote especial attention to it in this report.

The report on chemical products for the census of 1880 gave an interesting résumé of the existing information concerning the occurrences of natural soda, and later the subject was investigated, the result being published in "Natural Soda, its Occurrence and Utilization," T. M. Chatard, Bulletin No. 60, United States Geological Survey, 1888. An extensive abstract of this paper was made by Prof. George Lunge and published in the Zeitschrift für Angewandte Chemie, 1893, pages 3–11, because, as he states, he considered the existence of such enormous quantities of natural soda a most important factor in the future of the alkali industry. This same eminent authority, in The Mineral Industry for 1892, page 64, also says:

There can be no doubt that the immense quantities of "natural soda" shown by Dr. Chatard and other authorities of the United States Geological Survey to exist in the Californian and other soda

lakes, will not be allowed to lie dormant any longer. If these lakes are once worked with the energy which is otherwise not wanting in America, the days are numbered when Liverpool soda will rule in the New York market.

In 1892 Dr. Lunge visited Owens Lake, California, the most important natural soda locality, and, while confirming the general conclusions given in the above-mentioned bulletin, placed the cost of product at a much lower figure than there stated.

In the same volume of "The Mineral Industry" there is an article on "Natural Soda" which gives additional data and suggestions as to the lines to be followed in the commercial development of this industry.

Natural soda is the residue obtained by the evaporation of natural alkaline waters without the aid of artificial heat. It is composed of sodium carbonate and bicarbonate in varying proportions, mixed with other salts, mainly sodium sulphate and chloride. It is found to some extent in all dry regions, such as Hungary, Egypt, and the deserts of Africa and Asia, but in no other country does it occur in such enormous quantities as in the region lying east of the Sierra Nevadas. It forms the white incrustations of the alkali plains, but these are rarely of sufficient thickness and extent for prospective utilization, particularly as the "sinks," or lakes without outlet, in which nature has collected and concentrated the leachings and drainage of the alkaline districts, already contain more sodium carbonate than would suffice to supply the entire world demand for generations. That this is no exaggeration is made evident by considering only three of these lakes, the dimensions of which are known and the waters of which have been repeatedly and carefully analyzed.

In southeastern Oregon is Abert Lake; area 40 square miles, average depth 10 feet. In Mono County, Cal., we find Mono Lake; area 85 square miles, average depth 60 feet. In Inyo County, Cal., lies Owens Lake, with an area of 110 square miles and an average depth of over 17 feet. In computing the volume of water the usual unit is an acre-foot, which is equal to 43,560 cubic feet, and as the analysis tells the amount of the sodium carbonate, Na_2CO_3, and bicarbonate, $NaHCO_3$, in a given volume, we get the following results for these three lakes:

	Acre-feet.	Na_2CO_3, tons.	$NaHCO_3$, tons.
Abert Lake	256,000	3,428,352	1,560,000
Mono Lake	3,264,000	75,072,000	17,936,000
Owens Lake	1,088,000	39,875,200	8,431,000
Total		118,375,552	27,927,000

These are the largest occurrences, but there are many others, aggregating probably a far greater amount.

In addition to these two carbonates the waters of these lakes contain much sodium sulphate and chloride, with smaller proportions of sodium borate, potassium chloride, and other salts. The valuable constituents are the two carbonates, and the method of separating them from the other salts is based on fractional crystallization, which means the methodical stoppage of a crystallizing process by drawing off the mother liquor from the "crop" of crystals so far formed. This "first crop" may be either the desired material in a purer condition than it was in the original solution, or else may consist mainly of impurities which we wish to remove, this depending upon the proportions of the substances in solution or their relative solubilities under the conditions.

Now, all solutions of natural soda contain both sodium carbonate and bicarbonate, and it is upon the property of these two salts when in solution to unite to form a compound more soluble than bicarbonate but less soluble than carbonate, that the method of extraction is founded. If a solution of the two salts be exposed to spontaneous evaporation, there will be formed, at a certain degree of concentration, a crop of acicular crystals which have a composition corresponding to 46.90 per cent of Na_2CO_3, 37.17 per cent of $NaHCO_3$, and 15.93 per cent of H_2O (water). The scientific name of this salt is urao, but it is usually called "summer soda." The amount of this salt thus obtained will depend upon the amount of bicarbonate present, as every 37.17 parts of bicarbonate will, in crystallizing, take with it 46.90 parts of Na_2CO_3. If more bicarbonate is present than is needed to form summer soda, the excess will crystallize out before the summer soda forms. If too little is present, the excess of carbonate remains in solution.

If a sample of water be evaporated from any of these lakes to a certain concentration point (sp. gr. 1.260 for Owens Lake water), crystallization will begin, the crystals being crude summer soda. Owing to the presence of so much sulphate and chloride in the solution, the crop becomes more and more contaminated with these salts as the concentration proceeds. Hence, to obtain an article of a fair degree of purity, the process must be interrupted at some definite degree of specific gravity and the mother liquor drawn off. If the mother liquor be further evaporated, successive crops can be obtained, the earlier ones, in the case of Owens Lake, being principally sulphate and the later ones chloride. Finally remains a mother liquor rich in potash salts, from which, on cooling to a low temperature, the ordinary sal soda ($Na_2CO_3.10H_2O$) crystallizes.

While all of these localities can produce summer soda in the manner described, the proportion of bicarbonate present is, in each case, insufficient to give the largest possible yield. To obtain this, it is necessary to increase the proportion of bicarbonate, which can be done in several ways but most economically, probably, by utilizing the carbonic acid driven off in the process of furnacing to convert the urao into soda ash. When summer soda is heated to a moderate degree (about 150° C., 300° F.) it loses its water and excess of carbonic acid; 100 parts yielding 70.35 parts ash, 9.74 parts

gas, and 19.91 parts of water. This furnacing must be done in any case to reduce weight and save transportation charges; hence, if the gas can be economically used, there is a clear gain in so doing. While the refining work in which the crude product is converted into various marketable forms requires special training and use of improved machinery, arranged and handled to save labor and fuel, the production of the crude material is comparatively simple and can be done on a large or small scale with probably equal advantage. At the "little lake" at Ragtown, Nev., two men, in 1886, made 300 tons and could have made much more had the conditions of the locality permitted. The product of the "big lake," made under very adverse conditions, required but little more labor in proportion. The entire product was hauled 16 miles to the railroad and shipped to San Francisco where it was refined. Notwithstanding these heavy transportation costs, the operations were profitable and the works have been running steadily ever since.

These examples show that in the development of this industry the innumerable small localities can be utilized quite as well as the larger ones, if transportation to the refining point be not too expensive. An intelligent, industrious man, working a small but well-situated pool, can produce, with only occasional outside aid, an amount of summer soda which a refining works can take at a price advantageous to itself and remunerative to him. Furnacing before shipping to the refinery is not always advantageous, since, although the reduction in weight is about 25 per cent, the saving in transportation will rarely pay for the cost of furnacing when this is done on a small scale. Moreover, refiners prefer unfurnaced material, and by devoting attention exclusively to the production of summer soda, regularity of composition, which is very important, can be better assured. Such work can therefore be made a "poor man's job," a thing much needed in that region, and in time there would be a large direct consumption of the crude materials.

Borax and Other Soda Products.—Seven establishments manufactured borax during the census year, with a combined production of 11,756,000 pounds, valued at $541,160. No figures for borax were given at the census of 1890, so that no comparison can be instituted. The present number of borax works is undoubtedly smaller than it was ten years ago, because it has been found more economical to ship the crude material to central points for treatment than to work it up locally, as was formerly done.

"Other soda products," valued at $143,432, represent the total value of products so reported by many establishments. As they are not otherwise specified, no further distribution is possible.

The following table gives the geographical distribution of the soda industry, states having less than three establishments being grouped:

SODA PRODUCTS, BY STATES, ARRANGED GEOGRAPHICALLY: 1900.

STATES.	Number of establishments.	Value of products.
United States	55	$10,922,536
North Atlantic division	28	6,559,295
New Jersey	3	105,507
New York	12	4,699,481
Pennsylvania	9	861,195
Massachusetts, Rhode Island, Maryland, and Virginia	4	893,112
North Central division	16	3,694,436
Illinois	4	353,429
Michigan	3	2,814,969
Wisconsin	4	173,101
Indiana, Missouri, and Ohio	5	352,937
Western division	11	668,805
California	6	647,175
Nevada	5	21,630

The foreign commerce in soda products is set forth in the following table, compiled from the reports of the Bureau of Statistics of the United States Treasury Department:

SODA ASH IMPORTED DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.

YEAR.	Pounds.	Value.
1891	[1] 354,744,335	$4,382,917
1892	[1] 339,057,006	4,496,597
1893	388,910,183	4,855,098
1894	256,293,395	2,520,921
1895	300,599,257	2,367,109
1896	251,067,856	1,950,981
1897	162,585,074	1,241,321
1898	87,809,619	589,714
1899	45,444,305	310,742
1900	78,571,870	648,450

[1] Includes sal soda for 1891 and 1892.

SAL SODA IMPORTED DURING THE YEARS ENDING JUNE 30, 1893 TO 1900.

YEAR.	Pounds.	Value.
1893	27,531,554	$238,029
1894	16,893,760	120,794
1895	28,761,108	167,325
1896	17,966,996	84,423
1897	18,875,029	82,695
1898	8,851,011	40,266
1899	4,224,680	20,905
1900	6,624,314	81,072

CAUSTIC SODA IMPORTED DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.

YEAR.	Pounds.	Value.
1891	78,743,976	$1,874,700
1892	64,741,106	1,598,903
1893	57,485,106	1,344,525
1894	38,987,832	850,753
1895	57,653,959	1,044,809
1896	61,713,044	1,071,169
1897	66,476,152	1,147,763
1898	29,697,185	476,032
1899	18,405,272	252,297
1900	11,429,989	177,857

ALL OTHER SALTS OF SODA IMPORTED DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.[1]

YEAR.	Pounds.	Value.
1891	18,136,888	$118,713
1892	22,348,570	167,634
1893	47,664,938	297,761
1894	14,829,622	104,800
1895	11,808,171	141,070
1896	9,090,367	149,248
1897	3,919,339	67,684
1898	21,400,585	225,628
1899	23,891,135	317,032
1900	23,632,374	314,425

[1] 1893 to 1900 includes bicarbonate of soda.

Group III.—Potashes.

This classification was intended to include not only potash, which is an impure potassium carbonate, but also pearlash, which is the refined potassium carbonate, yet, though returns for the census year 1900 were received from 67 establishments, producing 3,864,766 pounds of potash, valued at $178,180, no pearlash was reported manufactured. Of these 67 establishments, 12 produced products valued at less than $500.

The burning of wood and the lixiviation of the ash to extract the potash, though of minor importance so far as the monetary value of the product is concerned, is one of the oldest of the purely chemical industries. Cognizance was taken of it in the census reports of the United States as early as 1850, so that the data is at command for comparing the condition of the industry in this country for each decade since 1850, as set forth in the following table:

TOTAL PRODUCTION OF POTASHES, BY DECADES: 1850 TO 1900.

YEAR.	Number of establishments.	PRODUCT.		Average price per pound (cents).
		Pounds.	Value.	
1850	569	.....	$1,401,533	.....
1860	212	.....	538,550	.....
1870	105	.....	327,671	.....
1880	68	4,571,671	232,643	5.09
1890	75	5,106,939	197,507	3.86
1900	67	3,864,766	178,180	4.82

This table shows that there has been a constant decrease in the value of the product, though the quantity has varied somewhat. Starting with 1880, for which year both quantity and value were reported, it appears that the increase in the quantity of product for 1890 over that for 1880 was 11.7 per cent, but the decrease in the value for 1890 compared with that for 1880 was 15.1 per cent. In 1900 the decrease in the quantity as compared with that of 1890 was 24.3 per cent, while the decrease in the value was 9.8 per cent. The establishments reported were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF POTASH FACTORIES: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Value of product.	Per cent of total.
United States	67	92	$70,899	$178,180	100.0
Michigan	44	52	25,851	79,642	44.7
Ohio	15	25	20,050	35,519	19.9
Indiana	3	4	2,275	6,560	3.7
Maine, Wisconsin, and Illinois	5	11	22,723	56,459	31.7

There were reported as having been used in this manufacture 812,399 bushels of wood ashes, valued at $40,191. The yield of potash per bushel of ashes, as reported, varied from 2.4 to 7 pounds. In the product given above there is included potash packed in cans, amounting to 820,000 pounds, having a value of $53,349. Excluding this, as being in the nature of a duplication, it appears that the total production of potash for 1900 was 3,044,766 pounds, and that therefore the average yield of potash per bushel of wood ashes, as shown by the entire returns, was 3.75 pounds. Pelouze and Fremy[1] give the yield by weight as 10 per cent, and this appears in other text-books; but all returns for ashes received at the census of 1900 were given in bushels.

As stated, potash is prepared by dissolving out the soluble contents of wood ashes and evaporating the solution to dryness. The process as carried out on a commercial scale is described by Muspratt,[2] as follows:

The American process for the extraction of potashes is thus described by Morfit. The incineration of the plant is effected in dry pits sunk into the ground to a depth of 3 or 4 feet. The plant is thrown in in portions, and burned until the pit is nearly full of ashes. The latter are then removed, mixed with about 5 per cent of lime, and drenched with successive portions of fresh water. The ash tubs or vats employed in this operation are usually formed from tar barrels, by cutting them in half. A number of these are furnished with two crossbeams, upon which rests a false cullendered bottom covered with straw, and below this is a cock for the removal of the lye. The first liquor running through, being saturated, is passed at once to the evaporating pan; while the second or third runnings, being weaker, are reserved and poured upon fresh ash until completely saturated. The evaporating pans are broad and shallow, and made of iron, with corrugated bottoms, to produce greater extent of heating surface; and as evaporation progresses, new supplies of strong liquor are poured in, and the heat is continued until a sirupy consistence is attained, when the fire is gradually slackened and the contents of the pan, becoming solid, are dug out and placed aside as *crude potashes*. By subjecting this mass to the heat of a reverberatory furnace, most of the sulphur (*sic*) and all excessive water and empyreumatic matters are expelled, causing a loss of 10 to 15 per cent. This modified product is white, with a bluish tinge; contains more carbonic acid than the original crude product, and takes the name of *pearlash*. The process em-

[1] Traité de Chimie, 1865, Vol. II, page 225.
[2] Chemistry as Applied to Arts and Manufactures, Vol. II, page 729.

ployed in Russia and northern Europe is the same in principle as that above described, and is conducted in a similar manner, except that no lime is used in the lixiviation process.

According to Mendeléeff:[1]

For the extraction of potash, which was formerly carried on extensively in the east of Russia (before the discovery of the Stassfurt salt), the ash of grasses and the green portions of potatoes, buckwheat, etc., are taken and treated with water (lixiviated), the solution is evaporated, and the residue ignited in order to destroy the organic matter present in the extract. The residue thus obtained is composed of raw potash. It is refined by a second dissolution in a small quantity of water, for the potash itself is very soluble in water, whilst the impurities are sparingly soluble. The solution thus obtained is again evaporated, and the residue ignited, and this potash is then called refined potash, or pearlash.

According to Wiley:[2]

The composition of the ash of woods is extremely variable. Not only do different varieties of trees have varying quantities of ash, but in the same variety the bark and twigs will give an ash quite different in quantity and composition from that furnished by the wood itself. In general, the hard woods, such as hickory, oak, and maple, furnish a quality of ash superior for fertilizing purposes to that afforded by the soft woods, such as the pine and tulip trees. The character of the unleached wood ashes found in the trade is indicated by the subjoined analyses. The first table contains the mean, maximum, and minimum results of the analyses of 97 samples by Goessmann.[3]

	MEAN COMPOSITION OF WOOD ASHES.		
	Means.	Maxima.	Minima.
Potash	5.5	10.2	2.5
Phosphoric acid	1.9	4.0	0.3
Lime	34.3	50.9	18.0
Magnesia	3.5	7.5	2.3
Insoluble	12.9	27.9	2.1
Moisture	12.0	28.6	0.7
Carbon dioxide and undetermined	29.9	.....	.....

The data obtained in sixteen analyses made at the Connecticut station are given below:[4]

	Means.	Maxima.	Minima.
Potash	5.3	7.7	4.0
Phosphoric acid	1.4	1.8	1.9

In fifteen analyses of ashes from domestic wood fires in New England stoves the following mean percentages of potash and phosphoric acid were found:

Potash	9.63
Phosphoric acid	2.32

[1] Principles of Chemistry, 1897, Vol. I, page 548.
[2] Principles and Practice of Agricultural Analysis, 1895, Vol. II, pages 251 to 253.
[3] Annual report, Massachusetts agricultural experiment station, 1888, page 202.
[4] Annual report, Connecticut agricultural experiment station, 1890, page 110.

In leaching, ashes lose chiefly the potassium carbonate and phosphate which they contain. Leached and unleached Canada ashes have the following composition:

	Unleached (per cent).	Leached (per cent).
Insoluble	13.0	13.0
Moisture	12.0	30.0
Calcium carbonate and hydroxide	61.0	51.0
Potassium carbonate	5.5	1.1
Phosphoric acid	1.9	1.4
Undetermined	6.6	3.5

In the wood ashes of commerce, therefore, it is evident that the proportion of the potash to the lime is relatively low.

The number of parts by weight of the chief ingredients of the ash in 10,000 pounds of woods of different kinds is given in table below, together with the percentage composition of the pure ash; that is, the crude ash deprived of carbon and carbon dioxide.

POUNDS OF THE INGREDIENTS NAMED IN 10,000 POUNDS OF WOOD.

	Dogwood (*Cornus Florida*).	Sycamore (*Platanus Occidentalis*).	Post oak (*Q. obtusiloba*).	Ash (*F. Americana*).	Red oak (*Quercus rubra*).	Hickory (*Carya tomentosa*).
Potash	9.02	18.06	16.85	14.94	13.95	13.80
Phosphoric acid	5.72	9.55	6.96	1.15	5.98	5.83
Lime	6.41	24.73	35.61	7.60	27.40	18.40
Magnesia	14.67	0.49	5.28	0.10	3.05	4.86

	White oak (*Q. alba*).	Magnolia (*M. grandiflora*).	Georgia pine (*P. palustris*).	Yellow pine (*P. mitis*).	Black pine (*Picea nigra*).	Chestnut (*Castana vesca or sativa*).	Oldfield pine (*P. mitis*).
Potash	10.60	7.13	5.01	4.54	3.02	2.90	0.79
Phosphoric acid	2.49	3.19	1.24	0.96	0.92	1.09	0.73
Lime	7.85	14.21	18.04	15.16	12.46	7.93	12.12
Magnesia	0.90	2.94	2.03	0.74	0.10	0.34	1.17

The pure ashes of the woods contain the following per cents of the ingredients named:

	Dogwood (*Cornus Florida*).	Sycamore (*Platanus Occidentalis*).	Post oak (*Q. obtusiloba*).	Ash (*F. Americana*).	Red oak (*Quercus rubra*).	Hickory (*Carya tomentosa*).
Potash	28.04	23.17	21.92	46.04	24.66	28.60
Phosphoric acid	8.51	12.23	9.00	3.58	10.55	11.97
Lime	38.93	31.62	46.39	23.57	48.26	37.94
Magnesia	6.80	0.62	6.88	0.60	5.38	10.04

	White oak (*Q. alba*).	Magnolia (*M. grandiflora*).	Georgia pine (*P. palustris*).	Yellow pine (*P. mitis*).	Black pine (*Picea nigra*).	Chestnut (*Castana vesca or sativa*).	Oldfield pine (*P. mitis*).
Potash	42.16	19.54	15.35	19.70	14.30	18.10	3.85
Phosphoric acid	9.48	8.75	3.82	4.18	4.33	6.76	4.11
Lime	29.85	38.94	55.24	65.53	58.98	49.18	67.73
Magnesia	3.43	8.05	6.25	3.20	0.50	2.11	6.54

From the data for production given above it is evident that, although the average price of potash for 1900 was higher than for 1890, the industry was not remunerative,

and that consequently the quantity and value of the product decreased. Indeed, owing to the competition of foreign potash, the industry can now exist only in localities where wood is very cheap and where there is a local demand for the product. In such places the product is of domestic manufacture and is an article of trade at the country stores, but with the increasing value of timber, the field of operations is continually being contracted.

The cost of producing a barrel of 650 pounds of potash is stated in a private communication from a Michigan manufacturer to be as follows:

Ashes, 150 bushels, at 3 cents	$4.50
Hauling ashes	6.00
Fuel	2.00
Labor	3.00
Barrel, cost of	1.25
Repairs, interest, etc	1.50
Total cost	18.25
Selling price at works	25.00
Gross profit per barrel	6.75

The ashes therefore yielded 4⅓ pounds of potash per bushel, and the potash sold at 3.85 cents per pound. It will be noted that the weight of a barrel of potash is given above as 650 pounds. From the returns it appears that the net weight of a barrel of this material varies from 650 pounds to 740 pounds, the average being about 700 pounds.

Competition with the ashes of wood as a source of potash is found in beet-root molasses and residues; wool scourings, known as suint; and the potash salts mined at Stassfurt and elsewhere abroad. In the case of the beet-root molasses and residues, and of the suint, the mass is calcined and the potassium carbonate extracted, as is done for wood. The potassium exists in the Stassfurt and other mineral salts as chlorides and sulphates in combination with magnesium and calcium, and after the potassium chloride is extracted from them, it is converted into pearlash by the Le Blanc process, or it may be converted into carbonate by the Solvay process, using trimethylammonium carbonate. Mendeléeff[1] states that about 25,000 tons of potash annually are now (1897) prepared from KCl at Stassfurt. Other proposed sources of potash salts are sea water; the mother liquor of salt works and mineral springs; the residues from seaweeds; and the feldspars and similar rocks.

There are, moreover, some industries which produce considerable quantities of wood ashes as a by-product, from which potash may be extracted with profit. For example, the wood-distillation industry uses hard wood and consumes much of the charcoal produced as fuel under the retorts. Hard-wood ashes are richer in potash than soft-wood ashes, and as the extra cost of obtaining the potash should be very trifling in connection with the other operation, considerable quantities of it might be obtained from this source.

As potassium carbonate crystallizes with difficulty, it can not well be purified by the method often employed for purifying salts. The pure material must, therefore, be obtained by indirect means. Among other methods in vogue, one is to purify cream of tartar, obtained from grapes, by repeated crystallization, and then, by burning it, obtain the refined potash. When the cream of tartar is ignited by contact with air there is left a mixture of finely divided charcoal and potassium carbonate, and this comes into the market under the name of "black flux," and is used in smelting operations as a reducing agent.

Potash is used in the manufacture of soft soap; in making potassium salts, such as potassium chromate; in making caustic potash; and, in the form of pearlash, in the making of glass.

The potassium found in wood ashes is extracted from the soil by the plant during its growth, the presence of potassium compounds in the soil being essential to the growth of vegetation. Consequently, wood ashes are a valuable fertilizing material. Wiley[2] says of this:

> The beneficial effects following the application of ashes, are greater than would be produced by the same quantities of matter added in a purely manurial state. The organic origin of these materials in the ash has caused them to be presented to the plant in a form peculiarly suited for absorption. Land treated generally with wood ashes becomes more amenable to culture, is readily kept in good tilth, and thus retains moisture in dry seasons and permits of easy drainage in wet. These effects are probably due to the lime content of the ash, a property, moreover, favorable to nitrification and adapted to correcting acidity. Injurious iron salts, which are sometimes found in wet and sour lands, are precipitated by the ash and rendered innocuous or even beneficial. A good wood-ash fertilizer, therefore, is worth more than would be indicated by its commercial value calculated in the usual way.

From the census returns for 1900 it appears that the leached ashes have a certain manurial value and the returns show that the establishments reported above sold 87,040 bushels of leached ashes to be used as a fertilizer at a total value of $3,268, or, on an average, at 3.75 cents per bushel. It is stated by the manufacturers that wood ashes in leaching gain one-third in bulk; one manufacturer specifically stating that his 15,000 bushels of raw ashes yielded 20,000 bushels of leached ashes.

From Wagner's Chemical Technology, 1892, page 299, it appears that "the yearly production of potash, according to H. Grüneberg, is from

	Tons.
Wood ashes, Russia, Canada, United States, Hungary, and Galicia	20,000
Beet sugar ash, France, Belgium, Germany	12,000
Mineral salts, Germany, France, England	15,000
Suint, Germany, France, Belgium, Austria	1,000
Total from all sources	48,000

"These conditions differ strikingly from those which existed thirty [thirty-eight] years ago, when wood ash was in exclusive use and Russia potash ruled the mar-

[1] Principles of Chemistry, 1897, Vol. I, page 549.

[2] Principles and Practice of Agricultural Analysis, Vol. II, page 254.

ket. The potash extracted from wood ashes amounts to scarcely one-half of the total production; it decreases year by year, and the time when it will disappear from the market seems within measurable distance." This agrees with the data shown in the table above for the "Total Production of Potashes by Decades, 1850 to 1900."

The foreign commerce in potashes for the United States is exhibited in the following tables compiled from "The Foreign Commerce and Navigation of the United States for the years ending June 30, 1891–1900, Vol. II."

DOMESTIC EXPORTS OF ASHES, POT AND PEARL: 1891 TO 1900, INCLUSIVE.

YEAR.	Pounds.	Value.	YEAR.	Pounds.	Value.
1891	430,582	$24,432	1896	969,874	$41,208
1892	1,307,634	99,566	1897	511,830	21,727
1893	634,421	31,775	1898	869,841	33,202
1894	650,261	29,205	1899	745,433	29,676
1895	664,876	30,188	1900	1,273,905	49,566

IMPORTS OF ASHES, WOOD AND LYE OF, AND BEET-ROOT ASHES, FOR CONSUMPTION: 1891 TO 1900, INCLUSIVE.

YEAR.	Value.	YEAR.	Value.
1891	$42,624	1896	$67,393
1892	54,855	1897	66,423
1893	76,306	1898	62,206
1894	74,050	1899	59,970
1895	77,708	1900	66,453

IMPORTS OF POTASH, CARBONATE OF, OR FUSED, FOR CONSUMPTION: 1891 TO 1894, INCLUSIVE.

YEAR.	Pounds.	Value.
1891	.....	$39,980
1891	6,207,419	219,557
1892	8,745,268	309,585
1893	10,115,017	329,895
1894	8,130,975	262,818

IMPORTS OF POTASH, CARBONATE OF, CRUDE OR BLACK SALTS, FOR CONSUMPTION: 1895 TO 1900, INCLUSIVE.

YEAR.	Pounds.	Value.
1895	11,602,272	$364,506
1896	12,439,180	401,819
1897	7,501,497	229,029
1898	15,844,374	471,919
1899	16,018,889	437,675
1900	21,191,258	625,922

LITERATURE.

Chemistry as Applied to the Arts and Manufactures, by Sheridan Muspratt, Glasgow, 1860.

Traité de Chimie, by Pelouze and Fremy, Vol. II, Paris, 1865.

A Manual of Chemical Technology, by Rudolf von Wagner, translated by William Crookes, New York, 1892.

Principles and Practice of Agricultural Analysis, by Harvey W. Wiley, Vol. II, Easton, Pa., 1895.

The Principles of Chemistry, by D. Mendeléeff, New York, 1897.

GROUP IV.—ALUMS.

During the census year 1900 there were 13 establishments engaged in the manufacture of alums either as a principal or subordinate product. The comparison with previous censuses is as follows:

PRODUCTION OF ALUMS, BY DECADES: 1880 TO 1900, INCLUSIVE.

YEAR.	Number of establishments.	PRODUCT.		PER CENT OF INCREASE.	
		Pounds.	Value.	Quantity.	Value.
1880	6	39,217,725	$808,165	.....	.....
1890	10	93,998,008	1,616,710	139.7	100.0
1900	13	179,467,471	2,446,576	90.9	51.3

There are no census statistics of production anterior to 1880, and the census of 1900 is the first one at which the various alums were separately reported, as shown in the table which follows:

KINDS OF ALUM PRODUCED IN 1900.

KIND.	Number of establishments.	Pounds.	Value.
Total	.....	179,467,471	$2,446,576
Ammonia alum	4	6,580,373	102,308
Potash alum	5	14,200,393	215,004
Burnt alum	6	16,028,464	403,100
Concentrated alum	10	103,016,815	1,062,547
Alum cake	4	4,048,655	34,047
Other alums	7	35,592,771	629,570

The legend "other alums" is as reported on the schedules, and no doubt under it are included some of the kinds named in the list above, but it has not been possible to separate them. However, there are in the classification 1,526,000 pounds of aluminum hydroxide (hydrate of alumina), valued at $31,500. There are included under "burnt alum" 9,399,550 pounds of material, with a value of $228,500, returned as "soda alum" from 4 establishments. In addition, there were reported 3,928,160 pounds of ammonia alum, valued at $58,922, and 1,149,666 pounds of aluminum sulphate, valued at $10,922, as having been produced and consumed in the manufacture of other products.

It should be said that of the 13 establishments reported above but 2 of them were reported as producing alum only, the others being engaged in the manufacture of many other chemical substances. Taking the ratio of value which the alum bears to the total value of products for these last-mentioned establishments as a guide, it appears that these 13 establishments employed 802 wage-earners and a capital of $3,888,445 in the production of alum, and that there were consumed 34,000 tons of bauxite, having a value of $230,000; 5,000 tons of cryolite, of a value of $110,000; 2,000 tons of sodium sulphate, in the form of salt cake or niter cake, of a

value of $4,100; 360 tons of ammonium sulphate, of a value of $21,900; 477 tons of potassium sulphate, of a value of $19,600; and 61,424 tons of sulphuric acid, there being used for this acid 3,323 tons of sulphur, of a value of $66,000; 49,081 tons of pyrites, of a value of $107,000; and 513 tons of sodium nitrate, of a value of $18,000.

The geographical distribution of these establishments is set forth in the following table:

GEOGRAPHICAL DISTRIBUTION OF ALUM FACTORIES: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Value of product.	Per cent of total.
United States	13	802	$3,888,445	$2,446,576	100.0
Pennsylvania	6	530	2,747,482	1,411,652	57.7
Massachusetts	3	74	255,930	306,754	12.5
Illinois, New York, and Michigan	4	198	885,033	728,170	29.8

Alum was known to the ancients and was used by them in dyeing, tanning, and in making medicine. Aluminum sulphate, mixed with more or less iron sulphate, occurs as efflorescences on rocks and as the mineral *feather alum*, and it was this limited natural supply that was the source of the material used. The manufacture of alum is of oriental origin and was introduced into Europe about the Thirteenth century, the materials used being the mineral *alunite* or alum stone, which has the formula $K_2SO_4.Al_2(SO_4)_3.4Al(OH)_3$ mixed with compounds of iron. This mineral is insoluble in water, but by calcining it and exposing it in heaps, with occasional moistening, the mass weathers, and after some months a potassium alum may be dissolved out which crystallizes in cubes and contains inclosed iron oxides which give it a red color. Such alum is known as "Roman alum" from its having been extensively manufactured at Tolfa, near Rome. Later, alum slates and shales, clay, bauxite, and cryolite have been employed as the raw materials of the alum manufacture, and the last-named two are the substances which are now almost exclusively used for this purpose.

When the minerals—clay, in its purer form of *kaolin* ($Al_2Si_2O_7.2H_2O$), or *bauxite*, which is aluminum hydroxide mixed with ferric, silicic, and other oxides in varying proportions, are used as the source of alumina, the process consists in decomposing the mineral with sulphuric acid and evaporating the solution of aluminum sulphate formed until, when cool, it sets to a stone-like mass. This cake contains impurities in the form of silica, ferric sulphate, and free sulphuric acid, there being usually from 2 to 3 per cent of the latter present. When but little iron is present, the substance is known as "alum cake;" when much iron is present it is known as "alumino-ferric cake." *Bauxite* is especially liable to yield this last-named product.

A purer aluminum sulphate is made from *bauxite* by calcining it with soda ash until sodium aluminate is formed. This is dissolved, the solution filtered, and carbon dioxide passed through it, by which the aluminum is precipitated as hydroxide. This purified hydroxide is dissolved in hot sulphuric acid and the solution formed run into leaden pans to cool, when it forms a crystalline mass much used in the arts under the name of "concentrated alum," and having the composition $Al_2(SO_4)_3 20H_2O$, though the separate crystals have but 18 molecules of water of crystallization. Manufacturers specify that bauxite for use in the manufacture of alum shall contain not more than 3 per cent of ferric oxide nor less than 60 per cent of aluminum oxide.

Cryolite is used not only as a source of alum, but also for the manufacture at the same time of caustic soda, calcium or sodium fluorides, and hydrofluoric acid. This mineral, which in commercial quantities is found only in southern Greenland, is a double fluoride of sodium and aluminum, having the formula $AlF_3(NaF)_3$. By calcining cryolite with powdered limestone and lixiviating the frit, or by boiling cryolite with milk of lime, sodium aluminate is obtained as one of the products of the reaction, and this may be converted into "concentrated alum" by the means above described. A modification of this consists in boiling sodium aluminate liquor with powdered cryolite, through which the sodium in each molecule is converted into sodium fluoride and the aluminum into alumina, and then producing "concentrated alum" by dissolving the alumina in sulphuric acid.

When "concentrated alum" is dissolved in water and mixed with a solution of potassium sulphate, the solution, on concentration, deposits beautiful, transparent, colorless, octahedral crystals, which have a vitreous luster and the composition $K_2Al_2(SO_4)_4.24H_2O$. This substance is known as "potassium alum" or "potash alum," and was the first complex alum recognized. It was the first to be manufactured commercially, since by this means the easily soluble aluminum sulphate was separated from the iron sulphates, and a very superior article for use in dyeing was obtained. Since purer raw material has been found, and improved methods for purification have been devised, concentrated alum has largely displaced the complex alums in dyeing as well as in the other arts.

Crystallized potassium alum of the composition given above is the type of a large number of complex alums which may be produced by mixing a solution of aluminum sulphate with a solution of an alkaline sulphate and crystallizing out the double salt. Among these we have in commerce crystallized ammonium and crystallized sodium alum, though the latter is not common, owing to its being difficult to crystallize and to the fact that the crystals, when formed, readily effloresce. When these crystallized alums are heated, the water of crystalliza-

tion, and usually a little of the sulphuric acid, is driven off and the material falls to a white powder known as "burnt alum," which is used in pharmacy. A similar sodium alum which is largely used in baking powders is prepared by mixing concentrated solutions of sodium sulphate and aluminum sulphate, allowing them to set in a cake, and roasting the alum to drive off the water, or by mixing the sulphates in the solid condition and heating them. By varying the proportions of the sulphates and the temperature, various desired properties are imparted to the burnt alum, and these preparations are sold under various trade names.

Effloresced sodium alum is sometimes known under the name of "porous alum," but this name, in the trade, is given to porous alum cake containing a little sodium alum and basic aluminum sulphate, which is made by stirring into alum cake, just before it sets, a desired quantity of soda ash. As the aluminum sulphate possesses an acid reaction it reacts with the sodium carbonate and the carbon dioxide evolved puffs up the mass and leaves it in a condition so that it may be readily dissolved.

Alums may be formed with selenic and other acids in place of the sulphuric acid of ordinary alum. Moreover, chromic, ferric, manganic, and other sulphates form double salts with the alkali sulphates, and though these compounds contain no aluminum whatever, they are called alums because they crystallize in the same form, have the same crystalline habit, the same oxygen ratio, and the same number of molecules of water of crystallization as the double sulphates of alumina and the alkali metals. None of these numerous alums has any commercial importance except "chrome alum," which has the formula $K_2Cr_2(SO_4)_4.24H_2O$.

Potash and ammonia alums were made by Charles Lennig, of Philadelphia, in 1837, and concentrated alum was manufactured by him in 1859. Harrison Bros. & Co., of Philadelphia, began the manufacture of crystal alum about 1840, and they began the manufacture of concentrated alum from *bauxite* in 1877. The Pennsylvania Salt Manufacturing Company began the manufacture of concentrated alum at Natrona, Pa., in 1876, and they were the first to manufacture porous alum.

Alums are used in dyeing, printing, tanning, paper making, in making lakes and other pigments, in purifying water and sewage, as a constituent of baking powder, in medicine, in stucco work for hardening plaster, in photography for hardening films, in rendering wood and fabrics non-inflammable, in "carbonizing" wool, in bleaching, and in the preparation of various aluminum compounds.

The foreign commerce in alums is shown in the following table, compiled from the reports of the Bureau of Statistics of the United States Treasury Department:

IMPORTS OF ALUMS FOR CONSUMPTION: 1891 TO 1900, INCLUSIVE.

YEAR.	Pounds.	Value.	YEAR.	Pounds.	Value.
1891	4,652,985	$58,863	1896	5,525,825	$86,371
1892	4,140,916	59,336	1897	5,301,544	96,529
1893	4,572,923	73,806	1898	2,787,639	36,099
1894	1,838,728	30,831	1899	1,601,829	14,244
1895	2,983,682	46,815	1900	2,186,266	19,354

And in the following tables, obtained from the same source, are shown the quantities and values of the raw or partly manufactured materials so far as they were set forth:

IMPORTS OF CRYOLITE FOR CONSUMPTION: 1891 TO 1900, INCLUSIVE.

YEAR.	Tons.	Value.	YEAR.	Tons.	Value.
1891	7,129	$95,405	1896	7,024	$93,198
1892	8,298	76,350	1897	3,009	40,056
1893	8,459	111,796	1898	10,788	144,178
1894	12,756	170,215	1899	5,529	79,455
1895	8,685	116,273	1900	5,878	78,658

IMPORTS OF BAUXITE FOR CONSUMPTION: 1897 TO 1900, INCLUSIVE.

YEAR.	BAUXITE, CRUDE.		ALUMINUM HYDRATE, OR REFINED BAUXITE.	
	Pounds.	Value.	Pounds.	Value.
1897	8,722,074	$14,915	.....	.....
1898	.....	.....	2,092,082	$60,194
1899	7,722,000	14,168	2,955,339	92,019
1900	6,850,000	11,413	3,474,421	109,574

LITERATURE.

Outlines of Industrial Chemistry, F. H. Thorp: Macmillan, New York, N. Y., 1898.

Manufacture of Alum, Lucien Geschwind: D. Van Nostrand, New York, N. Y., 1901.

Manual of Chemical Technology, Rudulf von Wagner: D. Appleton & Co., New York, N. Y., 1892.

Watts, Dictionary of Chemistry, Vol. V, Longmans, Green & Co., London, 1869.

Group V.—Coal-Tar Products.

Notwithstanding that as early as 1815 Accum had devised a process for obtaining a volatile oil from coal tar for use as a substitute for spirits of turpentine; that in 1845 A. W. Hofmann had discovered that this body contained benzene; that in 1856 a great impetus was given to tar distilling by the discovery of anilin colors by Perkin, since the benzol, which is the raw material for their manufacture, was exclusively derived from coal tar, and that from 1806, when coal gas was introduced for lighting by David Melville at Newport, R. I., coal tar had been a by-product of the industry in this country; yet it was not until 1880 that any mention was made in the United States Census Reports of these

bodies, and they are apparently given there in two classifications, as follows: On page 1001 of Statistics of Manufactures there are reported 344,114 pounds of anthracene of a value of $99,242, and in the table of specified industries on page 20 of the same report, it is stated that three works produced "coal tar" having a value of $466,800, from which it is inferred that as the original coal tar was being produced in the several hundred gas works then existing, the three works enumerated were engaged in producing coal-tar products. On pages 288 and 289 of Part III, Census of Manufacturing Industries, 1890, there are reported coal-tar products of a value of $687,591. The establishments were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF FACTORIES FOR COAL-TAR PRODUCTS: 1890.

STATES.	Value of products.	Per cent of total.
United States	$687,591	100.0
New Jersey	330,200	48.0
Pennsylvania	168,180	24.5
New York	138,324	20.1
District of Columbia	20,000	2.9
Georgia	20,000	2.9
Massachusetts and Tennessee	10,887	1.6

At the census of 1900 there were reported 14 establishments devoted to the manufacture of coal-tar products, which amounted in value to $1,322,094, and 8 establishments in which this manufacture was of secondary importance, with a value of $99,626, the total value being $1,421,720. These establishments were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF FACTORIES FOR COAL-TAR PRODUCTS: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Value of products.	Per cent of total.
United States	22	466	$1,448,622	$1,421,720	100.0
Missouri	3	155	381,959	415,600	29.2
Pennsylvania	6	177	651,482	396,759	27.9
New York	3	33	25,457	44,016	3.1
Louisiana, Tennessee, Ohio, California, Minnesota, Massachusetts, and New Jersey	10	101	389,724	565,345	39.8

Of these products, chemicals having a value of $205,047 were obtained from further action on the distillate of the coal tar. In addition, these factories produced tarred felt and tarred paper (in which part of the material from the coal tar was consumed), having a value of $442,529.

Coal tar, as its name implies, is obtained from coal, and it is produced by the destructive distillation of coal out of contact with the air, the other products being gas, coke, and ammoniacal liquor. From the beginning of the Nineteenth century the chief commercial source of the coal tar was found in the manufacture of coal gas for illuminating purposes, but to-day it is also obtained from the by-product coke ovens, while gas producers, blast furnaces, and water-gas plants furnish tars which now find commercial uses, though they differ in composition from coal tar. In the special report on coke for the census of 1900, it is reported that the production of tar from the by-product coke ovens for 1899 amounted to 104,687,330 pounds, or 52,344 tons. Although the returns for gas for 1900 are given in the special report on gas for the census of 1900, no separate returns are therein presented for the by-product of tar. This may, however, be estimated as follows: In Table 8 of that report it is stated that the total production of gas was 67,093,553,471 cubic feet, and in Table 9 that over 75 per cent of the gas manufactured during the census year was water gas. Putting the coal gas at 20 per cent, we have 13,418,710,694 cubic feet of coal gas.

The average yield of gas per ton of gas coal is 10,000 cubic feet, and dividing the volume of gas by this there results 1,341,871 tons of coal as having been used for making coal gas. The yield of tar per ton of coal is about 5 per cent by weight, which gives from the above figure 67,094 tons of tar. The total quantity of coal tar from the by-product coke ovens and the coal-gas industry in 1900 was, then, approximately 119,438 tons. The quantity of "water-gas tar" may also be estimated from the quantity of oil consumed, which is given in the special report on gas as 194,857,296 gallons. According to Douglas,[1] about 25 per cent of the oil is recovered as tar, which gives for the oil recorded above 48,714,324 gallons of tar. As, according to A. H. Elliott,[2] "water-gas tar" has a specific gravity of 1.1, a gallon will weigh 9.15 pounds, and therefore the total weight of "water-gas tar" obtained in the United States for 1900 as derived from the data given above is 222,868 tons. No tar is reported from any other source, though it is known that abroad the blast furnaces and gas producers are utilized as sources of this material. The total computed production of coal tar and water-gas tar for the United States for the census year 1900 is therefore 342,306 tons. It is worth noting that though the first by-product coke oven in the United States was erected in 1892,[3] yet the industry has grown so fast that the yield of coal tar from this source closely approaches that from coal gas making.

In connection with these estimates it is interesting to compare the following statement made by Lunge[4] in the recent edition of his standard work: "White and Hess (Jour. Soc. Chem. Ind., 1900, page 509), quote a number of analyses, from which they conclude that American coal tars are not well adapted to distillation for the recovery of benzol, etc., as they are inferior in

[1] J. of Gas-Lighting, page 1130. 1891.
[2] Am. Chem. J., page 248. 1884.
[3] J. D. Pennock, J. Am. Chem. Soc., vol 21, page 681. 1899.
[4] Coal Tar and Ammonia, 3d ed., Appendix, page 917.

quality to European tars except as regards anthracene. Their estimate of the production of coal tar in the United States, 400,000 tons, is probably much too high, since by far the greater portion of illuminating gas made there is (carburetted) water gas. Probably the quantity of 120,000 tons, which I gave as the production of coal tar in the United States in 1886, is not much, if at all, exceeded at the present time." The amount of coal tar reported as consumed in the United States in the census year 1900 was 22,004,650 gallons, which at 10 pounds per gallon gives 110,023 tons.

The yield of tar from the manufacture of gas in Europe in 1898 is given by Lunge[1] from data supplied by Dr. Bueb, as follows:

TAR PRODUCED IN MAKING GAS IN EUROPE IN 1898.

COUNTRY.	Tons.	COUNTRY.	Tons.
Total	1,120,000	Belgium	20,000
		Italy	16,650
Great Britain	666,650	Russia	16,650
Germany	166,650	Holland	15,000
France	135,000	Denmark	13,500
Austria-Hungary	41,500	Switzerland	6,750
Scandinavia	21,650		

The data of the census of 1900 places the United States fourth in the list of countries in the amount of tar produced in the distillation of coal for the manufacture of gas.

It is of historical interest that the first English patent referring to the destructive distillation of coal (that of John Joachum (sic) Becher and Henry Serle, dated August 19, 1681) does not treat of the manufacture of illuminating gas, but of "a new way of makeing pitch and tarre out of pit coale, never before found out or used by any other," and this German chemist, Johann Joachim Becher, appears to have been the originator of the coal-tar industry, he having employed the coal tar as a substitute for "Swedish tar from firwood" in tarring wood and ropes. The French metallurgist de Gensanne[2] describes a furnace in use before 1768 at Sulzbach, near Saarbrücken, for coking coal and recovering tar, the light oil from the tar being used for burning in lamps.

Notwithstanding the various inventions for producing coal tar, it is, according to Lunge[3]—

Certain that the manufacture of coal tar was never carried out on any extensive scale until it appeared as a necessary by-product in the manufacture of illuminating gas from coal, the idea of which seems to have occurred toward the end of the last century at the same time to the Frenchman Lebon and the Englishman William Murdoch. The former had already recommended the use of tar for preserving timber; but it was the latter who, along with his celebrated pupil Samuel Clegg, really laid the foundation of the enormous industry of gas making. The first private gas works was erected in 1798 at the engineering works of Bolton & Watts; the first public gas works in London in the year 1813; in Paris, 1815, and in Berlin, 1826.

The tar formed in the manufacture of coal gas necessarily forced itself upon the notice of the gas manufacturer, since it could not be thrown away without causing a "nuisance." It was probably from the first burnt under the retorts, but the method of doing this without giving very much trouble was not understood then. Other quantities, no doubt, were used, in lieu of wood tar, as a cheap paint for wood or metals, but it must have been soon found out that in the crude state it is not well adapted for this purpose. * * * It was also quickly perceived that in this respect tar is improved by boiling it down to some extent, and as early as 1815 Accum showed that if this boiling down is carried out in closed vessels (stills) a volatile oil is obtained which may be employed as a cheap substitute for spirits of turpentine. But this does not seem to have been carried out to any great extent, and coal tar remained, for more than a generation from the first introduction of gas lighting, a nuisance and hardly anything else.

In Germany the first more extensive employment of gas tar was for making roofing felt, for which purpose it has to be deprived of water and the more volatile constituents. Instead of condensing these, they were at first almost everywhere, and later on in many cases, removed by evaporating the tar in open vessels, thus creating a considerable risk from fire. In Germany, Brönner, of Frankfort, was the first (in 1846) to condense the more volatile tar oils, from which he prepared a detergent, long after known by his name, and consisting principally of benzene.

In England, where the manufacture of illuminating gas originated, and where it has always been, and still is, carried on to a very much greater extent than on the Continent, a more extensive industrial employment for coal tar was first opened out by the invention of Bethell (1838) for preserving timber, especially railway sleepers, by impregnation with the heavy oil distilled from gas tar. From that time dates the introduction of tar distilling on a large scale. The light oils may have been lost even here in some cases, but more usually they were condensed and employed as "coal-tar naphtha" for burning and for dissolving india rubber.

The day of the light tar oils came after A. W. Hofmann (1845) had shown the presence of benzene in them, but especially when Mansfield, in his patent specification (1847), for the first time accurately described the composition of these oils, along with a process for preparing benzene in a pure state and on a large scale, and with proposals for utilizing the tar oils of lowest boiling point for lighting purposes. The industrial preparation of benzene was soon followed by that of nitrobenzene, at that time only employed as a substitute for the essential oil of bitter almonds, and known by the French fancy name of "essence de Mirbane." But all these applications produced only a limited demand for the light oils which could be made from the rapidly increasing quantities of gas tar; so that the latter, except in a few instances locally, did not attain any considerable commercial value. But a sudden impetus was given to tar distilling in 1856 by the discovery of the anilin colors, the material which forms their starting point, benzol, being exclusively derived from coal tar.

Coal tar is an extremely complex mixture of chemical compounds, some of which have not yet been even isolated. As before stated, the tars from other processes than the destructive distillation of coal contain other constituents, and varying quantities of similar constituents, from those existing in coal tar. Likewise, coal tar will vary in its composition with the coal which is distilled and the manner in which the distillation is carried out. The "products" are obtained from the coal tar by fractional distillation, and the first products are crude naphtha and light oils of a specific gravity below 1.000, distilling over below 180° C.; dead oils and

[1] Coal Tar and Ammonia, 3d ed., page 17; ibid., page 4.
[2] De Gensanne, "Traité de la fonte des Mines," Paris, 1770, Vol. I, ch. 12.
[3] Coal Tar and Ammonia, pages 11–13.

creosote oils of a specific gravity above 1.000, distilling over between 180° C. and 270° C.; green or anthracene oils, distilling over between 270° C. and 360° C.; and soft pitch, which is left in the still.

The proportions of yields from different coals is shown in the following tables given by J. D. Pennock,[1] chemist in charge of the oldest by-product coke-oven plant in the United States:

ANALYSES OF COAL.

	A	B
	Per cent.	Per cent.
Volatile matter	34.20	32.68
Fixed carbon	57.15	59.40
Ash	8.65	7.92
Sulphur	0.93	1.19

ANALYSES OF TAR.

	A	B	I	II
Specific gravity	1.163	1.203	1.205	1.231
	Per cent.	Per cent.	Per cent.	Per cent.
Water	2.40	2.70	1.40	1.10
Light oil	4.60	2.03	3.12	1.63
Creosoting oil	1.26	0.50	0.29	0.34
Dead oil	22.81	16.40	25.09	19.23
Naphthalene	6.00	Trace.	0.20	1.72
Anthracene	0.60	Trace.	0.19	0.24
Soft pitch	68.80	70.50	67.40	74.14

Tars A and B, made from Coals A and B, whose analyses are given above, show what differences may exist in tars made from coals very similar in composition as shown by proximate analysis. Tars I and II represent two tars from gas works. They also vary greatly in composition. As a usual thing, they are found to be of much higher specific gravity and to contain less light oils than tars from the by-product coke oven, making them inferior as sources of benzene and for the manuture of tarred paper.

To obtain the desired commercial products, the distillate must be subjected to further treatment. Thus the light oil on fractional distillation, gives "benzol" to the extent, for the coke-oven practice, of from 0.6 to 0.9 per cent of the weight of the coal used. According to Lunge,[2] "the final products of general trade into which the crude benzol should be split up without residues, are the following:

	FURNISHES DISTILLATE PER CENT UP TO—					Specific gravity.
	100°.	120°.	130°.	160°.	200°.	
90 per cent benzol	90	.....	.....	.....	.....	0.885
50 per cent benzol	50	90	.....	.....	.....	0.880
Solvent naphtha	.....	.....	20	90	.....	0.875
Heavy naphtha	.....	.....	.....	.....	90	0.880

[1] J. Am. Chem. Soc., vol. 21, page 696. 1899.
[2] Coal Tar and Ammonia, 3d ed., page 588.

"Ninety per cent benzol" is a product of which 90 per cent by volume distills before the thermometer rises above 100° C. A good sample should not begin to distill under 80° C., and should not yield more than from 20 to 30 per cent at 85° C., or much more than 90 per cent at 100° C., but it should distill completely below 120° C. A 90 per cent benzol of good quality contains about 70 per cent of benzene, 24 per cent of toluene, including a little xylene, and from 4 to 6 per cent of carbon disulphide and light hydrocarbons.

"Fifty per cent benzol," often called 50/90 benzol, is a product of which 50 per cent by volume distills over at a temperature not exceeding 100° C., and 40 per cent more (making 90 per cent in all) below 120° C. It should wholly distill below 130° C. It contains a larger proportion of toluene and xylene than the 90 per cent benzol. It is nearly free from carbon disulphide, and contains comparatively little of the light hydrocarbons. It is employed for producing the heavy anilin used in manufacturing rosaniline or magenta.

"Thirty per cent benzol" is a product of which 30 per cent distills below 100° C. and about 60 per cent more passing over between 100° and 120° C. It consists chiefly of toluene and xylene with smaller proportions of benzene and cumene.

"Solvent naphtha" consists of xylene, pseudocumene, and mesitylene and is used in dissolving caoutchouc in the manufacture of waterproof materials and other articles.

From these "light oils," by fractional distillation and purification with sulphuric acid, water, milk of lime, and caustic soda, pure benzene, C_6H_6, toluene, C_7H_8, and xylene, C_8H_{10}, may be obtained, the benzene being crystallized out.

According to Pennock[3] the light oil obtained is from 6.6 pounds to 8.5 pounds per long ton of coal and it varies with the percentage of volatile matter in the coal. The light oil contains from 58 to 63 per cent of benzene, divided thus:

	Per cent.
90 per cent benzol	57
50 per cent benzol	2
Solvent naphtha	4

The dead oils and creosote oils which compose the material that is collected from the coal-tar distillate between 180° and 270° C. contain the "middle oil," and this fraction on further treatment yields crystallized carbolic acid, cresols, heavy solvent naphtha, pyridine bases, and naphthalene. In practice this is divided into further fractions, the fraction between 240° and 270° C. furnishing the creosote oil, which is a commercial source of naphthalene, coal-tar creosote, and the cresols. The naphthalene, which exists to the extent of 40 per cent or more in the creosote oil, is removed by chilling the oil, which causes the naphthalene to crystallize out, leaving the cresols. The crystals are

[3] J. Am. Chem. Soc., vol. 21, page 703.

then drained and pressed and purified further by sublimation.

The heavy coal-tar oil is used not only as a source of the more valuable products obtained by rectification or by "breaking" in red-hot tubes, but also for "pickling" timber; softening hard pitch; preparing varnishes; preparing cheap mineral paints, where the heavy oil is used in place of linseed oil; as an antiseptic; in the blue steaming of bricks; in carburetting gas; in the manufacture of lampblack; and by burning, as a source of heat and light.

The fraction between 150° and 200° furnishes the carbolic acid, it being obtained by treating the oil with caustic soda, through which sodium phenolate is formed, which separates from the oil. The sodium phenolate is drawn off and then decomposed by sulphuric acid or carbon dioxide and the carbolic acid set free. The crude carbolic acid is now purified by distillation or other means and the pure carbolic acid, or phenol, which crystallizes in colorless crystals, obtained. Pure carbolic acid is used in the manufacture of the dyestuffs, picric acid, and corallin, and of some azo dyes, also in the manufacture of salicylic acid, but most of the carbolic acid, both pure and crude, is used for antiseptic purposes. The oil drawn off from the sodium phenolate contains some of the higher homologues of benzene, and naphthalene with pyridine bases. In commerce it furnishes principally naphthalene, pyridine bases, and solvent naphtha of various degrees, the treatment being determined by the products sought. The pyridine bases are used in the manufacture of pharmaceutical preparations and in denaturizing grain alcohol for use in the arts.

The anthracene oil, which is the portion of the coal-tar distillate passing over above 270° C., is known also as green oil, green grease, and red oil, and it contains naphthalene, methyl naphthalene, anthracene, phenanthrene, acenaphthene, diphenyl, methyl anthracene, pyrene, chrysene, retene, fluoranthene, chrysogen, benzerythrene, carbazol, and acridine, together with a mixture of liquid high-boiling oils, of whose composition nothing is yet known, the whole forming a mass rather thinner than butter, filled with crystalline scales of a greenish-yellow color. The anthracene oil is treated by cooling and pressing, the liquid portion being sent to the heavy oil to be reworked with it. The solid portion is either sold as rough anthracene or it is further purified by washing with solvents which dissolve the impurities. On oxidation anthracene yields anthraquinone, which is used for the production of alizarine and other coal-tar colors. According to Pennock[1] there is as yet no market for anthracene in this country, but it is necessary that some anthracene should be present in coal tar pitch in order to produce a pitch of the right consistency for roofing purposes.

As indicated, the naphthalene is accumulated in the creosote oil and extracted from it in the crude condition by freezing and pressing, when it is purified by sublimation. It is used in the manufacture of artificial colors and as a substitute for camphor in protecting goods from the ravages of moths.

The coal-tar pitch, which forms the residue in the still, is used in the manufacture of roofing compositions and tarred felt and tarred paper; incorporated with coal or coke dust, it is fashioned into briquettes for use as fuel; dissolved in creosote oil or other solvents, it is used as a paint for iron and woodwork; and it is used as a substitute for asphalt in street pavements.

Benzene is employed as a solvent in the manufacture of nitrobenzene and dinitrobenzene, which are used in several arts and in the manufacture of many benzene derivatives. One important product is anilin, which is obtained by the reduction of mononitrobenzene. The anilin of commerce, which is known as anilin oil, is obtained from benzol, and this, as before stated, is a mixture of different cyclic hydrocarbons, the particular mixture used being determined by the color which it is sought to produce. In this case, as with pure benzene, the mixture is nitrated by exposure to a mixture of nitric and sulphuric acids, and the nitrosubstitution compounds that are produced are reduced by exposure to tin and hydrochloric acid or some other source of nascent hydrogen. Benzol is also used as a cleansing agent and as a vehicle in paint.

The nitrosubstitution compounds, and amido bodies, like anilin oil, represent in this group the "chemicals made from coal-tar distillery products."

The foreign commerce in coal-tar products is set forth in the following tables, compiled from the reports of the Bureau of Statistics of the Treasury Department on imported merchandise entered for consumption into the United States:

IMPORTS FOR CONSUMPTION OF COAL TAR DURING THE YEARS ENDING JUNE 30, 1891 TO 1896.

YEAR.	COAL TAR, CRUDE, AND PITCH.	
	Barrels.	Value.
1891	89,818	$263,593
1892	117,056	302,791
1893	102,136	244,291
1894	96,068	218,514
1895	112,536	247,957
1896	139,976	288,750

IMPORTS FOR CONSUMPTION OF COAL-TAR PRODUCTS, NOT MEDICINAL AND NOT COLORS OR DYES,[1] DURING THE YEARS ENDING JUNE 30, 1898 TO 1900.

YEAR.	Value.
1898	$228,037
1899	393,602
1900	397,780

[1] J. Am. Chem. Soc., vol. 21, page 697.

[1] These preparations are known as benzol, toluol, naphthalene, xylol, phenol, cresol, toluidine, xylidine, cumidine, binitrotoluol, binitrobenzol, benzidine, tolidine, dianisidine, naphthol, naphthylamine, diphenylamine, benzaldehyde, benzyl chloride, resorcin, nitrobenzol, and nitrotoluol.

IMPORTS FOR CONSUMPTION OF PREPARATIONS OF COAL TAR, EXCEPT MEDICINAL, AND PRODUCTS OF, NOT SPECIALLY PROVIDED FOR, FOR THE YEARS ENDING JUNE 1, 1895 TO 1900.

YEAR.	Value.
1895	$187,373
1896	313,943
1897	.....
1898	134,416
1899	221,101
1900	274,946

Literature.

A Treatise on Chemistry, by H. E. Roscoe and C. Schorlemmer, Vol. III: New York, 1887.

The Rise and Development of Organic Chemistry, by Carl Schorlemmer: London, 1894.

A Handbook of Industrial Organic Chemistry, by Samuel P. Sadtler: Philadelphia, 1895.

The Retort Coke Oven and the Chemistry of its By-Products, by J. D. Pennock, J. Amer. Chem. Soc., 21, 678–705. 1899.

The Spirit of Organic Chemistry, by Arthur Lachman: New York, 1899.

Coal Tar and Ammonia, by George Lunge: 3d ed. New York, 1900.

Group VI.—Cyanides.

In this classification are included potassium ferrocyanide, potassium ferricyanide, potassium and ammonium sulphocyanates (known commercially as sulphocyanides), and potassium, sodium, and other cyanides. No separate account was taken of the cyanides at any census previous to 1900. At the census of 1900 returns were made only for potassium ferrocyanide and for potassium cyanide. Twelve establishments were reported in which the cyanides were the principal products, the value being $1,466,061, and 6 establishments in which they formed secondary products, the value being $12,844. These 18 establishments employed $1,322,819 of capital and 391 wage-earners and produced $1,595,505 of product. They were distributed as follows:

GEOGRAPHIC DISTRIBUTION OF CYANIDE FACTORIES: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Value of product.	Per cent of total.
United States	18	391	$1,322,819	$1,595,505	100.0
New Jersey	6	166	533,001	1,053,472	66.0
Pennsylvania	4	107	317,816	303,245	19.0
Ohio	3	43	71,750	86,852	5.5
Maryland, Massachusetts, and Missouri	5	75	400,252	151,936	9.5

Of the products reported, 6,165,407 pounds, having a value of $994,014, were potassium ferrocyanide, and 2,317,280 pounds, having a value of $601,491, were the so-called potassium cyanide. There were consumed in this manufacture 9,315,080 pounds of potassium carbonate, having a value of $279,602; 3,456 tons of hoofs and of horn waste, having a value of $87,502; 19,417 tons of scrap leather, having a value of $150,213; 1,200 tons of spent iron oxide from the gas works, having a value of $3,000; 300,000 pounds of sodium, having a value of $93,183; 2,400 bushels of lime, having a value of $480; $9,520 worth of scrap iron, and 2,401,180 pounds of potassium ferrocyanide.

Potassium ferrocyanide (ferrocyanide of potassium; yellow prussiate of potash; blood-lye salt) was discovered by Macquer in 1752, through acting upon prussian blue with an alkali. It is made by fusing potassium carbonate in cast-iron vessels and adding to the fused mass a mixture of nitrogenous organic matter, such as horns, hair, blood, wool waste, and leather scraps, with from 6 to 8 per cent of iron turnings or borings, until the mixture added equals about 1¼ parts of the potash. The fused mass, when cooled, contains, among other substances, potassium cyanide, carbonate, and sulphide, iron sulphide, metallic iron, and separated carbon. This mass is broken up and digested with water at 85° C. for several hours, during which reactions take place by which the potassium ferrocyanide is formed. The solution is clarified and the potassium ferrocyanide purified by crystallization, when it appears in fine large yellow crystals, having the formula $K_4Fe(CN)_6.3H_2O$.

Potassium ferrocyanide is also prepared from the spent oxide of iron from gas works' purifiers, thereby utilizing the nitrogen compounds that have been taken up or formed during the process of purification. In this operation the oxide is lixiviated with warm water to remove the ammonium sulphocyanate and other ammonium compounds, and the residue is mixed with quicklime and heated by steam in closed vessels to 100° C., through which calcium ferrocyanide is formed, and separated by lixiviation. By treating this with potassium chloride, the difficultly soluble calcium potassium ferrocyanide is formed, and by decomposing this with potassium carbonate the potassium ferrocyanide results.

Potassium ferrocyanide was manufactured on a commercial scale by Carter & Scattergood in Philadelphia, before 1834. It is used largely for making prussian blue, potassium cyanide and ferricyanide, prussic acid, in calico printing, in dyeing, for case-hardening iron, and in white gunpowder and pyrotechnics.

Potassium ferricyanide (ferricyanide of potassium; red prussiate of potash) was discovered by Leopold Gmelin in 1822,[1] and is formed by passing chlorine gas through a solution of potassium ferrocyanide until the solution will no longer give a blue reaction with a ferric salt. Or the salt may be formed by exposing dry powdered ferrocyanide to the action of chlorine gas; or by acting on a calcium and potassium ferrocyanide solution with potassium permanganates; or, according to

[1] Schw. J., vol. 34, page 325.

Lunge,[1] by boiling a solution of the ferrocyanide with lead peroxide, while a stream of carbon dioxide is passed through the solution. Potassium ferricyanide crystallizes without water of crystallization in blood-red prisms. It is very soluble, yielding an intensely yellow solution which forms the blue pigment, known as Turnbull's blue, with ferrous salts.

Carter & Scattergood were manufacturing red prussiate of potash on a commercial scale at Philadelphia in 1846. When in solution with caustic potash, it is a powerful oxidizing agent, and as such is used in calico printing as a "discharge" on indigo and other dyes. It also forms a part of the sensitive coating for photographic "blue-print" papers, and has been recommended for use with potassium cyanide in the extraction of gold from its ores.

Ammonium sulphocyanate (sulphocyanate of ammonium; ammonium thiocyanate; ammonium sulphocyanide), the acid of which was first observed by Bucholz in 1799, is prepared by heating carbon disulphide and ammonium hydroxide to 125° C. in an autoclave until the pressure rises to 15 atmospheres, when the ammonium dithiocarbamate is formed. The pressure is now released and the autoclave heated to 110° C., when the dithiocarbamate is decomposed and the products distilled over. The ammonium sulphocyanate produced is obtained by evaporating the liquid remaining in the still in tin vessels and crystallizing out.

As pointed out above, ammonium sulphocyanate is also obtained by lixiviating the spent iron oxide used in purifying illuminating gas. The salt crystallizes in colorless plates which are very soluble in water and alcohol. It is used as a source of other sulphocyanates and in dyeing, to prevent the injurious action of iron on the color.

Among the sulphocyanates produced from it is the barium sulphocyanate which results from heating ammonium sulphocyanate with barium hydroxide solution under slight pressure; and this barium salt is used generally for the manufacture of potassium and aluminum sulphocyanates, which are used in textile dyeing and printing.

Potassium cyanide (cyanide of potassium) has been generally prepared by fusing potassium ferrocyanide with potassium carbonate until the evolution of gas ceases. Potassium cyanide, potassium cyanate,[2] carbon dioxide, and metallic iron are formed. The metallic iron sinks to the bottom of the crucible and the fused mixture of cyanide and cyanate is run off. Part of the cyanate may be reduced to cyanide by adding powdered charcoal to the fused mass, or it may be reduced by metallic zinc or sodium; or the cyanide may be extracted from the mass by a solvent such as alcohol, acetone, or carbon disulphide. By fusing the potassium ferrocyanide with sodium carbonate a mixture of sodium and potassium cyanide known under the name of "cyansalt" may be produced. An almost pure cyanide can be obtained by heating the ferrocyanide *per se* according to the following equation:

$$K_4Fe(CN)_6 = 4\ KCN + N_2 + FeC_2$$

but this method entails the loss of one-third of the nitrogen in the ferrocyanide, and to avoid the waste of nitrogen Erlenmeyer proposed to add the proper amount of an alkali metal to the melted ferrocyanide, giving for sodium the following reaction:

$$K_4Fe(CN)_6 + 2\ Na = 4\ KCN + 2\ NaCN + Fe$$

and it is in this way that most of the so-called chemically pure potassium cyanide now sold is made, though it consists of a mixture of potassium and sodium cyanides. It also contains a considerable quantity of potassium carbonate, which is added to it during the course of manufacture to reduce its strength, for the combined cyanides produced as above described have a higher percentage of cyanogen than chemically pure potassium cyanide could possibly have. The carbonate is added in sufficient amount to reduce the cyanogen contents to from 39 to 40 per cent, which is equivalent to from 98 to 100 per cent potassium cyanide.

Other processes have been devised for using sodium in making cyanides. One is to first convert the sodium into sodamine, thus: $2\ Na + 2\ NH_3 = 2\ NaNH_2 + H_2$ by heating it in contact with ammonia gas, and then heating the amine with carbon to form the cyanide thus: $NaNH_2 + C = NaCN + H_2$. Another and later method by which it is claimed a better yield is obtained, is to form a stable cyanamid, at a temperature of about 400° C., from the sodamine and carbon, thus:

$$2\ NaNH_2 + C = Na_2N_2C + 2\ H_2,$$

and then reacting on the cyanamid with a further quantity of carbon at a temperature of 800° C. to form the cyanide according to the equation:

$$Na_2N_2C + C = 2\ NaCN.$$

Each of these methods requires a large amount of expensive sodium for a given output of cyanide. J. D. Darling has lately devised a process of using sodium in the synthetic production of sodium cyanide, which gives good results and in which the larger portion of the metallic base is furnished in the form of caustic soda, and but a small amount of sodium is needed to finish the process. It is claimed that by this process a moderate-sized sodium plant can produce enough metal to manufacture a large amount of cyanide.

Potassium cyanide has been commercially manufactured by passing nitrogen over an intensely heated mixture of charcoal and potassium carbonate. Cyanides have also been produced by conducting ammonia

[1] Ding. poly. J., vol. 238, page 75.
[2] Gmelin, vol. 7, page 413.

gas through vertical retorts, heated to a red heat, and containing a mixture of charcoal and alkali carbonates. Potassium cyanide is sometimes obtained in considerable quantity from blast furnaces, being formed from the potassium carbonate in the ash of the fuel.[1] Because of this reaction between carbon and nitrogen in the presence of alkaline salts numerous efforts have been made to utilize the reaction in making the atmospheric nitrogen available.

Potassium cyanide was commercially manufactured by the H. V. Davis Chemical Works, at New Bedford, Mass., in 1852. As it is a powerful reducing agent, potassium cyanide is used as a flux in assaying and in metallurgy; as a solvent of silver sulphide it is used in cleaning silver articles; it has been used as a fixing solution in photography; for the preparation of Grénat soluble and potassium isopurpurate in dyeing; and, as it forms a soluble double cyanide with silver, gold, copper, and other metals, it is much used in electroplating; but its largest use is now found in the cyanide process for the extraction of gold from its ores.

The foreign commerce in the cyanides is set forth in the following tables, compiled from the publications of the Bureau of Statistics of the Treasury Department of the United States:

IMPORTS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.

YEAR.	YELLOW PRUSSIATE OF POTASH.		RED PRUSSIATE OF POTASH.	
	Pounds.	Value.	Pounds.	Value.
1891	2,223,154	$368,366	35,826	$10,650
1892	1,302,632	232,058	35,933	11,111
1893	1,047,910	206,259	16,679	5,743
1894	599,103	114,826	11,135	3,339
1895	878,727	161,009	26,703	7,593
1896	1,056,562	157,457	30,390	8,579
1897	3,252,931	359,037	59,087	14,893
1898	1,340,305	132,508	77,246	18,674
1899	1,809,089	204,974	62,697	15,211
1900	1,771,394	224,274	53,716	12,954

IMPORTS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1897 TO 1900.

YEAR.	CYANIDE OF POTASH.	
	Pounds.	Value.
1897	16,232	$4,190
1898	549,697	120,252
1899	1,102,780	253,613
1900	2,064,974	444,703

LITERATURE.

Handbook of Chemistry, by Leopold Gmelin, Vol. VII: London, 1852.

Encyclopédie chimique, by M. Fremy, vol. 2: Paris, 1886.

On the Fixation of Atmospheric Nitrogen, by A. A. Breneman, J. Am. Chem. Soc., 11, 2–48. 1889.

A Dictionary of Chemistry, Henry Watts, vol. 2: London, 1870.

[1] Bloxam's Chemistry, page 619. 1890.

Manual of Chemical Technology, by R. von Wagner: London, 1892.

Outlines of Industrial Chemistry, by F. H. Thorp: New York, 1898.

The Cyanide Process for the Extraction of Gold, by M. Eissler: London, 1898.

Die Cyan-Verbindungen, by F. Feuerbach: Leipzig, 1896.

Manufacture and Uses of Metallic Sodium, by J. D. Darling, J. Frk. Inst., 153, 65–74. 1902.

The Composition of Commercial Cyanide of Potassium, by Russell W. Moore, J. Soc. Ch. Ind., 21, 391–392. 1902.

Group VII.—Wood Distillation.

Wood distillation as now classified for census purposes deals solely with that treatment of wood by which wood alcohol, acetic acid, acetate of lime, pyroligneous acid, and charcoal, or any of these, are produced. This interpretation was given to it in 1880, the first census at which separate returns were set forth for the industry. The manufacture proceeds in two stages: First, the production of crude wood alcohol or wood spirits and crude acetate of lime; second, the refining of the alcohol, and the refining of the acetate of lime, or the production therefrom of acetic acid or acetone. The refining processes are usually carried out at other works than those in which the crude materials are produced, but while in the census reports the alcohol refineries remain identified and classified with the wood distillation works, the factories where the acetate of lime is treated are classified with "chemicals, acids." With this preface it can be stated that 99 establishments were reported as producing some of the crude substances enumerated above during the census year 1900. Of these, 84 were regular wood-distilling establishments and produced of crude alcohol 4,191,379 gallons, having a value of $1,660,061; of acetate of lime 81,702,000 pounds, having a value of $926,358; and of charcoal 14,428,182 bushels, having a value of $612,009.

These works employed $4,858,824 of capital, and 1,268 wage-earners. There were 9 establishments reporting the production of the crude material and the refining of the alcohol in the same factory; and these establishments produced of refined alcohol 637,856 gallons, having a value of $370,513; of acetate of lime 5,124,000 pounds, having a value of $54,928; and of charcoal 2,726,120 bushels, having a value of $114,663. They employed $760,156 of capital and 254 wage-earners. Besides these there were 9 establishments engaged in refining wood alcohol only, producing 2,400,284 gallons of refined alcohol, having a value of $1,926,385, and employing $1,098,719 of capital, and 52 wage-earners. Finally, there were 6 other establishments engaged in the production of pyroligneous acid or pyrolignite of iron as incidental to other manufacturing processes, the total quantity of pyroligneous acid reported from all sources being 182,446 gallons, valued at $9,481; of dye liquors 308,400 gallons, valued at $29,440, and of sundries, such as wood creosote,

wood oil, ashes, tar, and the like, amounting in value to $71,452.

At the first census of this industry in 1880 only crude materials were reported. At the census of 1890 refined wood alcohol was reported for the first time, and it was then stated that the total output of crude alcohol was found by adding to that produced at the "acid factories" that which was produced and refined in the same establishment. Proceeding in this way for the 9 establishments reported above for 1900 as producing the crude alcohol and refining it in the same establishment, and converting the refined 97 per cent alcohol into crude 82 per cent alcohol at a value of 42 cents per gallon, a total is obtained for these establishments of 754,584 gallons of crude alcohol having a value of $316,925. By taking, in these instances, the per cent of the total value for all products added in the refining of the alcohol, the proportion of capital and labor devoted to the production of the crude material is found to be, for these 9 establishments, $641,052 of capital and 219 wage-earners. There were, therefore, 93 factories producing crude alcohol, in which $5,499,876 of capital and 1,487 wage-earners were employed. The total output thus ascertained is compared with the returns for the previous censuses in the following table:

WOOD DISTILLATION, CRUDE MATERIAL PRODUCED: 1880 TO 1900.

YEAR.	Number of establishments.	WOOD ALCOHOL.		ACETATE OF LIME.		CHARCOAL.	
		Gallons.	Value.	Pounds,	Value.	Bushels.	Value.
1880	17	.....	$86,274	6,593,009	$156,892	.....	$31,770
1890	53	1,116,075	688,764	26,778,415	315,430	.....	.....
1900	93	4,945,963	1,976,986	86,826,000	981,286	17,154,302	726,672

The increase of 1890 over 1880 in acetate of lime was 306.2 per cent in quantity and 101 per cent in value. The increase for 1900 over 1890 was 224.2 per cent in quantity and 211.1 per cent in value. The increase for 1890 over 1880 in wood alcohol was 698.3 per cent in value. The increase for 1900 over 1890 was 343.2 per cent in quantity and 187 per cent in value.

These establishments were distributed as follows:

WOOD DISTILLATION, GEOGRAPHICAL DISTRIBUTION OF WORKS PRODUCING CRUDE PRODUCTS: 1900.

STATE.	Number of establishments.	Average number of wage-earners.	Value of products.	Per cent of total.
United States	93	1,487	$3,833,266	100.0
Pennsylvania	58	878	2,339,536	61.0
New York	24	354	786,252	20.5
Michigan	5	169	505,069	13.2
North Carolina	3	12	18,409	0.5
New Jersey, Indiana, and Massachusetts	3	74	184,000	4.8

Only the number of refineries and quantity of products were reported for 1890, and only with these can the present condition of the refined wood-alcohol industry be compared, but this is sufficient to show how marked the growth has been.

PRODUCTION OF REFINED WOOD ALCOHOL: 1890 AND 1900.

YEAR.	Number of establishments.	Gallons.	Value.
1890	4	166,342	.....
1900	18	3,038,140	$2,296,898

The increase of 1900 over 1890 is more than seventeenfold.

Although wood is usually spoken of as consisting of cellulose, it really consists of cellulose associated with a great variety of other organic substances, the kind differing with the different species of wood, and it is only necessary to recall the various gums, resins, tannins, sugars, and coloring matters found in commerce, which are obtained by simple processes of extraction from wood, to make this fact especially apparent. When subjected to heat out of contact with the air, the constituents of the wood are decomposed into liquids, gases, and a solid residue, and this process has been resorted to for ages as a means for obtaining charcoal. During the middle ages it became known that wood vinegar or pyroligneous acid could be obtained by distilling wood, but the identity of the acetic acid present with that obtained by the fermentation of alcohol was not known until 1802, when it was established by Thènard. The presence of wood spirit in the distillate from wood was discovered by Robert Boyle, in 1661, but its analogy to grain alcohol was first recognized by Taylor in 1812, and its composition was definitely fixed by Dumas and Peligot in 1831. Although charcoal, acetic acid, and methyl alcohol are the principal commercial products of the wood distillation industry, there is also produced, besides methyl alcohol, other alcohols, acetic acid and other acids, furfural and other aldehydes, acetone and other ketones, methyl acetate and other esters, methylamine and other amines, wood-tar creosote containing guaiacol and other phenols, and various hydrocarbons.

Originally wood was treated for charcoal alone by charring it in heaps or in kilns, thus allowing all the other products named above to go to waste. This process is still carried on, but before the middle of the Nineteenth century the process of distillation in retorts, by which the acetic acid in the form of pyroligneous acid, pyrolignite of iron, or acetate of lime, and the wood spirits were recovered, was well established in Europe. The manufacture of pyroligneous acid was begun in the United States by James Ward in 1830, at North Adams, Mass. The manufacture of acetate of lime and methyl alcohol was started in the United States about 1867 by James A. Emmons and A. S.

Saxon, in Crawford County, Pa., and in 1874 George C. Edwards established the Burcey Chemical Works at Binghamton, N. Y.,[1] to refine the crude wood spirit produced by the various acetate manufacturers. In 1876 Dr. H. M. Pierce obtained the first of a series of United States letters patent relating to inventions in this industry, which he was the first to apply to the recovery of the by-products from the smoke of the charcoal kilns in Michigan, where charcoal was being produced for use in blast furnaces. From that time he was most active in the promotion of the wood distillation industry, and largely contributed to the revolution which has since been effected in our foreign commerce in the products of this industry.

The wood used for the making of wood alcohol and acetate of lime is hard wood, preferably oak, maple, birch, and beech. It is cut in 50-inch lengths, so that a cord of wood in this industry measures 48 by 48 by 50 inches. It should be seasoned two and one-half years before "burning," to get the best results. The wood is burned in retorts, in ovens, or in kilns. The retorts are cylindrical, are made of three-eighths inch steel, 9 feet long by 50 inches in diameter, and are provided with a large, tightly fitting door at one end and an outlet pipe about 15 inches in diameter at the other end. The retorts are set horizontally in pairs in brickwork, and batteries of from 6 to 16 pairs are common. The cord wood is fed through the door and carefully stacked so as to completely fill the retort. The ovens consist of rectangular iron chambers set in pairs in brickwork and provided with large doors at one end and three or more delivery pipes on the side of each oven. They are usually 27 feet long, 6 feet wide, and 7 feet high inside, and rails are laid upon the floor of the oven by which steel cars loaded with cord wood may be run in. These cars each hold 2½ cords of wood, and an oven of the above dimensions will receive two such cars. Ovens, however, are in use in this country that are from 48 to 50 feet in length and capable of receiving four cars at one charge. The retorts are heated from beneath by burning wood, coal, or charcoal, supplemented by the tar, red oil, and gas, which are by-products of the industry. A very large part of the charcoal made in retorts is thus consumed. This furnishes another example of a chemical industry in which the former by-products have now become the principal products. The ovens are heated by natural gas.

When the wood is heated the moisture is driven out, but no decomposition occurs until the temperature approaches 160° C. Between this and 275° C. a thin, watery distillate, known as pyroligneous acid, is chiefly formed; from 275° to 350° C. the yield of gaseous products becomes marked; and between 350° and 450° C. liquid and solid hydrocarbons are most extensively formed. The quantity and character of the yield depend upon the character and age of the wood and the temperature and rate at which the charge is heated. In the ovens the wood is heated for twenty-four hours and then the cars containing the charcoal are drawn and immediately run into iron sheds where, when the doors are closed and luted, the charcoal is allowed to cool. The volatile portions, from retorts or ovens, are carried to condensers where the pyroligneous acid and tar are condensed and the gases are carried off to be burned under the boilers for generating steam, or under the retorts.

The yield of pyroligneous acid is about 30 per cent and of tar about 10 per cent of the weight of the dry wood. The acid averages about 10 per cent of acetic acid, 1 per cent of methyl alcohol and 0.1 per cent of acetone. As acetone is produced by the heating of acetates the yield of these two bodies will vary with the manner in which the heating is carried on. The pyroligneous acid is a dark red-brown liquid, having a strong acid reaction and a peculiar empyreumatic odor, and its density varies between 1.02 and 1.05 specific gravity. It is used to a limited extent in the manufacture of an impure acetate of iron, known as "black iron liquor," or "pyrolignite of iron," but it is usually treated to separate the methyl alcohol, acetone, and acetic acid from it. This is done by distillation, the alcohol being concentrated by dephlegmators, as is done in the manufacture of grain alcohol, to 82 per cent, when it is shipped to the refinery in iron drums holding about 110 gallons each, or in barrels holding from 45 to 46 gallons each. The acetic acid is recovered in two forms, viz, as "gray acetate of lime" or as "brown acetate of lime;" the first being produced when vapors from the distillation are passed through milk of lime, while the second is produced when the pyroligneous acid is neutralized with lime before distilling off the alcohol, and the resulting acetate of lime is thus contaminated with considerable tar.

The crude wood alcohol is sent to the refinery to be purified and rectified, which is accomplished by further distillation from lime or caustic alkalies. The acetone can not be separated by simple distillation, but it may be converted into chloracetones of high boiling points and thus removed, or the separation may be effected by crystallizing out the methyl alcohol with calcium chloride, or the acetone may be converted into chloroform and volatilized by distilling the mixture with chloride of lime. Most of the methyl alcohol of commerce contains acetone in varying quantities, even as much as 15 per cent, and such acetone containing alcohols are especially desired in several arts, as they serve for the purpose to which they are put better than pure methyl alcohol. A pure methyl alcohol is now produced in very considerable quantity which is of 100 per cent strength as it leaves the works, but it soon absorbs water on exposure so as to reduce its alcohol strength to 98 or 97 per cent.

[1] Tenth Census of the United States, Manufactures, general folio 1013.

In the Pierce process, as described by Landreth, the charring of the wood is effected in circular, flat-top, brick kilns holding 50 cords of wood each. The wood is charred by the heat produced by gas burned in a brick furnace under the kiln, into and through which the products of combustion pass. The gaseous products of the dry distillation of the wood pass from the kiln to condensers, where the tarry and liquid products are condensed and the gas sent back to the kiln. Thus none of the charcoal produced is burned to carbonize other wood, as in the common pits or ovens. The gas which elsewhere is wasted is here not only sufficient to effect the carbonizing of the wood, but furnishes fuel for the boilers required about the works.

The wood used is as thoroughly seasoned as the conditions of maintaining a year's supply in advance, cost of storage room, and interest on capital invested in stock render economical. If not thoroughly dry when placed in the kilns, the carbonization of the wood is automatically deferred, by the absorption of the heat in the evaporation of the sap and other moisture, until the seasoning process is complete. This seasoning commences at the top of the kilns and proceeds regularly downward, by a definite plane of seasoning. When this plane reaches the bottom and the seasoning is complete, which is indicated by a sudden change in the color of the escaping vapors, the process of charring begins at the top and proceeds downward precisely like the seasoning process.

The watery vapors driven off during seasoning are not preserved, but are allowed to escape through vents temporarily left open around the base of the kilns and through the top of the kiln chimneys, which, during this stage, are open at the top, but which, so soon as the watery vapor has escaped, are connected with a suction main. The time required for the several stages in the cycle of operations in producing a kiln of charcoal is as follows:

	Days.
For charging one kiln with wood	2
For completing the seasoning of the wood	1
For carbonizing the wood	7
For cooling the charcoal	6
For drawing the charcoal	2
Total length of cycle	18

As one 60-ton blast furnace requires 5,000 bushels of charcoal daily, or the output of 2 kilns, the total number of kilns in a plant to furnish a continual supply of fuel must be equal to twice the number of days in a cycle plus a margin for relays, for repairs, and unusual delays; the margin is usually chosen at one-sixth the effective number of kilns, so that the total number of kilns comprising a plant $= 2(18) + \frac{1}{6}(36) = 42$, of which at any one time—

4 kilns are being charged and closed.
2 kilns are being seasoned.
14 kilns are being carbonized.
12 kilns are being cooled.
4 kilns are being drawn.
6 kilns are idle or acting as relays.

42

These 42 kilns are arranged in 2 distinct batteries of 21 kilns each. Each battery has its own condensers and suction main carrying the products of distillation to the condensers, and its own gas main leading the noncondensable gases back to the kiln furnaces.

The condensers are composed of tall wooden tanks, 5 feet square by 20 feet high, through which the products of distillation pass, each inclosing 99 vertical copper pipes, 2 inches in diameter, through which the condensing water flows. The condensed products are trapped out at the bottom of each condenser, of which 10 comprise a battery, and conveyed to cooling tanks, where the tar is separated from the pyroligneous acid liquor by cooling. The tar is used to coat the kilns to render them impervious to air, and for this purpose one coating of tar suffices for four burnings, while the usual coating of lime whitewash has to be repeated after each burning. The circulation of the gaseous products through the system is maintained by exhaust fans, which draw the noncondensed gases through the condensers and force them through the gas main back to the kilns, when they are injected into the furnaces by a steam jet from a one-sixteenth-inch orifice playing in the center of an inch nozzle on the gas pipe. The minimum amount of air necessary to effect the perfect combustion of the gases is admitted through regulating dampers in the front of the furnace.

From the liquor coolers the pyroligneous acid liquor is conveyed to the distilling house, where the acetic acid in the liquor is converted into acetate of lime; the liquor is then sent to the fractional distillation system, which comprises 8 primary stills and condensers, 4 intermediate stills and condensers, and 2 final or shipping stills and condensers. The stills are circular tanks each holding about 2,500 gallons and are heated by steam coils of 2-inch copper pipe. The several stills of each of the 3 series are operated abreast. The distillation is not carried on continuously, but each series is charged and the distillation carried on until all of the alcohol available is evaporated, when the stills are emptied and recharged with new liquor. The degree of concentration attained in each series of stills is as follows:

The liquor entering the primary stills contains 1½ per cent of alcohol.

The distillate from the primary stills contains 15 per cent of alcohol.

The distillate from the intermediate stills contains 42 per cent of alcohol.

The distillate from the final stills contains 82 per cent of alcohol.

The yields of products differ with the different works and with the different processes employed. According to Landreth the yields by the Pierce process with brick kilns are as follows:

DRY WOOD.	Volume per cord of wood.	Mass per cord.	Per cent.
Resulting charcoal	50.6 bush	1,012 lbs	25.30
Resulting methylic alcohol	4.4 gals	30 lbs	0.75
Resulting acetic acid	4.6 gals	40 lbs	1.00
Resulting tarry compounds	16.5 gals	160 lbs	4.00
Resulting water	220.7 gals	1,838 lbs	45.95
Resulting noncondensable gases	11,000.0 cu. ft	920 lbs	23.00
Total		4,000 lbs.	100.00

Though 1 factory reports as high as 12.93 gallons of alcohol per cord of wood, yet the yields from the retort and oven processes average about 10 gallons of alcohol, 200 pounds of acetate of lime, and 50 bushels of charcoal per cord of wood in addition to the gas, tar, and chemical oil, all of which are burned. The yield of brown acetate of lime is about one-third larger than that of gray. As has been said, where retorts are used much of the charcoal is burned. Where coal is used, four-tenths of the charcoal produced is burned under the retorts. Where no coal is used six-tenths of the charcoal produced is thus consumed. In all of the works the whole of the gas, tar, and chemical or red oil is burned by the aid of steam, but it is probable that investigation will show that the tar and red oil are too valuable to be thus consumed.

The methyl alcohol is used for domestic fuel, as a solvent in varnishes, as a solvent in the manufacture of pyroxylin plastics, in the production of formaldehyde, in the making of methylated spirit, and in the manufacture of anilin colors.

The acetate of lime is used for the manufacture of acetic acid, acetone, "red liquor," and, when purified, as a mordant in dyeing.

Acetone is employed in the manufacture of chloroform, iodoform, and sulphonal, for denaturating grain alcohol, in making smokeless powder, and as a solvent in several of the arts.

A complete treatment of the wood distillation industry should include the production of turpentine, rosin, and tar by the distillation of the wood of the long-leaved pine, but this is made the subject of special report No. 126, issued January 11, 1902, entitled "Turpentine and Rosin."

The factories for the production of the crude products of this industry must be located near an abundant supply of hard wood and where there is a sufficient supply of water for cooling the condensers and charging the steam-generating boilers, this steam being employed in distilling the liquors, evaporating the acetate solutions, drying the acetate, and operating the pumps by which the liquors are raised from one level to another. In some cases, however, the acetate pans are placed over the retorts so that the heat radiated from them may be usefully employed. The total amount of wood reported as consumed in this industry for 1900 was 490,939 cords, having a value of $1,241,972, which gives an average value for it of $2.53 per cord as laid down at the works. Assuming one man to average one and one-half cords of wood per day, the cutting of the wood used would give employment to 3,273 men for one hundred days each. Comparing this total quantity of wood reported with the total quantities of crude wood alcohol, acetate of lime, and charcoal the average yields per cord of wood for all processes are found to be 10 gallons of alcohol, 176 pounds of acetate of lime, and 35 bushels of charcoal.

It is alleged in the "trade" that the importations of acetate of lime into the United States before the introduction of the by-product processes amounted to as much as 3,000,000 pounds annually. The only statistics discoverable in the records of the Treasury Department relative to this, is that in 1880 there were 38,000 pounds imported, having a value of $76. On the other hand, the following table, compiled from "The Foreign Commerce and Navigation of the United States for the Year Ending June 30, 1900," shows that the United States is exporting large quantities of both acetate of lime and wood alcohol:

EXPORTS, WOOD ALCOHOL AND ACETATE OF LIME: 1898 TO 1900, INCLUSIVE.

YEAR.	WOOD ALCOHOL.		ACETATE OF LIME.	
	Gallons.	Value.	Pounds.	Value.
Total	1,653,799	$934,411	134,274,564	$2,015,169
1898	385,938	199,230	37,496,288	537,850
1899	727,062	414,875	48,987,511	700,900
1900	540,799	320,306	47,790,765	776,419

From the same source is the following record of imports of charcoal and pyroligneous acid:

IMPORTS, CHARCOAL: 1891 to 1898, INCLUSIVE.

YEAR.	Value.	YEAR.	Value.
1891	$56,020	1895	$20,272
1892	48,029	1896	42,970
1893	51,034	1897	32,100
1894	40,249	1898	2,404

IMPORTS, FOR CONSUMPTION, ACETIC OR PYROLIGNEOUS ACID: 1891 TO 1900, INCLUSIVE.

YEAR.	Pounds.	Value.
1891	10,946	$1,036
1892	12,280	2,302
1893	18,421	2,795
1894	22,244	3,050
1895	92,889	8,938
1896	.....	.....
1897	.....	.....
1898	127,049	9,776
1899	202,838	14,467
1900	292,891	19,189

LITERATURE.

Acetic Acid, Chemistry of Arts and Manufactures, by Sheridan Muspratt, Vol. 1, *1–48*. 1860.

The Economical Production of Charcoal for Blast Furnace Purposes, by O. H. Landreth, Proc. A. A. A. S., 27, *145–151*. 1888.

Outlines of Industrial Chemistry, by F. H. Thorp: New York, 1898.

Handbook of Industrial Chemistry, S. P. Sadtler: Philadelphia, 1895.

The Distillation of Pine Wood in the South, by Franklin S. Clark, School of Mines Quarterly, 9, *163–166*. 1888.

Charcoal Production and Recovery of By-Products, by Consul-Gen. Frank H. Mason, U. S. Consular Reports, 66, *258–261*. 1901.

The Manufacture of Charcoal in Kilns, by T. Egleston, Trans. Amer. Inst. of Mining Engineers, May, 1879.

The Composition of Wood Oil, G. S. Fraps, Amer. Chem. Jour., 25, *26–54*. 1901.

Commercial Organic Analysis, Alfred H. Allen, revised by Henry Leffmann, 3d ed., Vol. 1: Philadelphia, 1898.

Group VIII. Fertilizers.

The term "fertilizer," as used in this report, includes all manufactured products which are intended to promote the growth of plants and which can be, and customarily are, so used without needing any further factory treatment. Under this definition raw phosphate rock, even if finely ground, can hardly be included, nor can crude cottonseed, ordinary tankage, nor unground bone. All of these have fertilizing properties, but require further treatment, usually chemical, if the full effect is to be economically obtained. The term "fertilizer works" should, strictly speaking, be confined to establishments producing "finished fertilizers," such as superphosphate, with or without ammoniates; "complete fertilizers," by which is meant a mixture of superphosphate with both potash and ammoniates; and "all other fertilizers," including bone meal and similar substances. But under the principle governing the classification of industries at the census of 1900 there can be included in fertilizer works all factories of which the main product, though not a finished fertilizer, was, nevertheless, a fertilizer material—say, tankage—in a condition of advanced manufacture, such products being included in "all other fertilizers."

The total number of establishments thus classified as fertilizer works, and forming Class A, is 422. In addition there are 18 small establishments, each of which reported a value, for all products, of less than $500, and hence are not included in the regular census tabulations. As the total fertilizer product of the 18 establishments amounted to but 46 tons of complete fertilizer, valued at $1,047, and 213 tons of "all other fertilizers," valued at $3,489, it will be seen that the omission to tabulate establishments under $500 is of small consequence.

Under Class B are included 10 establishments whose main product places them in some one of the 19 groups of "chemical industries," but which made more or less fertilizers as a subordinate, though sometimes very important, part of the product. The total fertilizer product of this class amounted to superphosphate, tons 1,810, value $20,417; complete fertilizer, tons 17,707, value $350,077; and "all other fertilizers," tons 7,983, value $98,510.

Class C includes 28 works, none of which belongs to "chemical industries," yet at which were made a certain amount of fertilizers. The importance of taking this class into consideration, if a full presentation of the industry is desired, is evident, since the total product of this class was superphosphate, tons 12,000, value $100,000; ammoniated superphosphate, tons 750, value $13,500; complete fertilizer, tons 24,391, value $521,825; and "all other fertilizers," tons 27,409, value $443,147.

Class D includes such by-products of "slaughtering and meat packing," "garbage reduction," "glue," and similar industries as were reported as "fertilizers." So far as known, such materials are bones, bone tankage, ammoniates, and the like, utilized in the preparation of ammoniated and complete fertilizers. While included here for the sake of completeness, it must be remembered that the amounts and values of these products, as well as those of Class C, are elsewhere reported in the census tables of their respective industries, and their presence here is a not unnoticed duplication. Of this class, 10 "garbage-reduction" works produced such materials aggregating 17,809 tons, value $256,322, while the report for "slaughtering and meat packing" gives "fertilizers," tons 160,962, value $3,326,119, and "glue" gives tons 15,942, value $331,268, a total of 204,713 tons, and a value of $3,913,709.

Included in "all other fertilizers" is fish scrap, the residue after the oil is pressed out of the fish, amounting to 27,035 tons, of a reported value of $448,602, in addition to which certain establishments made 1,942 tons which were consumed in works in making fertilizers. The fish oil reported from the 25 establishments engaged in this industry amounted to 1,135,264 gallons, valued at $222,929. The returns of scrap and oil per thousand fish, the customary unit of measure, naturally vary considerably, according to the condition of the fish, whether fat or lean, the lean fish yielding little oil in proportion to the scrap. In one case of a large and well-managed factory having good fish, the yield per thousand fish was given as 4.17 gallons of oil and 185 pounds of scrap, while another large works, having very lean fish, reported a yield of only 1.87 gallons of oil and but 140 pounds of scrap. The general average for all reports was, 2.98 gallons of oil and 149.2 pounds of scrap per thousand fish. After the scrap leaves the press in which the oil is expressed, it must be protected from decomposition, as this not only produces a local nuisance but results in serious pecuniary loss. In one case where 500 tons of good scrap were valued at $10,000, 500 tons of decomposed scrap were valued at only $3,000. In order to prevent this decomposition the laws of several states, for example, Massachusetts and Connecticut, require that the daily output of scrap shall be sprinkled with sulphuric acid, as this prevents the lighting of flies upon it and the consequent development of maggots. When acid is so used, finely ground phosphate is often mixed with the scrap before shipment, thus taking up the excess of acid and hindering the rotting of the bags in which the scrap is shipped.

The use of fish as a fertilizer was known to the aborigines of New England before the arrival of the whites, since it is stated in the records of the Plymouth colony that Squantum, a friendly Indian, showed the colonists

how to manure their corn by putting a fish into each hill. It would seem, therefore, that the colonists were ignorant of the fertilizing value of fish, which is rather surprising, since the value of barnyard manure has been known since a very early period in the history of agriculture, and marl, a phosphatic lime earth, was used in England, at least, prior to this period. It is possible, however, that the value of marl was considered to lie in its improving the physical condition of the soil rather than as furnishing any plant food, as the advantage of mixing clay with sandy soils or sand with clayey soils was known to the Romans.

As soon as the true action of fertilizers became known, it was seen that the presence of grease or oil in a fertilizer was harmful, as hindering the conversion of the fertilizing ingredients into the soluble forms into which they must pass before they can be assimilated by the plant. Hence by extracting the oil from fish a valuable substance was obtained and the residue of scrap became more quickly efficient. The same thing occurs in the cottonseed industry, the oil and "linters," valuable for other purposes, containing very little fertilizer material, while the cake and hulls are in much better condition for utilization as feed or fertilizer than in their original condition as part of the seed.

Little is known about the beginnings of the fish-oil industry, but it is stated that the Herreshoffs, of Rhode Island, were making fish oil and scrap as early as 1863. The fish generally used for this purpose is the menhaden or mossbunker, which appears on the Atlantic coasts in the summer in large schools and is a very oily fish, in no demand for edible purposes. The number reported as caught during the census year is 458,963,200, and yielded the quantities of oil and scrap noted above.

The most available statistics of this industry are those given by Eugene G. Blackford in One Hundred Years of American Industry, 1895, page 394. These are here presented with the statistics derived from reports classified at the census of 1900 as chemical industries, group "fertilizers," and may therefore not include all of the reports received from this industry. It is believed, however, that the showing is substantially complete, although the figures show an enormous reduction in capital invested and number of men employed, from the figures given for 1894. It is true that in some cases where complete fertilizers are also made, the men reported as employed are those engaged at the factory only, those employed in fishing being represented only by the cost of the fish as covering wages, supplies, and maintenance of vessels. Still the total capital, $497,760, bears a fair relation to total value of product, which is $703,866, made up of oil, $222,929; scrap sold, $448,602; and scrap used in works, 1,942 tons, of a calculated value of $32,237; and the general statistical position of the industry bears out the statements of some of those engaged in the industry to the effect that in 1900 there was little profit in it.

MENHADEN INDUSTRY, SEASONS OF 1874, 1880, 1890, 1894, AND 1900.

YEAR.	Factories.	Sail vessels.	Steamers.	Men employed.	Capital invested.	Number of fish caught.	Gallons of oil made.	Tons of scrap.
1874	64	283	25	2,438	$2,500,000	492,878,000	3,372,847	50,976
1880	79	366	82	3,261	2,550,000	776,000,000	2,035,000	19,195
1890	28	27	52	4,368	1,750,000	553,686,156	2,939,217	21,173
1894	44	30	57	2,560	1,737,000	540,361,900	1,999,505	27,782
1900	25	.....	.....	500	497,760	458,963,200	1,135,264	28,977

"Slaughtering and meat packing" furnishes a large quantity of fertilizer materials, because, in the large packing establishments of the present day nothing utilizable is allowed to go to waste. The blood is carefully collected and dried, making a high-priced ammoniate, and the gelatin, glue, grease, etc., of the horns, hoofs, and other bones and other offal extracted. The residues from this part of the work are sold as bones, tankage (which is meat offal dried and ground), and as "bone tankage" (which is tankage containing bone fragments). Dried blood, tankage, and all of the like materials, which are called "ammoniates," are valuable by-products of the packing industry, and are the most expensive constituents of a complete fertilizer.

The final aggregate of the reported amounts and values of the fertilizer products for 1900 from all sources so far as found, superphosphate and other products made but consumed in the works in the making of mixed fertilizers not being included, is as follows:

FERTILIZER PRODUCTS: KINDS, QUANTITY, AND VALUE, 1900.

	Number of establishments.	SUPERPHOSPHATE.		AMMONIATED SUPERPHOSPHATE.		COMPLETE FERTILIZER.		ALL OTHER FERTILIZERS.	
		Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
Class A	422	923,198	$8,471,943	142,898	$2,449,388	1,436,682	$25,446,046	291,917	$4,178,284
Under $500	18	.....	.....	.....	.....	46	1,047	213	5,489
Class B	10	1,810	20,417	.....	.....	17,707	350,077	7,983	98,510
Class C	28	12,000	100,000	750	13,500	24,391	521,825	27,409	443,147
Total	478	937,008	8,592,360	143,648	2,462,888	1,478,826	26,318,995	327,522	4,723,430
Class D	.....	.....	.....	.....	.....	.....	.....	204,713	3,913,709
Final total	478	937,008	8,592,360	143,648	2,462,888	1,478,826	26,318,995	532,235	8,637,139

The total product, by classes, is as follows:

	Tons.	Value.
Class A	2,794,695	$40,545,661
Under $500	259	4,536
Class B	27,500	469,004
Class C	64,550	1,078,472
Total	2,887,004	42,097,673
Class D	204,713	3,913,709
Final total	3,091,717	46,011,382

The total number of establishments in Classes A, B, and C, the only ones which can properly be denominated fertilizer works, is 476. This shows a considerable increase—392—over the figures for the census of 1890 but falls short of the estimates for 1898 made by the author of "The Fertilizer Industry."[1] The estimated number given by him, is "about 700." It is evident that this figure was too high, because while the business, as a whole, has much increased, the tendency, as in all other branches of manufacture, is to concentrate the industry into the hands of larger companies or combinations, who by reason of greater facilites in, and control of, the market can, if necessary, undersell competitors and work on a closer margin of profit. The author of the interesting bulletin just noted complains of the indifference, even "positive unwillingness of manufacturers to furnish the information desired." The experience of the Census Office with this group has been much more satisfactory. With but one exception, every establishment that was reached, either by the field force or by correspondence, endeavored to give a correct statement of the operations. From the large combinations and firms, reports were often received which were most valuable, and offers of any further information which might be needed. In other cases the reports, owing to the deficiencies of a hastily assembled field force were sometimes unsatisfactory, but correspondence brought the information, if existing. In the case of the positive refusal above mentioned, a little local inquiry enabled us to construct a satisfactory report, because the nature, quantity, and value of the product of the establishment were known, and from correct reports from establishments in the vicinity the quantities of ingredients and their cost could be fairly estimated. Such editing work must be done with great caution if the results are to have real value, and it is satisfactory to be able to state that, owing to the cheerful cooperation of manufacturers, such work has been reduced to a minimum.

"Fertilizers" appears as a special item for the first time in the census report for 1860. The condition of the industry then and its growth since are shown by the following comparison, the percentage of gain for each decade over the preceding one being also given:

[1] Miscellaneous Bulletin No. 13, United States Department of Agriculture, 1898, page 5.

FERTILIZER MANUFACTURE, BY DECADES: 1860 TO 1900.

YEAR.	Number of establishments.	Per cent of increase.	Product (tons).	Per cent of increase.	Value.	Per cent of increase.
1860	47	.....	.....	.....	$891,344	.....
1870	126	168	.....	.....	5,815,118	552
1880	278	120	727,453	.....	19,921,400	242
1890	392	41	1,898,806	161	35,519,841	78
1900	478	21	2,887,004	52	41,997,673	18

These figures are fairly in accordance with what is otherwise known of the history of the development of this industry. Of the 422 establishments in Class A only 7 stated that they manufactured fertilizers prior to 1860, 3 of these being in Baltimore, Md., where, so far as is known, the manufacture of fertilizers began. In 1840 Liebig published his classical researches on plant nutrition, in which he asserted that "the food of all vegetation is composed of inorganic or mineral substances." This was contrary to the then prevailing view, which was that the humus of the soil was the support of plant life, the mineral substances, the ash of the plant, being considered of subordinate importance. The researches of Wiegman and Polstorf showed, however, that a luxuriant plant growth could be obtained by planting the seeds in soil which had, by burning, been deprived of the last trace of humus or other organic matter, and then watering them with dilute solutions of the needed inorganic salts. Other investigators continued this line of research, and a rational agriculture was then developed. It was found that a plant derives its carbon from the air directly by means of its leaves, and also, but in a minor degree, through its roots by the absorption of water containing carbonic acid. On the other hand, while the plant can to a small extent supply its demand for nitrogen from the ammonia of the atmosphere by means of its leaves, this supply is quite inadequate for healthy growth. The deficiency, as also the demand for mineral salts, must be supplied through the roots. As these can only take up such substances when dissolved in water, it follows that not only the nitrogen which is taken up by the plant must be in soluble forms which are now considered to be nitrates, which are always soluble, but also the mineral constituents such as phosphoric acid, silica, lime, potash, iron, etc., must be in forms soluble in water to be available for the nourishment of the plant.

The importance of phosphoric acid being early recognized, the manufacture of superphosphate began. According to Kerl the first scientifically planned fertilizer works in Germany were erected in 1850. A letter from Dr. R. W. L. Rasin, of Baltimore, states that—

The manufacture of chemical fertilizers in the United States began about 1850. In that year Dr. P. S. Chappell, and Mr. William Davison, of Baltimore, made some fertilizer in an experimental way. About the same time Professor Mapes was experimenting. Later De Burg utilized the spent bone black derived from the sugar refineries and made quite a quantity of "dissolved bone black"

(superphosphate). In 1853 or 1854 Mr. P. S. Chappell commenced the manufacture of fertilizers, as did B. M. Rhodes, both of Baltimore. In 1855 Mr. John Kettlewell, recognizing the fact that Peruvian guano (then becoming quite popular), and containing at that time 18 to 21 per cent of ammonia, was too stimulating and deficient in plant food (phosphates), conceived the idea of manipulating the Mexican guano, containing no ammonia but 50 to 60 per cent of (bone) phosphate of lime, and called his preparation "Kettlewell's manipulated guano."

While in 1856 the sales of Peruvian guano had increased to 50,000 tons and of Mexican guano to some 10,000 tons, there was not at that date 20,000 tons of artificial fertilizers manufactured in the entire country. Baltimore was not only the pioneer but the principal market for fertilizers until some time after the Civil War. The 50,000 tons of Peruvian guano referred to was bought and sold in this market, and there was little demand for that or the Mexican guano in any other market unless the inspection brand of the guano inspector of Baltimore was upon the package. The Peruvian Government agent, who received and disposed of all importations, was located here, and all other markets were supplied from Baltimore. At that time no fertilizers were sold west of Pennsylvania.

Owing to the exhaustion of the sources of supply the importation of guano has almost ceased. In 1900 but 1,150 tons, value $15,543, were imported from Peru, the total amount of guano imported being 4,756 tons, value $56,956. Much of this is, however, practically phosphate rock, requiring chemical treatment before using. The original guano of Peru was produced from the excrements and remains of sea birds deposited upon islands in a very arid region. Its agricultural value was well known to the ancient Peruvians, whose wise laws forbade the killing or molestation of the birds. Owing to the scarcity of rain the ammoniacal salts developed in the deposits remained in the guano, while in less arid regions the soluble salts were leached out, and where the underlying rock was a limestone this became altered to a certain depth, becoming a more or less pure tricalcic phosphate, usually called bone phosphate of lime. The guanos of Sombrero, of Navassa, and of many other places are examples, and all require chemical treatment.

The importation of phosphate rock for 1900 amounted to 110,065 tons, value $504,092, coming mainly from Germany and Spain. The term "phosphorite" is used to cover all of the varieties of phosphate rock which range from the crystallized apatite of Canada to the comparatively amorphous rock of South Carolina, but was originally applied to the fibrous phosphate from Estremadura, Spain, which occurs in large quantities and is extensively exported. The German phosphate from the Lahn region and other places is usually concretionary in appearance. This concretionary structure is very characteristic of phosphorites, as shown in many places in Florida and in the so-called coprolites of England and other localities.

By treating phosphate rock or bones with sulphuric acid, superphosphate or acid phosphate is formed. The works making this, mix more or less of it with ammoniates, or potash or both, producing the various grades of ammoniated superphosphate, superphosphates with potash, or complete fertilizer. The remainder is sold as such, being bought by establishments that make various mixtures to suit local demands, while a very large quantity goes directly into consumption, being bought by farmers, who make their own composts.

Of the 422 fertilizer works belonging to Class A, 76 made sulphuric acid. The total quantity of acid thus made amounted to 642,938 tons of chamber acid of 50° Baumé, of which 571,831 tons were consumed by the works producing it in making superphosphates, while the remainder, 71,107 tons, was sold elsewhere mainly as chamber acid, only 5,360 tons being concentrated to higher strengths before sale. Thirty acid-making works did not make enough for their own demand and supplied the deficiency from other sources. In Classes B and C, 3 works made 12,028 tons of 50° acid and consumed it in making superphosphate, making a total of 583,859 tons thus made and consumed by 79 works.

Of the 478 works producing fertilizers, 76 made superphosphate, but purchased the needed acid, while 208 bought the superphosphate; in each case the final product sold was mixed fertilizers. The remaining works, 115 in number, as well as all of Class D, produced the fertilizer materials above mentioned and placed under "all other fertilizers." In so far as any of these products are purchased by other fertilizer works and used in making mixed fertilizers, the quantities and values of such purchases reappear in the mixed fertilizers, and to that extent there is a duplication. The extent of this duplication can only be estimated, since a considerable quantity of the products included in "all other fertilizers" consists of bone meal and other substances, which are used for composting or put on the land without further treatment. On the other hand, it is certain that "all other fertilizers"—tons 532,235, value $8,637,139—falls far short, both in quantity and value, of the real production of such materials. For example, the establishments under Class A report using 37,868 tons of cottonseed meal, and those in Class C, 3,608 tons, a total of 41,476 tons. These figures evidently represent only a fraction of the amounts actually used for fertilizer purposes, since the total product of cotton seed meal for 1900 was 884,391 tons, value $16,030,576, a very large proportion of which, amounting to 638,638 tons, was used in composting, as shown by the large quantity of superphosphate which goes into consumption as such.

The figures for superphosphate, ammoniated superphosphate, and complete fertilizer are quite close to the truth, as an examination of the complete returns will show. The total quantity of superphosphates reported as made and sold as such by all of the classes A, B, and C is 937,008 tons. The quantity of superphosphate purchased for mixing purposes is, for Class A, 286,918 tons; Class B, 240 tons; Class C, 9,402 tons; a total of 296,560 tons. Deducting this from the total, 937,008 tons, leaves the residue of 640,448 tons which was sold as such to

the ultimate consumer. To this amount must be added the superphosphate in the mixed fertilizers to obtain the total quantity produced for the census year. The returns show great variations in the proportions of superphosphate in the products of the various establishments, but comparisons show that ammoniated superphosphate will average 70 per cent of superphosphate and complete fertilizer 50 per cent, giving the following result:

Superphosphate, sold as such, total tons	937,008
Superphosphate, purchased, total tons	296,560
Difference, equals finally consumed as such, tons	640,448
In ammoniated superphosphate, 70 per cent of 143,648 tons	100,553
In complete fertilizer, 50 per cent of 1,478,826 tons	739,413
Total superphosphate produced, tons	1,480,414

The total product of superphosphate may also be ascertained from the amount of sulphuric acid reported as being used in its manufacture. Comparison of the returns at the census of 1900 fully confirms the current statement that in making superphosphate from a standard phosphate such as South Carolina rock the practice is to mix equal weights of phosphate and chamber acid. Reaction at once sets in, the mixture becoming quite hot and giving off vapors consisting of steam and volatile ingredients of the phosphate, such as carbon dioxide, fluorine, and chlorine. This volatilization loss amounts, for South Carolina rock, to 10 per cent of the total weight of the ingredients. Other phosphates, such as high-grade Florida rock, bones, etc., will of course require other proportions of acid and the volatilization loss will also differ, but the general average of all returns shows that every ton, 2,000 pounds, of phosphatic material required 2,000 pounds of chamber acid, lost 10 per cent, 400 pounds, by volatilization, and yielded 3,600 pounds of superphosphate. Taking all of the sulphuric acid reported as consumed in works and that purchased the results are as follows:

	SULPHURIC ACID.	
	Consumed (tons).	Purchased (tons).
Class A	571,831	231,528
Class B	5,028	268
Class C	7,000	200
Total	583,859	231,996
Add total, consumed		583,859
Total acid used		815,855
Add phosphate rock, equal amount		815,855
		1,631,710
Deduct 10 per cent loss		163,171
Total superphosphate produced, tons		1,468,539

Comparing the final quantity with that reported above, namely, 1,480,414 tons, the difference is found to be only 11,875 tons, or 0.80 per cent. This agreement is surprisingly close, since, under the conditions, a much larger difference would have been sufficient to demonstrate the general correctness of the returns.

The quantity of phosphate rock estimated above as used is 815,855 tons. Class A reported the purchase of 787,927 tons; Class B, 4,810 tons, and Class C, 7,700 tons; a total of 800,437 tons, or a difference of only 15,428 tons. This close agreement is, however, only fortuitous. Many of the larger works undoubtedly had more or less phosphate rock in stock at the beginning and end of the census year, and it is not always clear that the quantity reported is the amount actually used or only that which was purchased during the year. A part of the superphosphate estimated above as contained in the mixed fertilizers was made from bones, spent boneblack, and other materials, but how much can not be ascertained, because, although Class A reported the consumption of 96,679 tons of bones, part of this was used to make boneblack, part was disposed of as bone meal, and part mixed with the compounded fertilizers without any special addition of acid. Again, part of the tankage bought by the works is "bone tankage," containing considerable quantities of crushed bone, so that it is impossible to determine how much of the acid used actually went to make bone superphosphate.

Examination of the reports shows that only a comparatively small quantity of "concentrated phosphate" is made, although it would seem that there ought to be a considerable demand for this product which is so largely made in England, France, and Germany. It is made by treating phosphate rock with an amount of sulphuric acid sufficient to entirely decompose it, converting all of the lime into sulphate, allowing this to settle, and drawing off the solution of phosphoric acid. "The solution is then evaporated in lead pans to a density of 45° Baumé, at which strength the solution contains nearly 45 per cent P_2O_5. During this concentration the iron and aluminum phosphates separate and are removed. The strong solution of phosphoric acid is then treated with finely ground phosphate rock to form mono-calcium phosphate, which is dried and disintegrated."[1]

The phosphoric acid solution may be made from any form of phosphate, and low-grade material too poor for the manufacture of superphosphate can be used for this purpose. The phosphate rock added in the second stage of the process should, however, be high grade, if the best results are to be attained. For this reason, the Florida rock which contains up to 80 per cent or more of phosphate is mainly shipped abroad to supply the foreign demand for this purpose, while our own manufacturers, making only ordinary superphosphate, mainly use South Carolina rock containing about 60 per cent phosphate. The manufacture of superphosphate from South Carolina rock is a much simpler process and

[1] Thorp, Outline of Industrial Chemistry, page 144; 1898.

the product is a satisfactory one, although its contents in soluble phosphoric acid is low, ranging from 20 to 24 per cent as compared with concentrated phosphate or "double super," which may contain up to 47 per cent.

The further development of this industry in this country will depend upon transportation conditions as well as upon the advance of agricultural knowledge, but it would seem that there is a field for this work in the phosphate regions where much poor rock occurs for which there is no present demand, but which might be utilized in the local manufacture of "double super."

The use of tetrabasic phosphate, or slag phosphate, appears to have almost completely ceased in the United States, while its use is continually extending in Europe. The reasons assigned for this situation need not be given here, but doubtless in time this valuable material will assume the importance it deserves.

The following table shows the total fertilizer product of the United States, arranged geographically:

FERTILIZERS, PRODUCTS, BY STATES,

	STATES.	Number of establishments.	TOTAL.		SUPERPHOSPHATE.				
			Tons.	Value.	Tons.	Value.	Per cent of product.	Per cent of value.	Value per ton.
1	United States	478	2,887,004	$42,097,673	937,008	$8,592,360	32.5	20.4	$9.17
2	North Atlantic division	155	685,893	11,978,666	139,232	1,316,208	20.3	11.0	9.45
3	Maine	3	1,828	27,902	.....	.....	.....	.....	.....
4	Massachusetts	10	83,733	2,108,575	1,282	12,820	1.5	0.6	10.00
5	Connecticut	9	11,077	313,610	.....	.....	.....	.....	.....
6	New York	37	164,266	2,610,435	9,810	105,645	6.0	4.0	10.77
7	New Jersey	30	247,144	3,820,189	105,165	887,470	42.6	23.2	8.44
8	Pennsylvania	66	177,845	3,097,955	22,975	310,273	12.9	10.0	13.59
9	South Atlantic division	198	1,531,688	19,462,816	622,614	5,302,997	40.6	27.3	8.52
10	Delaware	11	49,942	634,213	2,385	28,250	4.8	4.4	11.84
11	Maryland	42	386,133	5,213,925	124,696	1,178,367	32.3	22.6	9.45
12	District of Columbia	7	3,859	76,480	.....	.....	.....	.....	.....
13	Virginia	42	258,474	3,325,542	120,633	1,024,893	46.7	30.8	8.49
14	North Carolina	20	139,582	1,727,270	60,820	497,397	43.6	28.8	8.17
15	South Carolina	24	388,572	4,657,275	173,183	1,404,569	44.6	30.1	8.12
16	Georgia	45	278,982	3,331,469	131,503	1,075,581	47.2	32.3	8.17
17	Florida	7	26,144	496,642	9,394	93,940	35.9	18.9	10.00
18	North Central division	63	258,726	4,349,157	62,945	814,300	24.3	18.7	12.93
19	Ohio	28	103,814	1,562,638	24,728	285,698	23.8	18.3	11.55
20	Illinois	12	104,120	1,842,300	26,108	313,850	25.1	17.0	12.02
21	Indiana	16	11,668	238,161	365	10,006	3.1	4.2	27.41
22	Missouri	4	8,753	156,115	2,766	44,248	31.6	28.3	16.00
23	Kansas	3	30,371	549,943	8,978	160,498	29.6	29.2	17.11
24	South Central division	39	352,778	5,053,564	110,649	1,140,376	31.4	22.6	10.30
25	Kentucky	4	17,315	295,520	.....	.....	.....	.....	.....
26	Tennessee	5	93,054	1,464,788	35,959	456,568	38.7	31.2	12.70
27	Alabama	21	139,282	1,944,283	38,246	369,587	27.5	19.0	9.70
28	Mississippi	3	37,704	492,772	7,200	50,400	19.1	10.2	7.00
29	Louisiana	6	65,423	856,201	29,244	263,821	44.7	30.8	9.00
30	Western division	9	22,131	636,687	.....	.....	.....	.....	.....
31	California	9	22,131	636,687	.....	.....	.....	.....	.....
32	All other states[1]	14	35,788	616,783	1,568	18,479	4.4	3.0	11.80

[1] Includes establishments distributed as follows: Iowa, 1; Michigan, 1; Minnesota, 1; Nebraska, 1; Oregon, 1; Rhode Island, 1; Texas, 2; Washington, 1; West Virginia, 2.

ARRANGED GEOGRAPHICALLY: 1900.

AMMONIATED SUPERPHOSPHATE.					COMPLETE FERTILIZERS.					ALL OTHER FERTILIZERS.					
Tons.	Value.	Per cent of product.	Per cent of value.	Value per ton.	Tons.	Value.	Per cent of product.	Per cent of value.	Value per ton.	Tons.	Value.	Per cent of product.	Per cent of value.	Value per ton.	
143,648	$2,462,888	5.0	5.9	$17.14	1,478,826	$26,318,995	51.2	62.5	$17.79	327,522	$4,723,430	11.3	11.2	$14.42	1
21,429	574,251	3.1	4.8	26.79	431,521	8,899,584	62.9	74.3	20.62	93,711	1,188,623	13.7	9.9	12.68	2
.....	.....	.....	.....	.....	828	21,602	45.3	77.4	26.09	1,000	6,300	54.7	22.6	6.30	3
.....	.....	.....	.....	.....	78,171	1,988,605	93.4	94.3	25.44	4,280	107,150	5.1	5.1	25.03	4
1,000	23,000	9.0	7.3	23.00	7,325	205,931	66.1	65.7	28.11	2,752	84,679	24.9	27.0	30.84	5
10,300	338,400	6.3	13.0	32.85	87,862	1,623,638	53.5	62.2	18.48	56,294	542,752	34.2	20.8	9.64	6
7,283	159,580	2.9	4.2	21.91	125,839	2,629,511	50.9	68.8	20.90	8,857	143,628	3.6	3.8	16.22	7
2,846	53,271	1.6	1.7	18.71	131,496	2,430,297	78.9	78.5	18.48	20,528	304,114	11.6	9.8	14.81	8
71,661	1,056,542	4.7	5.4	14.74	701,361	11,307,083	45.8	58.1	16.26	136,052	1,796,194	8.9	9.2	13.20	9
.....	.....	.....	.....	.....	17,180	283,873	34.4	44.8	16.52	30,377	322,090	60.8	50.8	10.61	10
48,608	690,671	12.6	13.2	14.21	184,095	2,985,015	47.7	57.3	16.21	28,734	359,872	7.4	6.9	12.52	11
.....	.....	.....	.....	.....	3,410	69,800	88.4	91.3	20.47	449	6,680	11.6	8.7	14.87	12
4,300	72,100	1.7	2.2	16.72	106,828	1,820,771	41.3	54.7	17.41	26,713	407,778	10.3	12.3	15.26	13
3,400	51,000	2.4	3.0	15.00	61,017	981,569	43.7	56.8	16.08	14,345	197,304	10.3	11.4	13.75	14
.....	.....	.....	.....	.....	207,875	3,147,202	53.5	67.6	15.14	7,514	105,504	1.9	2.3	14.04	15
15,353	242,771	5.5	7.3	15.81	105,521	1,641,318	37.8	49.3	15.55	26,605	371,799	9.5	11.1	13.98	16
.....	.....	.....	.....	.....	15,435	377,535	59.1	76.0	24.46	1,315	25,167	5.0	5.1	19.13	17
34,840	565,281	13.5	13.0	16.22	105,358	1,891,260	40.7	43.5	17.95	55,583	1,078,316	21.5	24.8	19.40	18
23,805	380,936	22.9	24.4	16.00	43,351	700,606	41.8	44.8	16.21	11,930	195,398	11.5	12.5	16.39	19
4,150	58,100	4.0	3.2	14.00	43,483	835,385	41.7	45.3	19.21	30,379	635,015	29.2	34.5	20.90	20
27	500	0.2	0.2	14.81	5,750	116,280	49.3	48.8	20.22	5,526	111,375	47.4	46.8	20.16	21
.....	.....	.....	.....	.....	2,774	39,039	31.7	25.0	14.07	3,213	72,828	36.7	46.7	22.67	22
6,858	125,745	22.6	22.8	18.33	10,000	200,000	32.9	36.4	20.00	4,535	63,700	14.9	11.6	14.05	23
15,037	256,599	4.2	5.1	17.06	199,609	3,242,648	56.6	64.1	16.75	27,483	413,941	7.8	8.2	15.06	24
.....	.....	.....	.....	.....	17,315	295,520	100.0	100.0	17.07	.....	.....	.....	.....	.....	25
.....	.....	.....	.....	.....	36,695	704,220	39.4	48.1	19.22	20,400	304,000	21.9	20.7	14.90	26
2,000	35,000	1.4	1.8	17.50	92,253	1,433,355	66.2	73.7	15.42	6,783	106,341	4.9	5.5	15.70	27
.....	.....	.....	.....	.....	30,504	442,372	80.9	89.8	14.50	.....	.....	.....	.....	.....	28
13,037	221,599	19.9	25.9	17.00	22,842	367,181	34.9	42.9	16.07	300	3,600	0.5	0.4	12.00	29
.....	.....	.....	.....	.....	19,570	591,187	88.4	92.9	32.08	2,561	45,500	11.6	7.1	17.76	30
.....	.....	.....	.....	.....	19,570	591,187	88.4	92.9	32.08	2,561	45,500	11.6	7.1	17.76	31
681	10,215	1.9	1.6	15.02	21,407	387,233	59.8	62.8	18.08	12,132	200,856	33.9	32.6	16.55	32

The establishments of the above table have been grouped according to the customary census divisions. Of the total product of the United States, 2,887,004 tons, valued at $42,097,673, superphosphate, sold as such, amounted to 32.5 per cent of quantity, and 20.4 per cent of value, the average value per ton being $9.17; ammoniated superphosphate, to 5 per cent quantity, 5.9 per cent value, and $17.14 per ton; complete fertilizer, 51.2 per cent quantity, 62.5 per cent value, and $17.79 per ton; and all other fertilizers, 11.3 per cent quantity, 11.2 per cent value, and $14.42 per ton. It must be remembered that while the quantities given in this table and elsewhere in this report are substantially correct, the values given in the reports are in most cases far below the market prices, since freight and other expenses must be added so that the final price to the consumer is very much higher. Moreover, as already stated, of the 937,008 tons of superphosphate, sold as such, 296,560 tons, or 31.6 per cent, were bought by other works and used for making mixed fertilizers, leaving 640,448 tons, or 68.4 per cent, which went directly into final consumption. At the average value of $9.17 per ton, the 296,560 tons would be worth $2,719,755, and, from one point of view, might be deducted, leaving superphosphate 640,448 tons, valued at $5,872,605, and the total product of the country 2,590,444 tons, valued at $39,377,918. Such a presentation, while possibly nearer the truth as regards ultimate consumption, would, however, be incorrect in a census report of manufactures which deals with capital, labor, materials, and products. The production of the 296,560 tons of superphosphate required capital, labor, and materials, and the figures of these demands are included in the general tables for this industry. The establishments purchasing this material saved the capital and labor required to produce it, so that if the deduction were made from the product, it would be necessary to make a corresponding deduction on the other side, which is plainly impossible.

On examining this table it will be noted that the South Atlantic division leads in quantity and value of product, the North Atlantic division being second. The average fertility of the Atlantic coast states is not high, and rational farming requires the continued application of fertilizer, much of it of high grade. The general status of agriculture in the various states in these two divisions is well shown by the figures. When the size of the average farms is small and most of these devoted to the growth of vegetables, fruit, and such products, as is the case in New England, the fertilizers demanded are high priced, as the requirements of the soil must be carefully studied and supplied if profits are sought. Proceeding southwardly, agriculture is on a larger individual scale and of a simpler character, until, in the cotton states, we find practically only a single market product, requiring a simpler fertilizer, low in price, and to be applied with judgment. Any excess of fertilizer acts injuriously upon the crop by stimulating a growth which can not resist the inevitable drought of the region. Moreover, a too liberally stimulated cotton plant runs to stems and foliage, with but little fruit, as may be seen in plants grown in gardens. For convenience in picking, the cotton plant should not be more than 3 feet high, nor more than an average arm's length to the center, and the bolls should open nearly simultaneously.

When a plant is grown in the rich soil of a garden, as is frequently done, for its beauty, it may reach a height of seven, eight, or more feet, with corresponding diameter, but, while quite beautiful, the yield of cotton is comparatively small, and costly to gather. The possibilities in cotton culture become evident when it is considered that for upland cotton the average yield of lint cotton is from 150 to 250 pounds per acre, while careful cultivation under favorable weather conditions has been known to bring up this yield to 1,000 pounds. Indeed, although a yield of 1,500 pounds has never been attained, it is the goal which many intelligent planters consider can be reached by careful selection of seed, and proper methods of planting, fertilizing, and tending. While it is not feasible, here, to make an extended comparison between the quantities and values of the fertilizers used in the different states in relation to the character of the agriculture and products, such a study will disclose that, while each state can show poor farming, yet in the main, what is done is best suited to local conditions so far as understood. The methods which may enrich a farmer in Massachusetts would impoverish him in South Carolina, while the methods which insure a good cotton crop are quite inapplicable to truck growing.

In comparing the various states it will be noted that South Carolina leads in quantity of product, 388,572 tons, while Maryland leads in value, $5,213,925. In the production of superphosphate, sold as such, South Carolina leads with 173,183 tons, valued at $1,404,569, Georgia being second with 131,503 tons, and Maryland third with 124,696 tons. The Maryland product is, however, valued at $1,178,367, thus exceeding the Georgia valuation of $1,075,581. In the proportion of such superphosphate to the total production of the state, Georgia is first as it disposes of 47.1 per cent of its total product in this form, and is followed by Virginia, Louisiana, South Carolina, North Carolina, New Jersey, and Maryland, in the order given. This large sale of superphosphate in these states is due to the numerous manipulators who mix special brands for local consumption, and also to the demands of farmers for home composting. This latter kind of work is naturally most frequent in the cotton states where the cottonseed and cottonseed cake furnish a large local supply of ammoniates, while the extensive truck farming of New Jersey and Maryland causes a similar demand.

The value of the superphosphate per ton ranged from

$7 in Mississippi to $27.41 in Indiana. The Mississippi valuation is very low, the average for the United States, $9.17, being about the price for superphosphate made from rock. The high value of this product in Indiana and other states of the North Central division is due to its having been made from raw bone and being practically an ammoniated superphosphate. Indeed, this value is higher than that given by any state for its product of "ammoniated super," with the exception of New York, which rates this product at $32.85, the average for the United States being only $17.14. In the production of "ammoniated super," Maryland leads all of the states, with a production of 48,608 tons, valued at $690,671, which is, however, only $14.21 per ton.

In the production of complete fertilizer South Carolina leads both in quantity and value, producing 207,875 tons, valued at $3,147,202, but the value per ton is low, $15.14. Leaving out California, the high valuation of whose fertilizer, $32.08, is due to the high cost of materials, it is found that the North Atlantic division, especially the New England states, makes the most expensive complete fertilizers. Connecticut leads with $28.11 average value per ton, followed by Maine with $26.09, and Massachusetts with $25.44. The Maryland product, next in quantity and value to South Carolina, being 184,095 tons, valued at $2,985,015, is quoted at only $16.21 per ton.

"All other fertilizers" amounts, for the United States, to 327,522 tons, valued at $4,723,430, being 11.3 per cent of the total product, 11.2 per cent of the total value, and averaging $14.42 per ton. As might be expected, New York leads in quantity, with a production of 56,294 tons, of an average value of $9.64 per ton. This low value shows the nature of the product, which is mainly garbage tankage, made by the garbage-reduction works near the large cities. Illinois, next in tonnage, 30,379 tons, is first in value, $635,015, or $20.90 per ton, while Missouri gives a value of $22.67 per ton; the reason in both cases being that the product is largely made from slaughterhouse offal, which yields high-grade products. The "fertilizers" of Class D, 204,713 tons, valued at $3,913,709, show an average value of $19.12 per ton, and belong to this category.

So far as it is possible to show the capital employed, also the labor and other elements of cost in the production of fertilizers, the statistics are given in the special tabulation of Class A for this industry. It is, however, not possible to do this for the other classes, since fertilizers form only a subordinate part of the product, and the capital employed and the costs can not be separated from the general operations of the works.

The importations of fertilizer materials for the census years 1890 and 1900, as given by the United States Treasury Department in "The Foreign Commerce and Navigation of the United States," 1890, pages 1150 to 1151; 1900, page 102, is as follows:

IMPORTS FOR IMMEDIATE CONSUMPTION FOR THE YEARS ENDING JUNE 30, 1890 AND 1900.

YEAR.	PHOSPHATES, CRUDE OR NATIVE.		KIESERITE, KYANITE OR CYANITE, AND KAINITE.		GUANO.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1890	31,179	$309,764	62,871	$422,225	8,432	$111,811
1900	14,075	86,763	133,244	762,493	4,765	58,474

YEAR.	BONE DUST OR ANIMAL CARBON AND BONE ASH, FIT ONLY FOR FERTILIZING PURPOSES.		APATITE.		ALL OTHER SUBSTANCES NOT ELSEWHERE SPECIFIED.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1890	3,219	$59,059	126	$1,297	21,277	$333,109
1900	1,968	30,189	333	4,019	99,169	745,724

The literature of the fertilizer industry is very voluminous, and it is difficult to make a selection. The books giving the most useful information are probably The Phosphates of America, by Francis Wyatt, Scientific Publishing Company; Principles and Practice of Agricultural Analysis, Vol. II, Fertilizers, H. W. Wiley, Chemical Publishing Company, 1895; and the articles on Fertilizers in Muspratt—Kerl, Technical Chemistry, Wagner's Technology, and The Mineral Industry, the yearbook published by the Engineering and Mining Journal.

Group IX.—Bleaching Materials.

Although bleaching materials of various kinds have been long in use and bleaching by chlorine or hypochlorites has been in vogue since the latter part of the eighteenth century, no separate returns have been secured for this industry at any previous census. Chlorine production has practically been, until recently, incidental to the manufacture of soda by the Le Blanc process, and as this process has not secured a foothold in the United States, the production of chlorine bleaches has heretofore undoubtedly been insignificant in quantity and value. As pointed out in the treatment of Group X, with the introduction of electricity as an agent in effecting chemical transformations, common salt and other chlorides are being electrolyzed on a commercial scale with the result that the production of chlorine and hypochlorites is assuming importance. The chlorine thus produced is converted into bleaching powder by means of lime, but other hypochlorites, and notably sodium hypochlorite, are made from imported bleaching powder. In addition there are produced and used in bleaching, disinfection, or as a preservative, hydrogen dioxide, sodium dioxide, sulphurous acid, sodium, calcium, and potassium bisulphites, and many special compositions.

In considering this industry in its entirety there must be discussed, not only those bodies specifically reported

as bleaching materials produced by the older processes, but also such bleaching agents as have been produced by the aid of electricity, or sent out for use in the compound or liquefied state, and also those which are the subordinate products of establishments whose principal products classify them with other industries. Combining these there were 26 establishments in 7 states, producing 26,794,338 pounds of material having a value of $592,658, and employing a capital of $672,969 and 216 wage-earners. These establishments were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF FACTORIES PRODUCING BLEACHING MATERIAL: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Product.	Per cent of total.
United States	26	216	$672,969	$592,658	100.0
New York	10	126	529,746	407,327	68.7
Pennsylvania	6	4	25,853	15,878	2.7
New Jersey	3	10	14,500	39,171	6.6
Illinois	3	12	15,039	42,399	7.2
Missouri, Michigan, and Ohio	4	64	87,831	87,883	14.8

Among the principal products were 10,979 tons of hypochlorites of a value of $462,949; 588,335 pounds of hydrogen dioxide of a value of $63,754; 350,585 pounds of sulphur dioxide of a value of $4,826, and 1,461 tons of bisulphites of a value of $34,486. There were consumed in this manufacture 15,000 tons of salt brine, equivalent to 1,574 tons of salt, or, together with the other salt consumed, 9,055 tons of salt of a value of $19,105; 158,561 bushels of lime of a value of $20,532; 168 tons of caustic soda of a value of $7,618; 92,600 pounds of metallic sodium; 93,000 pounds of black oxide of manganese of a value of $1,325; 227 tons of muriatic acid of a value of $4,325; 974 tons of soda ash of a value of $23,368; 7 tons of potash of a value of $420; 171 tons of sulphur of a value of $4,000; 74 tons of barium dioxide of a value of $16,540; 74,490 pounds of phosphoric acid of a value of $14,898; and 44 tons of bleaching powder of a value of $1,570.

Sulphur Dioxide (sulphurous acid gas; sulphurous anhydride; SO_2).—This substance has been used as a bleaching agent from ancient times. It results from the burning of sulphur or sulphur-containing bodies in air or oxygen. In the presence of water it bleaches wool, hair, straw, and other tissues; but the bleaching is not permanent. Sulphur dioxide is used also as a disinfectant and germicide; in ice machines as a refrigerating agent; in the preparation of bisulphites; to a small extent in the leather and glucose industries; and as the first product in the manufacture of sulphuric acid. Next to its use in making sulphuric acid, the largest consumption of sulphur dioxide is undoubtedly in the sulphite process for converting wood into wood pulp for the purpose of making paper. As it is made and consumed in the works no returns are available to determine how much of the gas is produced in this industry.

Bisulphites.—There is returned as having been manufactured during the census year bisulphites of sodium, calcium, and potassium. They are manufactured by saturating a solution of sodium carbonate, milk of lime, or potassium carbonate with sulphur dioxide and crystallizing out the salt formed. Or the solution may be used as made. These bodies are employed as antichlors in bleaching to remove the excess of chlorine from the fibers of the goods which have been bleached by hypochlorites, and thus prevent this chlorine from rotting the fiber. They are thus used to treat wood pulp in paper making, and it is probable that much of the material used in this art is not included here. The bisulphites are also employed in chrome tannage, in brewing, in glucose and starch making, and as preservatives.

Hydrogen Dioxide (hydrogen peroxide, H_2O_2).—Hydrogen dioxide is made by treating barium dioxide, or sodium dioxide in suspension or solution in water, with a dilute acid, and keeping the temperature at a low point by means of ice. Hydrochloric, hydrofluoric, sulphuric, nitric, or even carbonic acid may be employed. The hydrogen dioxide is set free as a gas, which dissolves in the water present. This solution is decanted off or filtered, phosphoric acid is added to it, and it is diluted, if necessary, so as to contain 3 per cent of H_2O_2, when it is sent into commerce, and is then known as a 10-volume solution. Hydrogen dioxide is a powerful oxidizing agent, and it is used in bleaching hair, silk, wool, feathers, bone, and ivory. It has been quite extensively used for toilet purposes; also as an antiseptic and disinfectant in surgery; as an antichlor; as a reducing agent in chrome tannage; and as a preservative for milk, beer, wine, and other fermentable liquids. The Oakland Chemical Company began the manufacture of hydrogen peroxide in Brooklyn, N. Y., in 1881.

Sodium Dioxide (sodium peroxide, Na_2O_2).—Sodium dioxide is made by heating metallic sodium in aluminum trays, in a specially contrived furnace, to 300° C. while purified air is being passed over it. It is a yellowish white very hygroscopic powder, and is chiefly used as a bleaching agent, being a very powerful one, as it gives off 20 per cent of its weight of active oxygen. Its solution is too strongly alkaline for silk or wool bleaching, and for this purpose it should be converted into magnesium dioxide, which is easily effected by adding a solution of magnesium sulphate to the solution of sodium peroxide.

Hypochlorites.—There have been returns made for bleaching powder (which, according to Lunge, is a compound containing in the same molecule calcium attached to chlorine and to a hypochlorous acid residue) and sodium hypochlorite. The bleaching powder is made by passing chlorine gas into absorption chambers so as to come into contact with lime which has been so slaked

as to contain from 24.5 to 25.5 per cent of water. The lime is exposed to the action of the gas until the test shows that the product contains from 36 to 37 per cent of available chlorine. The yield from 100 pounds of good lime is 150 pounds of bleaching powder. Bleaching powder is but partly soluble in water and when treated with water forms a milk-like fluid. It is an efficient bleaching, deodorizing, and disinfecting agent. To liberate the chlorine for bleaching purposes, an acid should be employed. The carbon dioxide of the atmosphere will effect this result, but in practice a dilute mineral acid is usually employed, the cloth first being saturated in the bath of bleaching-powder emulsion, called the "chemic," and then in the bath of dilute acid, called the "sour." Bleaching liquors may be made by passing chlorine gas into the milk of lime, and it was in this form that it was first used.

The emulsion of bleaching powder reacts with magnesium sulphate to form magnesium hypochlorite, with alum to form aluminum hypochlorite, with zinc sulphate to form zinc hypochlorite, and with sodium carbonate to form sodium hypochlorite. They are all efficient bleaching agents and are especially desirable because they are completely soluble in water. Potassium hypochlorite and sodium hypochlorite have been sold under the respective names of Eau de Javelle and Eau de Labarraque, they having been prepared by passing chlorine gas through a solution of potassium carbonate for the first, and sodium carbonate for the second. Sodium hypochlorite is still used for domestic purposes in removing spots from linen and also, together with oxalic acid, as an ink eradicator.

Bleaching by chlorine was first suggested and applied by Berthollet in 1785, and its adoption revolutionized the textile industry. He employed solutions of chlorine gas in water, but Tennant in 1798 patented a liquid bleach consisting of a solution of calcium or sodium hypochlorite prepared by passing the gas into milk of lime or a solution of caustic soda. This liquid bleach is difficult to transport and keep, and Tennant introduced a marked improvement by the invention of bleaching powder in 1799. Bleaching powder was made in this country at Bridesburg, Pa., by Charles Lennig in 1847. The Mathieson Alkali Works, at Niagara Falls, N. Y., and the Dow Chemical Company, of Midland, Mich., began the manufacture of bleaching powder from electrolytic chlorine in 1898.

Bleaching powder is still imported in very large quantities. The extent is shown in the following table, compiled from Volume II of the Foreign Commerce and Navigation of the United States for the years ending June 30, 1891 to 1900:

IMPORTS OF LIME, CHLORIDE OF, OR BLEACHING POWDER: 1891 TO 1900, INCLUSIVE.

YEAR.	Pounds.	Value.	YEAR.	Pounds.	Value.
1891	107,475,715	$1,429,509	1896	104,053,877	$1,579,358
1892	110,748,289	1,839,640	1897	99,274,138	1,375,560
1893	120,811,918	2,213,121	1898	114,232,578	1,421,920
1894	81,610,463	1,507,076	1899	113,107,250	1,159,271
1895	100,456,774	1,644,835	1900	136,403,151	1,464,019

LITERATURE.

Die Bleichmittel, Beizen und Farbstoffe, by J. Herzfeld, Volume I: Berlin; 1889.

Pharmacopœia of the United States. 1890.

The Chemistry of Paper Making, by R. B. Griffin and A. D. Little: New York, 1894.

A Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali, by George Lunge, Volume III: London, 1896.

Bleaching and Calico Printing, by George Duerr: London, 1896.

Outlines of Industrial Chemistry, by Frank Hall Thorp: New York, 1898.

Practical Treatise on the Bleaching of Linen and Cotton Yarn and Fabrics, by L. Tailfer: London, 1901.

Group X.—Chemical Substances Produced by the Aid of Electricity.

In no prior census has any mention been made of this art. As a fact, as shown in the historical account which follows, this industry has practically been developed since the census of 1890 was taken. Nevertheless, it has already grown to such magnitude in these ten years as to effect serious inroads on the older processes, and it will undoubtedly in the future assume a greater importance. Already it is found that sodium and other metals, caustic soda, bleaching powder and other bleaching agents, bromine and potassium bromide, potassium chlorate, litharge, graphite, calcium carbide, carborundum, carbon disulphide, and phosphorus are reported as being produced on a commercial scale, the total value of the output for 1900 being reported at $2,045,535. It is particularly to be noted that the Le Blanc soda process, which has for a century been a standard process for chemical manufacture, is now endangered not only by the Solvay ammonia process, but that the last prop on which it relied for profit has been thrown down by the development of economic methods for the electrolytic production of bleaching powder. It is to be regretted that statistics of the electrical energy efficiency, and other data which are essential to a full understanding of this art are not at present accessible. But it can be stated that, apart from works producing aluminum (which is not included in the chemical industries), there are 14 establishments in the United States belonging in Group X, and that these employ $9,173,060 of capital and 739 wage-earners. These establishments were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF ELECTRO-CHEMICAL FACTORIES: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Value of products.	Per cent of total.
United States	14	739	$9,173,060	$2,045,535	100.0
New York	10	614	8,311,538	1,836,606	89.8
Maine, Michigan, Connecticut, and New Hampshire	4	125	861,522	208,929	10.2

It is to be observed that the total value of the product given here differs from that given in the tabulation

of "Chemicals" under the legend "Electro-chemicals," because caustic soda is classed with Group II, bleaching powder with Group IX, and the like; while there is gathered here the value of everything in all the classes which has been reported as having been produced by the use of the electric current. It is evident that while in the tabulation the value for a substance appears but once, by this method of treatment the value of a given substance will appear each time that it is treated of in a different group, and that therefore the value of that caustic soda which was produced electrolytically will not only appear in the total value given for Group X, now under consideration, but also under Group II, when the caustic-soda industry is considered as a whole. For this reason, as well as because the establishments devoted to the manufacture by electricity of any particular product are too few to be discussed under the rules separately, the statistics will be found combined with other statistics in the treatment of other groups.

Sodium.—The remarkable experiments conducted by Sir Humphry Davy in 1807, which resulted in the isolation of sodium[1] and of potassium, not only added to the list of known chemical elements two of its most interesting and important members, but the method devised by him and used here for the first time, in which an element was isolated by the passage of an electric current through its fused electrolyte and in which also the vessel used to contain the fused electrolyte and in which the fusion was effected was made of conducting material and served simultaneously as a container, and as one pole of the decomposing cell, has been largely applied in recent times, since easily controlled supplies of electrical energy at reasonable cost have been at command. Unfortunately no adequately cheap source of electrical energy was available until the dynamo was invented in 1867.[2] In the meantime, and subsequent to Davy's discovery, Gay-Lussac and Thénard found that sodium could be displaced from fused caustic soda by metallic iron at a high temperature, and later Brunner discovered that this reduction could be effected under these circumstances by carbon also. Upon this discovery, and making use of the condenser of Donny and Maresca, Sainte-Claire Deville based the method of manufacture which he devised, and this was for many years the only one employed in the commercial production of this metal. In practicing this process a mixture of sodium carbonate, lime or chalk, and charcoal were heated in iron retorts, and the displaced sodium distilled off and condensed, the reaction taking place being represented by the equation:

$$Na_2CO_3 + 2\ C = 2\ Na + 3\ CO.$$

Darling says, "Deville * * * brought its manufacture to a high degree of perfection, reducing the cost of a kilo from 2,000 francs, in 1855, to 10 francs, in 1859."[3]

About 1886, H. Y. Castner, an American, greatly simplified the manufacture by acting on sodium hydroxide with iron and carbon, or iron carbide, effecting the following reaction:

$$6\ NaOH + FeC_2 = 2\ Na_2CO_3 + Fe + 2\ Na + 3\ H_2$$

by fusing the mass in steel or iron crucibles and passing the vapors into condensers opening under high-test petroleum. According to Mendelèeff,[4] "At present (1897) a kilogram of sodium may be purchased for about the same sum (2 shillings sterling) as a gram cost thirty years ago."

In 1890 Castner devised an electrolytic process which completely superseded the chemical processes for the isolation of sodium, and this has since been, until recently, the only process in use in this country or abroad for the commercial production of this metal. The electrolyte consists of fused caustic soda, which is melted in a cylindrical steel crucible with a contracted neck at the bottom, so set in a flue that as the crucible is heated from the outside the body of it only becomes heated while the neck remains cool, so that the caustic soda which fills the crucible remains solid in the neck and protects the joint between the cathode and the crucible at that point. There is a perforation in the bottom of the crucible at the neck, through which the cathode is passed up vertically and sealed by the solid caustic soda, as described above. The electrodes are of iron, and the anode, which may be cylindrical in form, is inserted from above so as to surround the end of the cathode. Encircling the cathode within the anode, and depending from a collecting pot above, is a cylinder of iron-wire gauze which serves to prevent the sodium, as it is liberated, from passing into the anode compartment. The inverted collecting pot above the cathode is filled with hydrogen, which is one of the products of the electrolysis, and this protects the sodium, as it collects, from chance oxidation. The sodium is baled from the collecting pot as soon as it has accumulated in sufficient quantity. More recently Darling has devised a process by which sodium is obtained from sodium nitrate.

Metallic Sodium and Nitric Acid from Fused Sodium Nitrate.—The Darling process, as carried out in the works of Harrison Bros. & Co., of Philadelphia, Pa., is characterized by the kind of diaphragm used. A cast-iron pot, set in a brick furnace and containing the nitrate to be decomposed, acts as the anode or positive electrode. A 6-inch layer of refractory insulating material is placed in the bottom of the pot and the porous cup rests centrally upon this, leaving a 3-inch space between the cup and the pot. This space is then filled with sodium nitrate and the cup itself nearly filled with melted sodium hydroxide. The cathode, or negative electrode, consisting of a short length of 4-inch wrought-iron pipe, provided with proper elec-

[1] Phil. Trans., vol. 98, page 1. 1808.
[2] Borcher, Electric Smelting and Refining, page 104.
[3] J. Frk. Inst., vol. 153, page 65. 1902.
[4] The Principles of Chemistry, D. Mendelèeff, vol. 1, page 535: London, 1897.

trical connections, is suspended inside the cup, reaching nearly to the bottom, and bridges made of wrought-iron pipe support these cathodes in a row of porous cups. When external heat is applied to the furnace, the electrolytes melt, and, permeating the walls of the cup, allow the passage of the current which, when of suitable strength, causes the decomposition of the sodium nitrate into sodium, nitrogen dioxide, and oxygen. The nitrogen dioxide and oxygen are liberated as gases at the positive electrodes, escape through a hole in the cover provided for that purpose and are utilized.

The positive sodium ions pass through the walls of the cup and on through the molten sodium hydroxide to be ultimately liberated in the metallic state at the cathodes. The first sodium liberated is absorbed by or combined with the sodium hydroxide, hydrogen gas being evolved and sodium monoxide, probably, being formed. After some time, metallic sodium rises to the top of the electrolyte in the cups and at intervals of about one hour is dipped off with a spoon and preserved under mineral oil. This style of porous cup and furnace gives excellent results. The use of two electrolytes of different character, yet having a common base, allows of the sodium being liberated in a neutral medium away from all danger of oxidation by the nitrate from which it is obtained. At first the sheet-metal walls of the porous cup had a very short life, being quickly eaten away by the local action caused by the secondary effects of the current. This trouble was overcome by shunting about 5 per cent of the current directly through the metal walls of the cup, making them positive. This plan reduced the local action and increased the life of the cup about ten times. The material now used for the porous cup is a mixture of ground dead-burnt magnesite and Portland cement, and it makes a very satisfactory diaphragm.

The nitrogen dioxide and oxygen evolved at the positive poles are conducted by means of earthenware pipes to a number of receivers or Woulff bottles connected together and containing water. The nitrogen tetroxide which is produced on coming in contact with the water combines to form nitric acid, $3N_2O_4+2H_2O=4HNO_3+N_2O_2$. The N_2O_2 takes up a molecule of oxygen to again form N_2O_4, and more nitric acid is formed. If it is desired to make a very strong acid for use in the manufacture of high explosives, a system of towers that automatically brings the strength of the acid up to a high degree is used.

Each furnace takes a current of about 400 amperes at an average E.M.F. of 15 volts. External heat is used only when starting up and when changing the cups, which have a life of from 425 to 450 hours; at other times during the operation the heat generated by the resistance to the passage of the current is sufficient to keep the electrolytes melted.

It is interesting to note, in connection with this process, that in December, 1902, the supply of metallic sodium on hand and in storage at these works had become so great that the city authorities, fearing accidents, compelled the operation of the process to cease.[1]

Up to some ten years ago, about the only use for sodium outside of the laboratory was in the isolation of aluminum, and when the electrolytic method for the production of aluminum was developed it looked as if the isolation of sodium on any large scale would cease. It was only when electricity was also applied to the isolation of sodium that it could be obtained cheaply enough to permit of its use in fields that had hitherto been closed to it on the score of cost. Chief among these new uses is the manufacture of alkaline cyanides, which are so largely used in the extraction of gold from low-grade ores and tailings; for "quickening" mercury in gold amalgamation; for electroplating; in photography; and other minor uses. Large amounts are also converted into sodium peroxide to be used in bleaching wool, silk, and feathers, and thereby replacing the more expensive hydrogen peroxide. It is also used in making certain anilin colors and organic compounds, and wherever a powerful reducing agent is needed.

Caustic soda and hypochlorites.—When common salt is electrolyzed it is separated into its constituents, sodium and chlorine, and this electrolysis may be effected by passing a proper current through fused sodium chloride, or through an aqueous solution of the salt; but in the latter case the sodium set free at the cathode immediately reacts with the water present, forming sodium hydroxide and liberating hydrogen. As shown in the discussion in Group II, the soda industry is one of the most important of the chemical industries, and as common salt is used in the Le Blanc, Solvay, and the other established processes of soda manufacture as the raw material of the art, it is not surprising that since, as stated above, common salt is readily electrolyzed, numerous processes and devices have been invented for effecting this on a commercial scale. Among them are the Vautin, Hulin, and the Borchers processes, in which fused sodium chloride is the electrolyte, and the Holland and Richardson, Hargreaves-Bird, Castner or Castner-Kellner, Solvay, Le Sueur, and the Dow, in which an aqueous solution of common salt, which in some instances is native brine, is used as the electrolyte. According to Blount,[2] the Castner-Kellner process is the only one which in 1900 was being worked in England on a large scale and in a profitable manner, but while this process is carried on in the United States, the Le Sueur and Dow processes are also in active operation here.

The difficulties in making the simple electrolysis of common salt a commercial success have been various. In the fused electrolyte processes they have been

[1] Science, vol. 15 (N. S.), page 129, Jan. 24. 1892.
[2] Practical Electro-Chemistry, page 309.

largely due to the corrosive action which fused salt exerts on most materials that can be used for making the vessels in which the electrolysis can be conducted, while, since the melting point of sodium chloride is 800° C., and metallic sodium begins to distill below 900° C., the metal comes off mostly as a vapor, which greatly increases the difficulties of collecting it. In the dissolved electrolyte processes, among other difficulties, trouble has arisen from the evolved chlorine wandering into the cathode compartment and reacting with the previously formed sodium hydroxide, or vice versa, to form hypochlorites and chlorates, while the complete separation of the caustic soda from the sodium chloride was not at first easily effected.

C. L. Parsons,[1] writing in 1898, says:

Ernest A. Le Sueur enjoys the distinction of having invented the first electrolytic process for the commercial decomposition of sodium chloride, which became a regular contributor to the markets of the world. Since February, 1893, caustic soda and bleaching powder have been manufactured at Rumford Falls, Me., on a commercial scale.

It appears that Le Sueur began his experiments in the winter of 1887–1888, and after associating with him Charles N. Waite, who afforded him valuable assistance and some facilities at his chemical works in Newton, Mass., they together ran an experimental cell from October, 1890, to May, 1891, in a paper mill at Bellows Falls, Vt. In 1892 an association was formed, which in August of that year began the erection of a plant at Rumford Falls, and in February, 1893, began the manufacture of caustic soda and bleaching powder, using to generate the required current one 200-kilowatt dynamo of the Thompson-Houston pattern. The success of the venture was such that three more dynamos of the same capacity were installed in the fall of 1894, and the Electro-Chemical Company was organized.

Parsons describes the Le Sueur cell as follows:

The cell as now used is contained in a tank 5 by 9 feet and 1½ feet deep, and made of one-quarter inch boiler steel. Excepting the asbestos, which composes the diaphragm, the wire netting of the cathode, and the materials of the positive electrode, it is built entirely of spruce, red brick, Portland cement, sand, and slate. These substances are so disposed in the cell as to be practically permanent, the wood being exposed to no action except that of the caustic solution, which has little effect upon it. The anodes are introduced from the top of the cell and may be removed singly without interrupting the process. Troublesome joints are closed with a specially prepared plastic cement. The diaphragm is tipped somewhat from the horizontal for the purpose of permitting the easy egress of the hydrogen bubbles. The foundation of the cell within the tank consists of an oblong frame of spruce, 8 feet 4 inches by 4 feet 10 inches, outside measurement, and 8 inches less on both dimensions inside. This frame is 11 inches deep, only the side pieces, however, resting upon the floor of the tank. The end pieces consist of four 4-inch timbers, whose upper surfaces are 10 inches above the floor of the tank and 1 inch below the top surface of the longer side. The frame is divided transversely by a timber, similar to each of the end timbers, which crosses the middle of the frame at the same level as the end pieces. This center beam forms a bridge over which the flat iron ribs supporting the cathode are hung. The cell is thus divided into two equal spaces merely for mechanical convenience. The ribs referred to consist of four parallel pieces of flat iron, three of them being 1½ by three-eighths inch, and the fourth, twice as wide. This wider piece is fastened at both ends to the containing tank, so as to receive from the latter the electric current, which enters through the material of the tank and communicates the current to the cathode, which rests upon these iron ribs. The diaphragm rests directly upon the cathode. The depth of the trough formed by the slanting ribs is 4 inches. There is an adequate arrangement at the ends of the bridge pieces by means of which the hydrogen, finding its way to this higher level, is delivered to exit pipes communicating with the atmosphere, or with any system of piping to which it is desired to deliver it. The inch of space between the tops of the cross timbers and the side pieces is utilized to take a piece of slate 4 feet long by 4 inches wide by 1 inch thick. This presses down upon the diaphragm and the cathode netting and keeps all solid. On top of the sides and ends of the frame there are four courses of common brick laid in clear cement. There is a coating of cement applied to the inside walls of the portion of the cell forming the anode compartment, and this includes not only the brick walls, but the small portion of the wooden sides above the cathode, which would otherwise come in contact with the anode liquid. The ceiling of the cell consists simply of pieces of slate, 2 feet by 1 foot, and suitably supported by transverse strips of slate, 1 inch thick by 4 inches wide. Through the ceiling plates pass the glass tubes to which the anodes are attached.

The anodes which are now used are made from an alloy of iridium and platinum, and are so constructed that a very large anode surface is presented at an almost incredibly small cost, when it is considered that it is not at all of the nature of a plated surface, but is an anode of solid metal. Sixty anodes on an average are used to each cell, and each anode costs 73 cents at the present market price of platinum. They are acted upon chemically but slightly, if at all. If the glass holders break there is no loss of platinum, and a new anode can immediately be put in place. The total cost for the anodes of a plant producing, per month, 200 tons of bleaching powder, is approximately $5,000, or $40 for a cell producing 55 pounds of sodium hydroxide and 50 pounds of chlorine per day; and this allows for a very low cell efficiency. The total cost for the renewal of the platinum, including labor, is less than half the cost of the bare carbon alone, as it was formerly used. Besides, it must be remembered that carbon anodes are certain to give more or less carbon dioxide if hypochlorite be present, while with these iridio-platinum anodes no carbon dioxide can possibly be produced.

At Rumford Falls, the Electro-Chemical Company obtains power at a very low cost, so that it pays to obtain a maximum of work from each cell by using a higher current density in proportion to the anode surface than might be tenable under other conditions. As the cells are now constructed, a current of 1,000 amperes is passed through each cell under a pressure of six and one-half volts. I am aware that this voltage is high, and from a statement in Lunge[2] he would probably, at first thought, condemn the process on this ground alone. But it will readily be understood how this increased voltage can be economically employed when it is considered that at $8 per electrical horsepower per year, which is the cost of power to the company at Rumford Falls, the extra cost per pound of product, on an average efficiency of 80 per cent, is but $0.00015 for each extra volt used. This high voltage is by no means an essential of the process, and each cell can be run on a lower amperage, when of course less pressure would be required. It is simply a fact that at Rumford Falls it is economical to run the cells on this voltage, forcing through them all the current they can take without undue heating. Under these conditions, the renewal of the cell is usually made necessary only on account of the deterioration of the diaphragm. The diaphragms have an average life of seven weeks, and have been used twenty-four consecutive weeks

[1] J. Am. Chem. Soc., vol. 20, page 868. 1898.

[2] Alkali Industry, vol. 3.

without renewal. The cathodes are but little acted upon, and the steel tanks are practically indestructible.

The cells are arranged so that twenty-two are in series, and three series are run in parallel on two dynamos. The hydrogen is used only for working platinum, the larger part being allowed to escape into the atmosphere. The chlorine is conducted by earthenware pipes to lead chambers and absorbed by lime in the usual manner, although at present a part is used for manufacture of potassium chlorate. The caustic solution is concentrated by evaporation in *vacuo*, and is separated from the major part of the undecomposed salt by centrifugals. Any chlorate is now readily removed, and the solution is then boiled down in cast-iron kettles, to a first-quality caustic soda, analyzing about 74 per cent sodium oxide. The recovered salt is converted into brine and is used in the cathode compartment of the cells, nothing but fresh brine and some hydrochloric acid ever being added to the anode side. Whole bays of twenty-two cells have shown daily averages of over 90 per cent chlorine efficiency, and weekly averages of 87 per cent. If the anode compartment could be kept constantly acid, as can be done with single cells, a chlorine efficiency approaching very closely to the theoretical may be reached. The efficiency, reckoned upon the sodium hydroxide produced, is not quite so high.

One great field for electrolytic processes is the production of bleaching liquors and caustic solutions for bleacheries, paper mills, and the like. Large economies might be introduced by companies of this kind by making their own solutions electrolytically instead of by the usual method of first transporting the chlorine in the form of bleaching powder and the alkali in the solid state. This is almost self-evident when one considers that the final evaporation of the caustic soda, which is quite costly, is done solely for purposes of transportation; that the absorption of chlorine by milk of lime is a very simple operation, and the bleach liquors so produced are much more efficient per unit of chlorine than bleaching powder; and that the raw material (salt) is easily and cheaply obtained and transported without deterioration, while a small plant can be run almost as economically as a large one. In fact, the Electro-Chemical Company has sold a great deal of chlorine in the form of bleach liquors to pulp mills at reasonable distances from the works, that preferred to take this liquid carrier of chlorine on account of its ready-settled solution, ease of manipulation, and its greater efficiency, although the cost of transportation might be somewhat greater. In works which do not require caustic soda, the process would also be highly economical, for under such conditions the cathode liquor can be directly used to absorb the chlorine, in excellent condition for bleaching purposes, thus doing away entirely with the cost and use of lime. I do not hesitate to predict that we shall yet see many Le Sueur plants established in connection with mills now using bleaching powder. In fact, one of our largest American sulphite pulp mills has already made arrangements for a trial of the Le Sueur plant, with a view of bleaching to a very large extent.

Parsons points out that the chief difficulty of the process from the outset has been to keep the sodium hydroxide in its proper compartment, for with the best of diaphragms a limited amount of diffusion into the anode compartment goes on, and sodium hypochlorite is formed, which is oxidized to sodium chlorate either before diffusion into the outer space or during evaporation of the cathode solution, and is eventually recovered as a by-product in the form of potassium chlorate. In addition, the diffusing sodium hydroxide is partly electrolyzed, and, if carbon anodes are used, the oxygen liberated will attack them, forming carbon dioxide. The sodium hypochlorite may also be electrolyzed, giving rise to nascent oxygen and increasing the amount of carbon dioxide produced, and this formation of carbon dioxide is a very serious matter, for unless removed from the chlorine gas, it renders the manufacture of a standard grade of bleaching powder impossible. Le Sueur has overcome many of these difficulties, first, by having the liquid in the anode compartment at a higher level than that of the cathode, thus diminishing the entrance of sodium hydroxide by diffusion; second, by using platinum-iridium anodes; and third, by adding hydrochloric acid to the anode compartment so as to keep the solution slightly acid. This acid, so added, at once decomposes any hypochlorite, and is itself oxidized so that all of its chlorine is regained in the form of that gas. No chlorine is lost by this operation, for the chlorine obtained as bleaching powder is greater than the equivalent of the sodium hydroxide by the amount of chlorine in the added hydrochloric acid. This use of hydrochloric acid is a matter of some expense, for an equivalent of chlorine at Rumford Falls costs more in the form of hydrochloric acid than it is worth as bleaching powder, but in other localities, and especially near the Le Blanc soda factories, such use of hydrochloric acid may prove a positive advantage from the standpoint of economy. Parsons points out that while in 1892, when the Rumford Falls plant was built, bleaching powder sold in Boston for $45 per ton and caustic soda for $74 per ton, in 1898 the prices were $30 and $36, respectively.

According to Chandler,[1] all the difficulties enumerated above were completely overcome by the Castner process, in which the usual porous diaphragm is avoided, and a moving cathode of quicksilver is used in its place which absorbs the metallic sodium as fast as it is produced and removes it at once from the decomposing cell to a neighboring one, where the sodium is withdrawn electrolytically and converted into sodium hydroxide. The operation is accomplished in what is known as the "tipping cell," which is so arranged that once a minute it is rocked upon its support just enough to cause the mercury cathode in the bottom to flow back and forth under the partition to and from the neighboring cell, where the sodium hydroxide is produced free from chlorine. The metallic sodium never exceeds more than 0.2 per cent of the mercury, and consequently there is very little loss from the recombination of sodium and chlorine in the decomposing cell.

An important adjunct to the tipping cell is Castner's graphitized anode. With the ordinary carbon anodes, such as have been previously employed, it was found that the combined action of the chlorine and other substances resulting from the electrolysis of sodium chloride, together with the chemical reactions which occurred at or near the surface, disintegrated them rapidly. By converting the anodes after they have been shaped and baked into the graphitic form, they are of much greater durability, and the graphitizing process

[1] The Mineral Industry, vol. 9, page 765. 1901.

has been regularly employed on a large scale for this purpose. Other modifications and improvements in the details of construction of the tipping cells have been made which facilitate the production and have increased the efficiency of the process. The Castner process yields pure caustic soda and pure chlorine, and has been in successful operation for several years in England, on the Continent, and at Niagara Falls, N. Y. At the last-named locality the company now using it is extending its plant.

According to Blount,[1] the Castner-Kellner process is at work in England, at Weston Point, in Lancashire, where a plant of about 1,000 horsepower is in use and where a second plant of equal size is now being put down. Another plant of 2,000 horsepower (also about to be doubled), belonging to the Mathieson Alkali Company, is running at Niagara, using current supplied by the Niagara Falls Power Company. The output of this company is stated to be 10 tons of caustic soda and 24 tons of bleaching powder per day of twenty-four hours; the current efficiency, from 85 to 90 per cent; the pressure required, 3.5 volts—i. e., the energy efficiency is from 55.6 to 58.9 per cent. These statements are found to be concordant if we assume that the joint efficiency of the transformers and dynamos is 80 per cent.

This is not an unreasonable loss, inasmuch as the current has not only to be let down in voltage, but has to be transformed from an alternating to a direct current. The current comes from the power house at a pressure of 2,200 volts; it is transformed down in stationary transformers to a pressure of 120 volts. At this pressure the current, (which is, of course, still alternating,) passes to motor transformers, which transform it to a direct current delivered at a pressure of 200 volts, this being a convenient voltage for working a group of electrolytic cells.

The anodes used are ordinary "squirted" carbons; they are subjected to a "special treatment," designed to render them more refractory, and are said to last a year. Connection is made with them by means of a lead cap cast on one end. The caustic soda solution obtained is fairly concentrated, e. g., about 20 per cent strength. Much is sent in liquid form in tank wagons to soapmakers in Buffalo, about 20 miles from Niagara. Some is boiled down and sold in the solid state to the Electro-Chemical Company, whose works are close to those of the Mathieson Alkali Company.

The Dow process, as set forth in United States patent No. 621908, of March 28, 1899, has for its object the production of the chlorine and sodium hydroxide from common brine, consisting of sodium chloride, calcium chloride, and magnesium chloride in aqueous solution, and the invention is in the peculiar kind of diaphragm employed and its method of formation. To form this diaphragm a quantity of metallic iron is introduced into the brine in the neighborhood of the anode. On the electric current being passed through the solution the first actions that take place are the decomposition of the electrolytic solution near the anode and cathode, free chlorine being formed at or near the anode, and free sodium, calcium, and magnesium being formed at the cathode. These latter in turn react with the water of the electrolyte to form sodium, magnesium, and calcium hydroxides, this formation also taking place near the cathode, thus $2Na+2H_2O=2NaOH+H_2$. Part of the chlorine at the anode combines with the iron and forms iron chloride ($3Cl_2+2Fe=2FeCl_3$). The sodium, calcium, and magnesium hydroxides and the iron chloride diffuse toward the middle of the cell and meet between the electrodes. On such meeting the iron is precipitated as iron hydroxide, which forms part of the diaphragm,

$$3NaOH+FeCl_3=Fe(OH)_3+3NaCl,$$
$$3Ca(OH)_2+2FeCl_3=2Fe(OH)_3+3CaCl_2,$$
$$3Mg(OH)_2+2FeCl_3=2Fe(OH)_3+3MgCl_2.$$

Calcium and magnesium hydroxides are precipitated by the sodium hydroxide from the calcium and magnesium chlorides,

$$2NaOH+CaCl_2=Ca(OH)_2+2NaCl,$$
$$2NaOH+MgCl_2=Mg(OH)_2+2NaCl.$$

The diaphragm begins to form and build up from these precipitates, consisting of iron, calcium, and magnesium hydroxides. The chlorine diffusing toward the cathode on passing into the diaphragm, is absorbed by the calcium and magnesium hydroxides, forming calcium and magnesium hypochlorites, thus preventing the contamination of the cathode solution by the chlorine. These hypochlorites, whose formulæ are not positively known, decompose very rapidly, probably into chloride and oxygen. In actual working these hypochlorites are not found present. The iron hydroxide being inert so far as the chlorine is concerned, is not disturbed, so that eventually the side of the diaphragm near the anode is almost completely depleted of calcium and magnesium hydroxide by the action of the chlorine, and only iron hydroxide is left, while the cathode side consists mainly of calcium and magnesium hydroxides. The iron hydroxide prevents to a great extent the chlorine of the anode compartment from being consumed by the parts of the diaphragm with which it will combine. As the pores of the diaphragm contain iron, calcium, and magnesium chlorides, the sodium hydroxide of the cathode side upon entering the diaphragm is absorbed by these chlorides before it can diffuse to the anode side, so that the sodium hydroxide can not contaminate the anode solution.

Thus the products of electrolysis are effectually prevented from passing into and contaminating the opposite solutions. The precipitation and formation of the diaphragm will take place most rapidly where the diffusion is the greatest, and should any portion become

[1] Practical Electro-Chemistry, pages 313–314.

detached or mutilated diffusion will be greater at the mutilated point, and the consequent greater precipitation at this point will mend the break. It is thus seen that the diaphragm will thicken evenly. While one or more sheets of porous material—such as paper, cloth, asbestus, and the like—might be placed as a nucleus upon which the two essential layers of the diaphragm would be precipitated in the practical working of the cell, such a procedure has not been found necessary or advantageous, the diaphragm being readily produced in the proper place without such foundation. The physical qualities of the mixed hydroxides when made into a diaphragm in this manner are such that they form a coherent and self-supporting mass offering very little resistance to the passage of the electric current, but at the same time they offer a high resistance to the diffusion of the products of electrolysis and the electrolyte.

In the Dow process carbon electrodes are used. In all the processes bleaching powder is produced by absorbing the chlorine in dry slaked lime kept at a temperature below 46° C. The yield of bleaching powder from 100 pounds of good lime is 150 pounds.

Chlorates.—Chlorates have heretofore been prepared by passing chlorine into alkaline solutions maintained at a temperature at or above 100° C. In making potassium chlorate, which is the salt most largely used, the chlorine was first passed into a hot milk of lime, and after this had become saturated with chlorine and had acquired a density of 25° to 30° Twaddle, the solution was run off to settle. When clear, potassium chloride in calculated quantity was added, which, by reacting with the calcium chlorate, gave rise to calcium chloride and potassium chlorate.

As noted above, sodium chlorate may be obtained as a secondary product in the Le Sueur and other processes of electrolyzing common salt, and by metathesis with potassium chloride the potassium chlorate results. Since potassium chloride occurs native, and is mined at Stassfurt, it would appear to be a simple matter to electrolyze a hot solution of this salt directly to the chlorate, using a vessel without any diaphragm, but this is found feasible only up to a small concentration. Kellner has proposed to add to a saturated potassium chloride solution about 3 per cent of a sparingly soluble hydroxide, such as slaked lime or magnesia, and to keep the whole in agitation as the current is passed. The lime or magnesia assists in the formation of the chloric acid and serves to bring about the transfer of the potassium from its combination as a chloride to that as a chlorate. By concentration of the solution the potassium chlorate formed crystallizes out. As shown by United States patent 493023, of March 7, 1893, Gibbs and Franchot make use of a cathode of copper oxide in electrolyzing the potassium chloride. The theoretical yield of potassium chlorate is 164 parts for every 100 parts of potassium chloride used.

Potassium chlorate is used in manufacturing explosives, fireworks, fuse compositions, safety and parlor matches, and as an oxidizing agent in color works, in dyeing, and in other arts.

Lead Oxides.—Under Salom's process these are produced by the oxidation of spongy metallic lead, which is obtained by the electrolytic reduction of galena. Dilute sulphuric acid is used as the electrolyte, and sheets of lead are employed for electrodes. As neither the galena nor the lead reduced from it is soluble in the electrolyte, there is no ionization of the lead compounds or conveyance of the lead, but the latter is left as a porous mass, having the form of the original mass from which it was obtained, while the sulphur is evolved as hydrogen sulphide, and in this regard this process differs from all other electrolytic processes in use or proposed for use. The porous lead heats up on exposure to air, and is readily converted to oxides, or may be employed in the Dutch process of making white lead, where its porous condition constitutes an advantage in promoting the speed of corrosion. The lead may also be directly compressed into grids for secondary batteries.

Graphite.—Graphite is distinguished by being the first substance existing in nature as a mineral which has been commercially produced in the electric furnace. Its existence as a mineral under the names plumbago and black lead has long been known, and its employment in pencils is described in a work written by Conrad Gessner in 1565, but it was not until 1779 that its identity was established by Scheele and it became recognized as one of the allotropic forms of carbon. Several methods for the artificial production of graphite have been discovered, and that it is obtained from other forms of carbon by exposure to high temperatures, such as obtain in the electric furnace, has long been known, but the discovery that this is brought about through the formation first of carbon compounds, such as silicon carbide, and their subsequent decomposition is due to E. G. Acheson, and he has reduced this discovery to practice, producing graphite in quantity. An interesting feature of his discovery is that the phenomenon of the conversion is a progressive one and that a small portion of the other constituent of the carbide acts, as he says, "by catalysis" to convert a large mass of the amorphous carbon into graphite. This conversion is effected in a similar furnace to that used in the manufacture of carborundum, and the methods employed are similar.

The factory for working this process and making graphite from coke, bituminous coal, or other amorphous forms of carbon was established at Niagara Falls in 1899, and is to-day the only factory in the world, and the material has been here produced in several forms. One is an intimate mixture of pure amorphous carbon and graphite in fine powder for use as paint and for foundry facings. Another consists of articles pre-

viously molded from amorphous carbon which contains the catalytic agent. Among them are electrodes for use in alkali processes, like the Castner process, and carbon plates for use as brushes in dynamos and motors; and the life as well as the efficiency of these articles is much increased by being graphitized. It is expected that this process may utilize much of the fine refuse from the coke ovens.

Graphite is used in the manufacture of pencils, crucibles, stove polish, foundry facing, paint, motor and dynamo brushes, antifriction compounds, electrodes for metallurgical work, conducting surfaces in electrotyping and for glazing powder grains.

As pointed out, the chief source of graphite is from mines, and the extent of its production from this source in the United States will be shown when the census of the mining industry is taken. The amount imported is, however, very large, as shown by the following table, compiled from Vol. II of the Foreign Commerce and Navigation of the United States, for the year ending June 30, 1900:

IMPORTS OF PLUMBAGO, 1891 TO 1900, INCLUSIVE.

YEAR.	Tons.	Value.	YEAR.	Tons.	Value.
1891	10,135	$509,809	1896	11,891	$384,554
1892	13,511	726,648	1897	12,459	321,355
1893	14,207	866,309	1898	11,154	472,401
1894	7,935	410,819	1899	15,970	1,081,859
1895	7,051	208,935	1900	20,597	2,345,294

Calcium Carbide, CaC_2, was prepared in 1862 by Woehler, by heating an alloy of zinc and calcium with an excess of carbon, and in 1893, by Travers, by heating a mixture of calcium chloride, carbon, and sodium. Its commercial production began in the United States at Spray, N. C., in 1894, when Thomas L. Willson produced it by heating lime and coke together in an electric furnace, and out of this has grown the large industry which exists to-day. The furnace employed by Willson was of the simplest kind, as it consisted merely of a rectangular fire-brick box lined with carbon, to serve as one electrode, into which a stout carbon rod or bundle of rods dipped vertically to serve as the other electrode. The charge of mixed lime and coke was piled about the vertical electrode, which, after making contact to establish the arc, was raised as the mass was caused to react. Since the reaction is effected solely by the high temperature attained in the electric furnace, and not through electrolysis, either an alternating or a direct current can be employed, and as the former can be brought from a distance at a high voltage and transformed on the spot where it is to be used, by a stationary transformer, it is generally to be preferred.

As carried on at Spray, the operation was a discontinuous one, since, when the movable electrode had been raised to its greatest height and a prismatic mass of the carbide had been formed between the electrodes, the current had to be cut off, the furnace cooled, and the carbide removed, before a fresh charge could be put in. Besides, a very large part of the charge of coke and lime failed to be heated to the reaction temperature, and yet its presence was necessary to protect the walls of the furnace from the high temperature of the arc.

Through the invention of Charles S. Bradley, this process has now been made continuous. He prefers to employ a rotary wheel or annulus, into which projects at one side an electrode; the wheel being provided with means for preventing the material from spilling; with means for supplying fresh material to be acted upon by the current; and with facilities for removing the product; the whole being so arranged that the operation may be carried on in an uninterrupted manner, as the furnace is constantly forming fresh additions to the product and permitting the latter to be removed as frequently as may be necessary. The wheel is preferably turned by power-driven machinery, and is provided with a hollow periphery, to which (over an arc covering the lower part of the wheel) buckets are attached, forming throughout the arc a closed receptacle for the material to be operated upon. These buckets are arranged to be withdrawn or opened when they reach the discharge-end of the wheel-arc. The material, in the form of powder or granules, is supplied to the side of the wheel which contains the electrode or electrodes. The electric arc, or the limits of the space within which the electric action on the material takes place, is wholly within the mass of pulverized material, so that a wall of unchanged or unconverted material will surround the product of the furnace, and the motion of the wheel is in such direction as to keep the converted material surrounded by a body of unconverted material, and thus to exclude air until the converted mass has become sufficiently cool to permit of its removal and further treatment for packing for shipment or storage.

In the formation of the calcium carbide, the intimate mixture of ground lime and ground carbon is supplied to that side of the wheel-arc into which the current is introduced and is here fused and forms a pool of liquid carbide within the wheel rim, the pool being surrounded by a mass of the uncombined mixed carbon and lime which acts as an efficient heat insulator and keeps the walls of the receptacle comparatively cool. As the wheel turns, the pool is withdrawn from the neighborhood of the arc, or region of electrical activity, so that the liquid carbide cools and solidifies under a superincumbent and surrounding mass of material, which prevents access of air and thus prevents wasteful consumption of carbon by combustion. Thus a core of solid calcium carbide is formed within a granular or pulverized mass of material, the core growing in length as the receptacle recedes from the electrode until it emerges from the other end of the wheel-arc, when the removable sections of the wheel rim may be taken off one at a time, which permits the pulverized material to fall away

from the solid core of carbide, so that the latter may be broken off or otherwise removed periodically. Thus the formation of carbide goes on continuously without any necessary interruption for recharging or removal of the product.

The wheel used is formed in sections which are bolted together, and it has a horizontal axis mounted in boxes at or near the floor level. The rim of the wheel is concave in cross section and is provided at intervals with pivoted latches to engage studs on semicylindrical sections of plate iron and thereby support them on the wheel. Auxiliary plates of thin sheet iron may be bent around the joint between the sections on the inside of the wheel rim, to prevent the pulverized material from sifting through the cracks at the joints. The wheel may with advantage be made about 15 feet in diameter, and the rim and plate-iron sections of such proportions as to form a circular receptacle of 36 inches in diameter. The inner wall of the wheel rim is provided with holes at intervals to receive copper plugs connecting with the several plates of a commutator on which bears a brush, connecting with one pole of an electric generator. The other pole of the generator connects with a carbon electrode about 4 inches in diameter, mounted in a sleeve and provided with a screw thread on the outside, which engages an internally threaded sleeve secured to a bevel gear, on the axis of which is a crank for adjusting the electrode. The electrode and its regulating mechanism are mounted on a framework adjacent to the wheel pit, so that the electrode may be fed into the receptacle formed by the wheel rim and the rim sections when partly consumed.

A feed hopper is provided with a spout projecting into the wheel rim and a gate for regulating the supply of mixed material to be acted upon. The wheel pit is preferably provided with sloping sides, so that any powdered material which drops from the wheel at its discharging end or elsewhere may slide by gravity to a conveyor, the buckets of which return it to the feed hopper, to again pass through the furnace.

The wheel is preferably connected with an electric motor by speed-reducing gearing. The motor shaft carries a worm, acting on a spur gear, on the shaft of which is secured another worm, meshing with another gear, on the shaft of which is a third worm, meshing with a gear on the wheel shaft. By this mechanism, a very slow speed of the wheel may be maintained, a complete revolution being made once in five days. In using the apparatus, the rim sections are latched over the wheel rim above an arc covering the lower part of the wheel, and the gate of the feed hopper is opened. A charge of intimately mixed carbon and lime, in proper proportions to form calcium carbide, falls into the receptacle around the wheel rim and accumulates until the top of the electrode is immersed therein. The circuit of the electric machine may then be closed and the electric motor thrown into operation. As the charge is moved away from the electrode, intense heat is created and the refractory material fuses. As the wheel turns, the pool gradually recedes from the electrode and slowly cools while inclosed within walls of refractory, uncombined material on all sides, and the cool product forms a bottom for the liquid compound. Thus a continuous core of the product is formed, new rim sections being added by the workman at intervals of a few hours.

The electrode, at starting, should project well into the receptacle, and, as the wheel turns, the electrode rises relatively to the charge, and when it reaches a point near the top of the rim section, a new rim section is hung on the wheel by means of the next set of supports, and a strip of sheet iron is bent around the joint between the rim sections. The gate of the hopper is then opened and the rim filled, or partly filled, with material. As this material in its powdered state is a very poor conductor of electricity as well as of heat, the immersion of the electrode does not interfere with the heating action. When a new rim section is added on the electrode side of the wheel, one is removed at the other side. Thus the process continues until the solid core of the furnace product appears at the discharge end of the wheel, when a rim section is taken off and the powdered material falls into the pit, leaving a pillar of solid product projecting vertically, which may be broken off or otherwise removed. Solid calcium carbide is a conductor of electricity, and the copper plugs make a good contact with it, thereby constituting the carbide itself one of the electrodes. The action of the commutator leads the current to a point of the carbide core close to the electrode, and prevents unnecessary resistance, which would intervene if the plugs were more widely spaced. The conducting plugs which are remote from the arc help to carry the current, and thus the heating of any one contact with the carbide core is reduced.

Calcium carbide is used in generating acetylene gas, the reaction taking place when it is brought in contact with water at the ordinary temperature. As the manufacture of calcium carbide is a fairly efficient process, and as it may be produced wherever a head of water is available, as the energy is stored in it in a compact form, and as this energy may be readily made available again by generating the acetylene and burning it, calcium carbide is looked upon as a material by means of which the energy of remote waterfalls that is now going to waste may be made useful to man.

Carborundum (Silicon carbide, SiC), the production of which is covered by E. G. Acheson in United States patent No. 492767, of February 28, 1893, is made in the United States only, and is made by heating a mixture of 34.2 per cent of coke, 54.2 per cent of sand, 9.9 per cent of sawdust, and 1.7 per cent of common salt in an electric furnace. The furnace is built up of bricks put together without any binding material, because of the necessity

of permitting the gases generated during the process to freely escape, and because the furnace must be pulled down at the end of each run. At each end of the bin-shaped furnace, which is about 15 feet long, 7 feet high, and 7 feet wide, is a heavy bronze casting to which the leads are attached, which carries, on its inner surface, a bundle of sixty 3-inch carbon rods, each of which is 2 feet in length. These electrodes project into the furnace and are discontinuously connected by a cylindrical mass of coarsely powdered coke which forms a core about 9 feet long by 2 feet in diameter in the center of the furnace. The charge of the above-described mixture, weighing about 10 tons, is packed all about this core.

When the current is turned on, heating proceeds slowly until, after about two hours, carbon monoxide is evolved at all the openings in the brickwork and from the upper surface of the charge, where it burns with a blue flame. After some twelve hours the outside of the charge becomes red hot, and after twelve hours more the reaction has proceeded as far as practicable. After cooling, the furnace walls are pulled down, when the charge is now found to be separated into several layers, viz.; an outer one consisting of about 11 per cent salt, 56 per cent silica, and 33 per cent of carbon, which represents the portion of the charge which has not been heated sufficiently high to be converted into carbide. Within this outer layer is a layer of greenish-colored material, concentric with the core and consisting of amorphous silicon carbide, mixed with raw materials. It is not hard enough for use as carborundum, and is reworked in the next charge. The third layer, which is about 10 inches in thickness, consists of crystallized silicon carbide, the crystals being small on the outside and increasing in size toward the core. This is the carborundum. Within this layer is the portion about or within the core, which has been converted into graphite. The 10-ton charge yields about 2 tons of carborundum, though the theoretical yield of a charge of this size, consisting of silica and carbon mixed in equivalent proportions is about 4.2 tons. The energy used is about 1,000 horsepower.

Although pure silicon carbide is colorless, the crystals obtained in the commercial manufacture are blue, black, or dark brown, and are iridescent; and as they possess an almost adamantine luster, they are very beautiful. They are hard enough to scratch ruby and very permanent. Carborundum is largely used as an abrasive, the crystals being crushed in edge runners, washed with water and acid, dried, and graded by sieving. In this condition it is molded in a great variety of forms. It is also employed in the manufacture of steel as a substitute for ferro-silicon, and in the manufacture of graphite.

Carbon Disulphide.—One of the most ingenious as well as one of the most recent chemical applications of electricity is in the manufacture of carbon disulphide (carbon bisulphide; bisulphide of carbon; CS_2), a substance which was discovered by Lampadius in 1796, and which has been heretofore manufactured by passing the vapors of sulphur over coke or charcoal which has been heated to a "cherry red" in retorts made of cast iron or glazed earthenware. The further steps in the process are for the purpose of purifying the carbon disulphide by removing uncombined sulphur, hydrogen sulphide, sulphur dioxide, and other foreign bodies which may be present, and this is accomplished by condensation in towers, washing in water, treatment with chemicals, such as lead acetate, caustic soda, milk of lime or anhydrous copper sulphate, mercury or mercuric chloride, and redistillation. For certain uses the presence of certain of the impurities adds to the efficiency of the material, and in such cases the methods of purification alluded to are dispensed with. Owing to the corrosive action of the heated sulphur vapors and their products, but few materials can be employed in the construction of retorts, and those which have been used have been short lived, so that the manufacture has not only been conducted in a discontinuous manner, but the renewal account has been large.

In the electric process of Edward R. Taylor, which was put into operation in 1900 at Torrey, N. Y., several sets of carbon electrodes are introduced into the base of a stack furnace and connected by a bridge consisting of broken coke or other conductive carbon, while the body of the stack is filled with charcoal. Sulphur is fed in by suitable ports so as to cover the electrode faces when, as the current is passed through, it becomes melted and vaporized. At the same time the charcoal is heated above the electrodes, and reaction with the sulphur occurs. From the construction of the furnace, the heat radiated through the walls of the stack is utilized in heating the sulphur to the melting point, and the heat resident in the carbon disulphide vapors is largely utilized in heating up the charcoal as the latter descends the stack. The process is a continuous one, and the current may be regulated either by the amount of conductive carbon introduced into the furnace or by reducing the working surfaces of the electrodes by partly submerging them in the molten sulphur.

Carbon disulphide is extensively used as a solvent and extractive agent, as it dissolves sulphur, phosphorus, iodine, rubber, camphor, wax, tar, resins, and nearly all oils and fats. It is a germicide and insecticide and is very largely used by transportation and storage companies for the destruction of weevils in wheat, and other insect pests, and by farmers for exterminating mice, rats, prairie dogs, gophers, and other subterranean animals that damage the crops. It is employed in the manufacture of thiocyanates, carbon tetra-chloride, sulpho-carbonates, viscose, rubber cement, and in organic preparation work, and for prisms.

Phosphorus.—Heretofore phosphorus has been pro-

duced from burnt bone or mineral phosphates by treating them with sufficient sulphuric acid to convert part or all of the calcium present into calcium sulphate and the phosphorus contents into calcium metaphosphate or eventually into phosphoric acid, and reducing these products by charcoal.

Quite long ago Wöhler suggested that the manufacture be carried out by heating the calcium phosphate, such as exists in burned bones or rock phosphates, with sand and carbon, by which a reaction of the following nature may be realized:

$$2Ca_3(PO_4)_2+6SiO_2+10C=6CaSiO_3+10CO+P_4;$$

but until recently it has been impracticable to use this simple process on account of the high temperature required. This difficulty is now met in the electric furnace, and at present the electric production of phosphorus is on a profitable basis. In the continuous process of Readman, Parker, and Robinson, 100 parts of calcium phosphate, 50 parts of sand, and 50 parts of coke are intimately mixed and heated in a tightly covered electric furnace provided with an outlet pipe leading to a condenser and a tap hole. The phosphorus volatilizes as it is liberated, and, together with the carbon monoxide, passes to the condenser, where the phosphorus condenses and is collected in water. The residue of calcium silicate and foreign bodies fuses to a slag and is tapped off at intervals, fresh charges of the phosphate mixture being introduced into the furnace without interrupting the electric current.

The phosphorus as first produced is contaminated with sand, carbon, clay, and other impurities, and this crude phosphorus is purified by melting under warm water and straining through canvas, or by redistillation from iron retorts. For final purification it is treated, when molten, with a mixture of potassium dichromate and sulphuric acid, or by sodium hypobromite. Theoretically, 100 parts of $Ca_3(PO_4)_2$ should yield 20 parts of phosphorus, but in practice with the electric furnace only about 17 parts are recovered. This is, however, much more than the yield given by the older process, in which part of the phosphate was converted into calcium metaphosphate; there the maximum yield on the original phosphate was but 11 parts in 100.

Phosphorus is used in the manufacture of friction matches and fuse compositions; for making rat poison; and as a source of phosphoric acid and other phosphorus containing compounds that are used in medicine and in the arts. As phosphorus is a very active reducing agent, it has found some application in the precipitation of the precious metals and in electrotyping.

Other Products.—As an evidence of what may be expected in the future, attention is called to the fact that hydrogen sulphide (which may be burned to produce sulphuric acid), white lead, chromic acid from chromium sulphate, and lampblack from acetylene are being made by the aid of electricity. Especial activity is to be looked for in the field of organic chemistry. So long ago as 1849 Kolbe[1] electrolyzed alkaline salts of fatty acids, obtaining hydrocarbons, and since then halogen derivatives of the hydrocarbons have been made from organic salts or alcohols and haloid compounds; chloral from alcohol and potassium chloride; mono and dichloracetones and monobrom acetone from acetone and hydrochloric or hydrobromic acid; azoxybenzene, azobenzene, hydrazobenzene, benzidine, and anilin from the reduction of nitrobenzene; piperidine by the reduction of pyridine in acid solutions; and vanillin and heliotropine from the ozonization of eugenol or oil of cloves; and many other laboratory reactions. According to Swan[2] the manufacture of iodoform, vanillin, chloral, azo and hydrazo compounds, oxidation products of fusel oil, dyestuffs of the triphenylmethane type, anilin blue, anilin black, Hofmann's violet, alizarin, Congo red, oxidation products of the alcohols, sulphonic acids, piperidine, dihydroquinone, benzidine, and amidophenol have already been produced abroad by electrochemical means, and that at least the first five are being so produced on a commercial scale.

LITERATURE.

Electric Smelting and Refining, W. Borchers: Philadelphia, 1897.

Practical Electro-Chemistry, Bertram Blount: New York, 1901.

Notes on Electro-Chemistry, by Charles F. Chandler. The Mineral Industry, vol. 9, 763–772. 1901.

Manufacture and Uses of Metallic Sodium, James D. Darling, J. Frk. Inst., 153, 65–74. 1902.

The Le Sueur Process for the Electrolytic Production of Sodium Hydroxide and Chlorine, Charles Lathrop Parsons, J. Am. Chem. Soc., 20, 868–878. 1898.

Production of Phosphorus and Chlorides of Carbon by means of the Electric Furnace, Sci. Am., 74, 180. 1901.

Lighting by Acetylene, William E. Gibbs: New York, 1898.

Carbon Disulphide in the Electric Furnace, Elect. World and Engineer, 38, 1028. 1901.

Graphite; Its Formation and Manufacture, E. G. Acheson, J. Frk. Inst., June, 1899.

Some Electrolytic Processes for the Manufacture of White Lead, Sherard Cowper-Cowles. The Electro-Chemist and Metallurgist and Metallurgical Review, 1, 145–147. 1901.

Applications of Electrolysis to Organic Compounds, J. T. Hewitt. The Electro-Chemist and Metallurgist, 1, 34–35, 99–100, 120–122, 170–172. 1901.

Chemical and Technical Education in the United States, Charles F. Chandler, J. Soc. Chem. Ind., 19, 591–620. 1900.

Electro-Chemical Industry, Jos. W. Swan, J. Soc. Chem. Ind., 20, 663–675. 1901.

Group XI.—Dyestuffs.

Under the classification "dyestuffs and extracts" reports have been rendered for the two previous censuses. As the sources of much of the natural raw materials of the two industries and the methods for their treatment are in many respects similar, both dyestuffs and tanning materials were embraced in this

[1] Liebig's Annalen, vol. 69, page 259. 1849.
[2] J. Chem. Soc., vol. 20, page 668; 1901.

classification. Combining the returns of the census of 1900 in the same manner we have the following comparison:

COMPARISON OF DYESTUFF AND EXTRACT FACTORIES: 1880 TO 1900.

YEAR.	Number of establishments.	Capital.	Wage-earners.	Value of product.
1880	41	$2,363,700	992	$5,253,038
1890	62	8,645,458	2,302	9,292,514
1900	77	7,839,034	2,094	7,350,748

This comparison shows a gain of 76.9 per cent in the value of the product for 1890 over that for 1880, and a loss of 20.9 per cent in the value of the product for 1900 as compared with that of 1890. Considering the general character of trade conditions in 1900 and the activity of the dyeing and tanning industries, it is believed that this falling off is not real, but that it is due to a difference in rulings as to the category in which certain of the products reported should be put. For instance, the chromium compounds are used in dyeing, in tanning, for paints, and as chemicals in many arts. Where shall they be classified? Again, citric, lactic, tartaric, and other acids are used in calico printing and in other arts. Shall they be classified under acids or under dyestuffs? Questions like these continually arise, and they will necessarily be settled, to a certain extent, in different ways in the different censuses. The endeavor in the present report has been to classify substances as chemicals in the categories of acids, sodas, potashes, alums, cyanides, and fine or heavy chemicals unless they very distinctively belonged in one of the other categories in the scheme of classification.

Another cause might arise from an extension of the work and an increase in the output of an establishment, if that increase took place in another industry, for the return would be classified under the principal product. Thus, if in 1890 an establishment were grinding sumac leaves part of the time and wheat part of the time, and the value of the ground sumac in 1890 exceeded that of the flour, the establishment would in that year have been classified under "dyestuffs and extracts;" but if in 1900 the value of the flour exceeded that of the sumac, the returns would be classified under "food and kindred products." As a rule these variations tend to balance one another and to give a result that is a close approximation to the true one, but in certain instances this may not be the case, though in each census they all appear in the final summation.

Taking the returns thus assembled, the geographical distribution of the dyestuff and extract industry is presented in the following table:

GEOGRAPHICAL DISTRIBUTION OF DYESTUFF AND EXTRACT FACTORIES: 1900.

STATES.	Number of establishments.	Capital.	Wage-earners.	Value of product.	Per cent of value.
United States	77	$7,839,034	2,094	$7,350,748	100.0
New York	19	2,548,136	562	2,111,811	28.7
Massachusetts	10	592,510	56	1,320,881	18.0
Pennsylvania	12	1,778,173	361	1,269,246	17.3
New Jersey	10	591,916	172	502,798	6.9
Virginia	8	385,904	271	479,372	6.5
West Virginia	5	272,192	98	245,754	3.3
California, Connecticut, Florida, Illinois, Kentucky, Maine, Michigan, Rhode Island, and Tennessee	13	1,670,203	574	1,420,886	19.3

A clearer idea of the dyestuffs industry may be obtained by separating the statistics for this industry from those rendered for tanning materials and by combining with them the data from those schedules in which dyestuffs have appeared as a minor product and which have therefore been sunk in another classification. There have been 72 establishments found in which such manufacture is carried on and the product is shown in the following table:

TOTAL PRODUCTION OF DYESTUFFS IN THE UNITED STATES: 1900.

CHARACTER OF PRODUCT.	Number of establishments.	Quantity (pounds).	Value.
Total	72	61,209,231	$5,868,006
Natural dyestuffs	21	48,245,628	3,435,808
Artificial dyestuffs	32	7,698,435	2,280,899
Mordants	6	734,000	85,466
Iron liquor	5	3,344,568	32,065
Red liquor	5	707,040	7,340
Other products	3	479,560	26,428

There were consumed in the manufacture 51,955 tons of logwood, of a value of $1,084,746; of fustic 3,104 tons, of a value of $51,586; of cutch 798,508 pounds, of a value of $61,697; of indigo 109,034 pounds, of a value of $125,069; of yellow oak bark 4,907 tons, of a value of $29,451; of anilin dyes 1,734,717 pounds, of a value of $840,229; of alizarine and other coal tar colors 1,417,325 pounds, of a value of $333,317; of logwood extract 2,364,792 pounds, of a value of $163,408; and of wood for the manufacture of iron liquor 2,838 cords, of a value of $9,629; besides small amounts of nicwood, quercitron, turmeric, quassia, persian berries, myrabolans, gambier, sumac, nutgalls, quill-bark and oils, and other materials for assistants and mordants.

Coloring matter obtained from vegetable or animal substances have been used in coloring textiles from prehistoric times, and as they were supposed to exist ready

formed in the organism, they became known as natural dyestuffs. Prominent among natural dyestuffs is the coloring matter obtained from logwood and known as "hæmatein." The color-forming substance (or chromogen), hæmatoxylin, exists in the logwood partly free and partly as a glucoside. When pure, hæmatoxylin forms nearly colorless crystals, but on oxidation, especially in the presence of an alkali, it is converted into the coloring matter hæmatein, which forms colored lakes with metallic bases, yielding violets, blues, and blacks with various mordants. Logwood comes into commerce in the form of logs, chips, and extracts. The chips are moistened with water and exposed in heaps so as to induce fermentation, alkalies and oxidizing agents being added to promote the "curing" or oxidation. When complete and the chips have assumed a deep reddish-brown color, the decoction is made which is employed in dyeing. The extract offers convenience in transportation, storage, and use. It is now usually made from logwood chips that have not been cured. The chips are treated in an extractor, pressure often being used, but a pressure above 15 pounds to the square inch is to be avoided, as it may cause a decrease in the coloring power of the product. The liquor is settled to remove fibers and resin, and evaporated in a vacuum pan to a density of about 50° Tw., or it may be continued until a solid extract is obtained on cooling. The yield of solid extract produced with pressure is about 20 per cent and without pressure about 16 per cent. The extract is sometimes adulterated with chestnut, hemlock, and quercitron extracts, and with glucose or molasses. Reynolds & Innis made "dyestuffs" at Poughkeepsie, N. Y., in 1816. Browning and Brothers made extracts in Philadelphia in 1834.

Fustic is the heart wood of certain species of trees indigenous to the West Indies and tropical South America. It is sold as chips and extract, yields a coloring principle which forms lemon-yellow lakes with alumina, and is chiefly used in dyeing wool. Young fustic is the heart wood of a sumac native to the shores of the Mediterranean, which yields an orange-colored lake with alumina and tin salts.

Cutch, or catechu, is obtained from the wood and pods of the *Acacia catechu*, and from the betel nut, both being native in India. Cutch appears in commerce in dark brown lumps, which form a dark brown solution with water. It contains catechu-tannic acid, as tannin and catechin, and is extensively used in weighting black silks, as a mordant for certain basic coal-tar dyes, as a brown dye on cotton, and for calico printing.

Indigo, which is obtained from the glucoside indican existing in the indigo plant and in woad, is probably one of the oldest known dyestuffs. It is obtained from the plant by a process of fermentation and oxidation, the yield being from 0.2 to 0.3 per cent of the weight of the plant. Indigo appears in commerce in dark blue cubical cakes, varying very much in composition as they often contain indigo red, and indigo brown (which affect the color produced by the dye), besides moisture, mineral matters, and glutinous substances. Thus Java[1] indigo contains from 70 to 80 per cent of the pure color; Bengal, 60 to 70 per cent; and Kurpah, 30 to 55 per cent. It has been found that "lots" of natural indigo sold as one quality varied in themselves, and that samples drawn from the same chest and identical, so far as appearances went, differed as much as 7 to 8 per cent in their contents of pure indigo. Powdered indigo dissolves in concentrated fuming sulphuric acid, forming monosulphonic and disulphonic acids. On neutralizing these solutions with sodium carbonate and precipitating the indigo carmine with common salt there is obtained the indigo extract, soluble indigo, and indigo carmine of commerce. True indigo carmine is the sodium salt of the disulphonic acid, and when sold dry it is called "indigotine." Alexander Cochrane made extract of indigo at Lowell, Mass., in 1849.

One of the most important of the recent achievements of chemistry is the synthetic production of indigo on a commercial scale. For some years approaches have been made, as in the case of what was known as "propiolic paste," containing about 25 per cent of o-nitrophenylpropiolic acid, which was used for a time in calico printing, but abandoned because of the unpleasant odor which was developed in the process, and which persistently adhered to the goods, and because the blue color produced was slightly gray in shade, and in the case of Kalle's artificial indigo prepared from o-nitrobenzene chloride. The synthetic indigo now made by the Badische Anilin und Soda Fabrik is manufactured by the Heumann[2] process (D. R. P. 91202). Starting with naphthalene, the cheapest and most abundant of the coal-tar products, by treatment with highly concentrated sulphuric acid, phthalic acid is obtained. This phthalic acid is converted into phthalimide by the use of ammonia; the phthalimide is converted to anthranilic acid by means of sodium hypochlorite; the anthranilic acid is united with chloracetic acid to form phenylglycocollorthocarboxylic acid; by fusing this last mentioned acid with caustic soda, indoxyl or indoxylic acid is formed, according to the existing conditions, and when these are oxidized by air, in the presence of alkalies, they pass into indigo. In this manufacture 10,000 tons of naphthalene, over 1,200,000 pounds of ammonia, 4,500,000 pounds of glacial acetic acid, and 10,000,000 pounds of salt are consumed. The recovery of the 40,000 tons of sulphur dioxide, which occurs as a by-product in the treatment of the naphthalene with sulphuric acid (which is the first step in the process of making indigo) is an important matter, and the recently perfected contact process for its conversion into sulphuric acid for reuse comes in most opportunely.

[1] J. Frk. Inst., vol. 153, page 50. 1902.
[2] J. Am. Chem. Soc., vol. 23, page 911. 1901.

Lachman says:[1]

The present annual production of synthetic indigo has not been given to the public, but from the data obtainable it can not be far from 3,000,000 pounds, about one-fourth of the world's supply. It is going to be a question of business rather than of manufacture when the indigo factories will have supplanted the indigo fields. Some of the above calculations will give a faint idea of the purely commercial side of this stupendous undertaking. The 'Badische' has already invested over $4,500,000 in the plant and the preliminary experiments.

Although mineral dyes such as prussian blue, chrome yellow, orange and green, and iron buff, or nankin yellow, have long been used, artificial dyestuffs assumed preponderating importance with the discovery of the lilac color *mauve* by Perkin in 1856, and *fuchsine* or magenta by Verguin in 1859, for with each succeeding year other colors have been discovered, until at the present time there are several thousand artificial organic dyes or colors on the market. Since the first of these were prepared from anilin or its derivatives the colors were known as "anilin dyes," but as a large number are now prepared from other constituents of coal-tar than anilin they are better called "coal-tar dyestuffs." There are many schemes of classification. Benedikt-Knecht[2] divides them into I, aniline or amine dyes; II, phenol dyes; III, azo dyes; IV, quinoline and acridine derivatives; V, anthracene dyes; and VI, artificial indigo.

Of the anthracene dyes, the alizarin is the most important, since this is the coloring principle of the madder. The synthesis of alizarin from anthracene was effected by Gräbe and Liebermann in 1868, but a commercial process for its production was not developed until some years later, when it was worked out by the above-named chemists in conjunction with Caro, though the process was discovered simultaneously by Perkin. Schorlemmer[3] said in 1894: "Gräbe and Liebermann's discovery produced a complete revolution in calico printing, turkey-red dyeing, and in the manufacture of madder preparations sooner than was expected. Madder finds to-day only a very limited application in the dyeing of wool. Twenty years ago the annual yield of madder was about 5,000,000 tons, of which one-half was grown in France, while ten years ago the whole export from Avignon was only 500 tons."

It is to be observed that the quantities of substances like indigo, coal-tar dyes, alizarin, and the like reported as consumed in the United States in the further manufacture of dyestuffs are less than the amount of these articles that is imported; but this follows naturally from the fact that a large, and in some instances the largest, part of this material goes directly to the dye works and print works, while there is recorded here only such as is the subject of further manufacture before being offered for sale. As much of the material is made up in the dye and print works into other compositions of matter before being used, a complete summary of the dyestuff manufacture of the country would embrace also the manufacture at this point of consumption, but such data are not at command.

In textile dyeing and printing, substances called mordants are largely used, either to fix or to develop the color on the fiber. Substances of mineral origin, such as salts of aluminum, chromium, iron, copper, antimony, and tin, principally, and many others to a less extent, and of organic origin, like acetic, oxalic, citric, tartaric, and lactic acid, sulphonated oils, and tannins are employed as mordants. In all technologies and treatises on dyeing and printing the mordants are regarded as of equal importance with the coloring matters, and from this standpoint they are properly included in a census of the dyestuffs industry; but in the larger scheme of the chemical industries, such as is now under consideration, the point of view will necessarily be different, and therefore when a substance like alum or copperas or tannic acid is a distinctively chemical substance and is applied to other uses than in dyeing or printing, it is classified in its proper category under acids, bases, or salts, but when a substance is a composition of matter and is used exclusively or principally as a mordant it is embodied under that heading in the table given above.

Iron liquor, known as black liquor or pyrolignite of iron, is made by dissolving scrap iron in pyroligneous acid. It is sold as a dirty olive-brown or black liquid, having a density of about 25 Tw. (1.12 sp. gr.) and consists mainly of ferrous acetate with some ferric acetate and tarry matters. It is used as a mordant in dyeing silks and cotton and in calico printing. It was manufactured by James Ward, at North Adams, Mass., in 1830.

Red liquor is a solution of aluminum acetate in acetic acid, and is produced by acting on calcium or lead acetate solutions with aluminum sulphate or the double alums, the supernatant liquid forming the red liquor. The red liquor of the trade is often the sulpho-acetate of alumina resulting when the quantity of calcium or lead acetate is insufficient to completely decompose the aluminum salt. Ordinarily the solutions have a dark-brown color and a strong pyroligneous odor. It is called red liquor because it was first used in dyeing reds. It is employed as a mordant by the cotton dyer and largely by the printer.

[1] Loc. cit.
[2] Chemistry of Coal-tar Colors.
[3] Rise and Development of Organic Chemistry, page 248.

IMPORTS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1891–1900.

YEAR.	LOGWOOD.		EXTRACTS AND DECOCTIONS OF LOGWOOD AND OTHER DYEWOODS.		CAMWOOD.		FUSTIC.		ALL OTHER DYEWOODS.		CUDBEAR.	
	Tons.	Value.	Pounds.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Pounds.	Value.
1891	84,381	$1,842,954	3,282,227	$275,802	3	$220	9,100	$132,841	1,002	$28,969	402,241	$37,889
1892	60,297	1,233,592	4,227,017	325,576	29	3,339	8,490	125,067	2,527	50,131	276,690	24,597
1893	56,404	1,218,934	3,757,259	287,723	26	3,745	10,293	165,807	479	8,978	320,348	25,317
1894	53,709	1,313,376	2,817,451	196,397	70	5,770	7,765	126,309	347	4,426	151,121	12,666
1895	60,683	1,478,618	3,565,277	261,762	23	1,676	6,299	89,696	553	12,386	148,024	13,129
1896	66,074	1,522,069	4,910,176	287,120	50	3,748	6,832	90,389	1,155	18,583	118,517	9,256
1897	33,462	611,010	5,459,302	277,798	.....	.....	7,918	102,472	639	8,327	66,804	4,902
1898	46,977	744,135	3,664,623	232,986	.....	.....	9,923	137,666	2,726	33,475	66,795	4,795
1899	37,518	547,334	3,113,558	207,406	.....	.....	9,198	121,665	8,834	103,276	36,487	2,919
1900	48,190	628,464	3,420,276	227,527	1	161	4,440	60,886	20,967	205,351	61,305	3,944

YEAR.	GAMBIER OR TERRA JAPONICA.		CRUDE INDIGO.		INDIGO CARMINE.		EXTRACTS OR PASTES OF INDIGO.		SUBSTITUTE INDIGO.	MADDER AND MUNJECT, OR INDIAN MADDER, GROUND OR PREPARED.		ORCHIL OR ORCHIL LIQUID.
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Value.	Pounds.	Value.	Value.
1891	27,610,594	$1,343,604	2,089,500	$1,600,865	28,175	$33,145	881,969	$58,288	$416	673,260	$39,806	$81,974
1892	25,808,495	1,069,043	2,460,635	1,772,506	23,600	28,636	826,887	58,845	.....	518,786	52,063	68,779
1893	35,762,646	1,305,468	3,226,314	3,137,511	29,687	35,304	1,317,835	101,347	2,793	653,779	61,720	64,928
1894	26,408,458	981,328	1,717,635	1,218,580	12,504	16,907	829,380	68,474	1,587	262,563	17,576	43,235
1895	29,022,603	963,255	3,411,539	1,940,250	26,173	33,405	605,750	57,317	187	329,477	18,541	59,317
1896	32,343,256	1,108,611	2,707,928	1,571,018	34,967	42,369	590,664	55,361	.....	318,313	15,746	62,831
1897	31,349,555	959,501	3,010,005	1,586,309	52,192	59,182	469,729	51,153	.....	292,462	12,963	38,965
1898	42,333,486	1,021,288	3,058,787	1,807,336	25,671	26,642	396,760	59,001	.....	246,218	11,816	56,755
1899	38,123,478	754,497	3,127,182	1,698,583	17,505	17,172	254,531	23,324	.....	280,081	12,298	45,494
1900	38,857,515	906,282	2,747,043	1,446,490	18,204	15,767	251,538	20,094	.....	120,736	5,869	47,134

YEAR.	SAFFLOWER AND EXTRACT OF, SAFFRON AND SAFFRON CAKE.	COCHINEAL.		OIL OF ANILINE.		SALTS OF ANILINE.	ALIZARIN, NATURAL OR ARTIFICIAL AND DYES COMMERCIALLY KNOWN AS ALIZARIN YELLOW, ORANGE, GREEN, BLUE, BROWN, AND BLACK, INCLUDING EXTRACT OF MADDER.		COAL-TAR COLORS OR DYES NOT SPECIALLY PROVIDED FOR.	ALIZARIN ASSISTANT OR SOLUBLE OIL, OR OLEATE OF SODA, OR TURKEY-RED OIL.		ALIZARIN ASSISTANT, ETC., ALL OTHER.	
	Value only.	Pounds.	Value.	Pounds.	Value.	Value only.	Pounds.	Value.	Value only.	Gallons.	Value.	Pounds.	Value.
1891	$44,598	86,797	$19,935	1,489,908	$299,662	$713,732	3,443,167	$674,101	$1,632,642	653	$437	1,325	$717
1892	55,391	230,039	55,883	1,428,070	253,248	536,477	4,838,220	1,029,122	1,640,024	.....	.....	3,997	2,262
1893	27,697	215,512	52,572	1,211,818	168,539	432,134	5,729,221	1,125,506	2,322,258	.....	.....	2,901	1,157
1894	24,341	104,284	28,124	951,671	115,141	395,575	3,960,079	722,919	1,429,101	.....	.....	1,153	577
1895	16,462	130,205	37,285	1,315,934	143,426	548,110	5,287,720	870,383	2,739,933	92,158	25,735	.....	.....
1896	33,765	160,422	50,988	1,364,674	164,238	662,459	6,154,156	994,395	2,918,332	82,376	24,626	.....	.....
1897	38,022	137,261	41,943	.....	.....	812,884	6,169,018	1,023,425	3,163,182	.....	.....	.....	.....
1898	52,482	158,055	45,762	.....	.....	1,087,704	5,871,962	886,349	3,723,388	.....	.....	.....	.....
1899	32,477	97,563	23,207	.....	.....	743,130	5,226,452	700,786	3,900,099	.....	.....	.....	.....
1900	44,502	158,911	31,408	.....	.....	537,812	6,009,552	771,336	4,792,103	.....	.....	.....	.....

LITERATURE.

A Practical Handbook of Dyeing and Calico Printing, by William Crookes: London, 1874.

History of Anilin and Allied Coloring Matters, by W. H. Perkin: London, 1879.

Chemistry of the Coal-Tar Colors, by R. Benedikt: London, 1889.

Chemistry of the Organic Dyestuffs, by R. Nietzki: London, 1892.

The Rise and Development of Organic Chemistry, by C. Schorlemmer: London, 1894.

Systematic Survey of the Organic Coloring Matters, by G. Schultz and P. Julius: London, 1894.

Handbook of Industrial Organic Chemistry, by S. P. Sadtler: Philadelphia, 1895.

Dyeing and Calico Printing, by Antonio Sansom, London, Vol. I, 1895; Vol. II, 1896; Vol. III, 1897.

Outlines of Industrial Organic Chemistry, by F. H. Thorp: New York, 1898.

Group XII.—Tanning Materials.

The making of leather is one of the older arts. From the best records attainable, according to Robert H. Foerderer,[1] it appears that the first tannery in this country was operated about the year 1630 in Virginia. A year or two later the first tannery in New England was established in the village of Swampscott, Lynn, Mass., by Francis Ingalls, and the vats used by him remained until 1825. With the establishment of the tanning industry necessarily came the gathering of the tanning materials from forest and field, and subsequently their preparation for use, but the first mention of this industry in census reports appears under the head of "sumac" in the report for 1850, and from this time, except in 1880, separate returns for tanning materials have been made in each census report, though the methods of statement have been so varied as to make comparison, except in certain items, almost impossible. Thus in 1850, 1860, and 1870 there are the classifications "sumac," "sumac bark and prepared sumac," and "ground sumac;" in 1860 and 1870 also, "ground

[1] One Hundred Years of American Commerce, Vol. II, page 495.

bark;" in 1870, also "hemlock-bark extract;" in 1890, "dyeing and tanning extract," and "chipped wood and other products of this group."

In this report for the census of 1900 there are included, under "tanning materials," the ground, chipped, and other comminuted materials, and the extracts obtained from oak bark and wood, hemlock, sumac, and palmetto root, together with the chrome solutions that are employed in tanning. Under this classification, and taking into account establishments not in the chemical classification of the census, but which produce tanning materials in addition to other products, like drugs or leather, 39 establishments were reported, employing $2,107,040 of capital and 700 wage-earners, and producing $1,899,220 of product. They were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF FACTORIES PRODUCING TANNING MATERIALS: 1900.

STATES.	Number of establishments.	Capital.	Wage-earners.	Value of product.	Per cent of total.
United States	39	$2,107,040	700	$1,899,220	100.00
Virginia	8	385,904	271	479,372	25.33
Pennsylvania	8	566,869	103	357,462	18.82
New York	4	341,870	90	295,356	15.55
West Virginia	4	270,192	90	232,365	12.23
New Jersey	6	94,762	27	181,800	9.57
Massachusetts, Maryland, Florida, Tennessee, Kentucky, Illinois, Michigan, and California	9	447,443	119	352,865	18.50

There were 23 establishments employing $1,055,665 of capital and 351 wage-earners in the manufacture of tanning materials from the oak. There were used of oak and chestnut oak 36,897 cords of bark, of a value of $265,557, and 34,871 cords of wood, of a value of $92,252, and there were produced of ground bark 29,948,237 pounds, having a value of $186,381, and of extract, 34,673,997 pounds, having a value of $661,119.

There were 10 establishments employing $586,681 of capital and 156 wage-earners engaged in the manufacture of tanning materials from the hemlock. There were used of hemlock bark 43,566 cords, having a value of $210,930, and there were produced 35,591,329 pounds of extract, of a value of $572,882, whereas in 1870 (the only previous record at command) 2 establishments were reported employing $85,000 of capital and 37 wage-earners, and having a product valued at $185,300.

There were reported 11 establishments employing $333,648 of capital and 105 wage-earners engaged in the manufacture of tanning materials from sumac. There were used of sumac leaves 11,538 tons, having a value of $214,353, and there were produced 9,528,800 pounds of ground sumac, valued at $114,660, and 8,102,742 pounds of sumac extract, valued at $215,677. This output is compared with data accessible in previous census reports in the following table:

PRODUCTION OF SUMAC, BY DECADES: 1850, 1860, 1870, AND 1900.

YEAR	Number of establishments.	Capital.	Wage-earners.	Value of product.
1850	9	$15,550	25	$36,731
1860	4	11,700	12	16,850
1870	19	167,450	85	267,180
1900	11	333,648	105	330,337

There was produced of chrome tannage solution, as reported, 1,837,134 pounds, of a value of $52,516, but it is probable that much of this material produced and consumed in tanneries is not accounted for. Besides these materials there was a quantity of tannic acid from nutgalls and other sources reported, but this is more properly classified and treated of under acids.

The sources of tannin in nature are very numerous. Bernadin, in his book,[1] treats of 350 different vegetable sources. Mineral salts have also been employed as tanning agents, while more recently still the electric current and organic compounds, such as formaldehyde, have been employed to convert hides or skins into leather. The tannin which exists in or is produced from vegetation varies with the genus and the species, and even, it is believed, with the part of the plant from which it is obtained. Trimble[2] classifies the tannins as follows: Group *a*, gallo-tannic acid; chestnut-wood tannin; chestnut-bark tannin; pomegranate-bark tannin; sumac tannin. Group *b*, oak-bark tannin; mangrove tannin; canaigre tannin; rhatany tannin; kino tannin; cetechu tannin; tormentil tannin. According to the prevailing views, tannin is a glucoside and the tannic acid obtained from it is digallic acid. Gallnuts are the richest in tannin contents of any vegetable source, amounting to upward of 50 per cent, but the sources of tanning materials reported as used in tanning in the United States are oak and hemlock barks, oak wood, sumac leaves, and palmetto root.

Oak and Hemlock.—The bark and the wood are chipped fine and sold in this form for making the tan liquor, or they are treated to extract the tannin and other principles, and this extract is put upon the market. For making leather it has been found essential that the aqueous extract shall contain sugars, gums, resins, and coloring matters as well as tannin, since the above-mentioned substances play an important part in the conversion of the hides into leather. According to Hough,[3] the yield of bark is 3 cords per acre, and 4 to 6 trees yield a cord of bark.

Sumac.—The sumac stands next in importance to the hemlock as a source of tanning material in the United States. It is obtained from several species of the *Rhus*, but chiefly from the *R. glabra* and *R. tyhina.*

[1] See Literature at the end of this group.
[2] The Tannins, Vol. II, page 132.
[3] Report upon Forestry, page 145.

The sumac best suited for tanning and dyeing purposes grows wild in a belt of country extending from Maryland down through the Atlantic states to Georgia, Alabama, Mississippi, Louisiana, and Texas, and in portions of Kentucky and Tennessee. The northern climate appears too cool for developing the tanning properties of this plant to the best advantage, although in the past large quantities of the leaves gathered in Pennsylvania and New York have been sold to tanners of goatskins, who put them in vats to strengthen and keep the sewed skins from leaking, and they have been used by many tanners to brighten the color of their leather.

According to Hough,[1] in 1877 the state of Virginia led in the production of sumac, and the business of collecting, grinding, and packing was carried on at Richmond, Fredericksburg, Alexandria, Culpeper, Winchester, and perhaps other places. According to Bernadin,[2] in 1880, 6,000 tons of American sumac were annually brought into the market, principally from Alabama, Tennessee, Kentucky, and, above all, Virginia. Sumac leaves contain 24 per cent of tannin, but a sample of *Rhus glabra* from Georgetown, D. C., went as high as 26.10 per cent in tannin contents.

The season for picking sumac begins about the first of July and ends the last of September, or with the first frost, for when the leaves turn red in the autumn they are no longer of value. The tanning properties of the sumac reside in the leaves, and only these should be gathered. The differences existing in various samples of sumac is found often to be due to the care with which the leaves were gathered and dried. The blossoms and berries, as well as the stems, should be thrown out and the leaves should be dried in the shade. When cured, the sumac is ground in mills under heavy wooden wheels, revolving in circles, at the ends of axles attached horizontally to a vertical shaft. These grinding wheels are inclosed in a tight covering to prevent the escape of the dust, which arises quite abundantly. John G. Hurkamp began grinding sumac at Fredericksburg, Va., in 1847.

Palmetto Root.—The palmetto root is a source of tannin which has attracted attention in recent years in the South. It is found abundantly in Florida, and grows in Alabama, Louisiana, and Tennessee. It shows 10 per cent of tannin and the root can be cut up like bark. The tannin from this source produces tough grain and strong, durable leather. It tans rapidly, giving a pleasing light color, toughness, and pliability, and is a good filler of leather. There was but one factory reporting palmetto extract at the census of 1900. The extract is put up in barrels containing 52 gallons, and a gallon weighs about 10½ pounds.

Tanning Extracts.[3]—"The use of extracts in tanning has grown to large proportions during the past fifteen years. There are many advantages in the use of such extracts. The liquids are always under perfect control; that is, by putting in so much extract the quantity of tanning material is known. It does away with the storing of large quantities of bark, as 1 barrel of extract is equivalent to about 1 cord of bark—128 cord feet. Where space costs money, this is quite an item, and it also saves interest and insurance on the bark.

"There is no difference in the fiber produced by bark liquors and pure tanning extracts, as properly prepared extract is nothing more than concentrated liquor. Tanning extracts in common use in the United States are made from chestnut oak bark, chestnut oak wood, chestnut wood, hemlock bark, quercitron bark, canaigre, and sumac. Black oak bark extract is used to give a bloom to leather, and coloring or dyeing extracts are made from logwood, fustic, and from a large number of other materials.

"The chestnut tree, after it is felled is peeled of the bark, which is objectionable on account of the coloring matter which it contains. The chestnut oak tree is used as it comes from the stump. The chestnut tree and the chestnut oak tree are cut into suitable lengths, say about 4 feet long, in the forest. These pieces are then carried to the factory, where they are further reduced by 'chipping' by a machine built especially for the purpose. This machine is a cast-steel disk 4 feet in diameter, revolving rapidly, and carrying a suitable arrangement of knives, which cut the wood into small chips. These chips are carried to the leaches and leached or extracted as is usual in tanneries. No chemicals should be used in the leaches. The liquor is then run into settling tanks, and next passed through 10 wire-cloth strainers of the finest meshes to clarify it, after which the liquor goes to the vacuum pan and is concentrated under diminished pressure at a temperature of between 120° and 140° F.

"The above-described method of settling and straining is the one in common use in the United States, and it produces a liquor which is pure and transparent enough to be made into an extract suitable for tanneries.

"When the degree of heat has been carried too high in the leaches, such liquor can only be clarified sufficiently by first lowering the temperature below the coagulating point of blood and adding blood; second, raising the temperature of the liquor sufficiently high to coagulate the blood, which gathers up the fine suspended matter and settles to the bottom of the vat or tank, and is then still further strained. It is then concentrated as usual.

"Extract, however, made from a liquor which has been produced at too high a degree of heat, although clarified by blood albumen, will not produce a satisfactory article; that is, such an extract is not, strictly speaking, a concentrated liquor.

[1] Report upon Forestry, page 153.
[2] Classification de 350 matieres tannantes, page 23.
[3] The Manufacture of Leather, by Charles T. Davis, pages 74–77.

"The extract maker, it is true, obtains a larger yield or number of pounds of finished extract from his material, but it is at the expense of the tanner. The excessive degree of heat in the leaches extracts not only nontanning substances, which are objectionable, but destroys also certain bodies which act favorably in the production of leather.

"In the concentration of the liquor in the vacuum pan, extreme caution must be observed as to the degree of heat. A temperature of over 140° F. or thereabouts produces a change in the tanning substances and in its allied nontanning substances which is very objectionable, and which produces an undesirable leather, not only in color but in quality. In other words, a liquor, although carefully made, when subjected in the pan to a degree of heat in excess of 140° F., or thereabouts, yields an extract which, when diluted with water, is not what it was before concentration It is on this account that the multiple vacuum pans—that is, more than one pan—can not successfully be used in the concentration of liquors or the making of extracts.

"In the use of extracts the tanner should always be on the lookout for only the pure article, free from adulterations of any kind. Extract is now being extensively used for sole, upper, belting, harness, union, enameled, and patent leather, and in nearly all the cases which have fallen under our observation giving good results in both tannage and weight.

"There are various methods followed in the preparation of hemlock extract, but that used by a prominent extract company in Pennsylvania is a good one. The bark is ground in the old-fashioned mill and is very carefully leached in the old-fashioned way and boiled down in the vacuum pan under the least degree of heat that can be employed. No chemicals whatever are used. They do not press or crush their bark to get from it a larger yield, but are doing their best to give a pure article which will produce a pure, strong, old-fashioned liquor. They take a good, fresh 10° barkometer liquor and boil it down to 27½° Baumé in vacuum. There is no other description than this, for this is all they do.

"The manufacture of tanning extracts now closely resembles the process for extracting sugar; the sliced wood is exhausted by diffusion in autoclaves under slight pressure, and the liquor is filter-pressed and evaporated in some cases in triple-effect apparatus which differs from those used at the sugar works merely in being constructed entirely of copper and bronze, to the exclusion of iron, and in being worked at a higher vacuum than sugar pans are. Most manufacturers decolorize the liquor before concentration, either by the addition of some metallic salt or with albumen and bisulphite of soda. In the former case the acid of the salt remains in the extract, and in the latter, sulphate of soda and noncoagulable albuminoids are retained, whilst in both cases tannin is necessarily precipitated. The presence of salts in tanning extracts is much to be deprecated, since they accumulate in the tan pits to the detriment of the leather.

"Roy has shown that the so-called decolorizing processes are beneficial to the extract, not because they eliminate coloring matters, for they do this in a very minor degree, the color of the liquor after treatment being but slightly diminished if estimated on the basis of equality of tannin content, but because they precipitate together with the first portions of tannin, certain earthy and metallic bases, such as lime, magnesia, manganese, iron, and copper, derived from the wood and from the apparatus. It is these foreign matters combined with tannin, which are taken up, by the leather, imparting bad color and harsh and brittle grain. By substituting an aqueous solution of potassium ferrocyanide for the precipitate previously used, Roy has succeeded in removing these metallic compounds without appreciably decolorizing the extract, and finds that the leather produced by the treated extract is in every way comparable with that prepared with oak-bark liquor made in the tanyard.

"It follows that tanning extracts must be examined for salts of the alkalies and the alkaline earths and for metallic compounds, and valued in accordance with their content of these, as well as with their content of tannin."

John H. Heald & Co. began the manufacture of hemlock-bark extracts at Baltimore, Md., in 1860; at Elmira, N. Y., in 1862; and at Lynchburg, Va., in 1869.

Chrome Solution.—As far back as 1856 the system of tanning, or tawing, by the use of chromium compounds was discovered by a German chemist,[1] but all the early experiments failed because the tannage could not be made permanent. A remedy was finally found in the subsequent use of hyposulphite of soda by which the tannage was made lasting. The discovery of the remedy and its successful application were made in Philadelphia, and the use of hyposulphite of soda for this purpose is covered by United States letters patent of June 28, 1888, granted to William Zahn. According to Foerderer[2] the consequence of this invention was the creation in Philadelphia of what is to-day the largest and best equipped leather factory in the world. In carrying out the process, the skin is first dipped in a solution of a chromium salt, such as potassium dichromate, acidified with hydrochloric acid, and subsequently in a solution of sodium thiosulphate or a bisulphite acidified with hydrochloric or sulphuric acid. It appears that for 100 pounds of skins 4 to 5 pounds of potassium dichromate, 2.5 to 4.5 pounds of hydrochloric acid, 8 to 10 pounds of sodium "hyposulphite," and 0 to 1.5 pounds of sulphuric acid are consumed. Of course any equivalent chromium salt may be used, and latterly the use of other metallic radicals as coagulants has been tried.

Considering leather as a chemical product (and it is always treated as such in the full chemical technologies) a notable example of the application of electricity is found in its use in the tanning of hides and skins to con-

[1] One Hundred Years of American Commerce, Vol. II, page 497.
[2] Ibid.

vert them into leather. There have been many such electric processes invented, some employing tannin solutions, but most of them referring to the use of mineral tannage, with chromium, aluminum, tin, and other metallic salts, on light skins, such as calf, goat, and sheep. One of these electric processes, "the Groth system of rapid tannage by electricity," has, according to Davis,[1] "so far been demonstrated in the United States at Kansas City, Mo., where good results are claimed for it." Further on, in discussing electric and other rapid tannage systems, Davis[2] says:

> The bark methods of tanning are passing away with great rapidity, extracts and chrome are taking their place, and in the larger establishments the chemist has become an invaluable part of the personnel of the tannery, and he is kept busy making investigations and suggestions.

The foreign commerce in tanning materials is set forth in the following tables, compiled from the publications of the Bureau of Statistics of the United States Treasury Department.

[1] The Manufacture of Leather, page 526.
[2] Ibid., page 530.

IMPORTS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.

YEAR.	SUMAC, EXTRACT OF.		SUMAC, GROUND.		SUMAC, UNMANUFACTURED.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1891	2,399,028	$77,152	11,412,297	$235,729	2,953,202	$65,802
1892	1,902,089	68,853	10,822,614	225,891	2,841,200	60,657
1893	2,880,210	108,447	14,363,922	289,953	3,817,568	70,152
1894	1,277,609	54,535	8,315,551	191,333	970,207	21,427
1895	1,604,024	53,260	12,242,216	236,541	2,203,645	40,021
1896	2,472,923	78,504	13,349,233	231,324	1,027,824	24,861
1897	2,907,521	84,150	18,530,104	245,992	2,117,439	30,554
1898	1,266,542	48,399	8,336,117	121,461	3,754,307	62,553
1899	1,133,662	38,709	14,156,344	202,605	3,011,810	42,297
1900	1,419,827	50,295	10,644,001	233,846	1,048,955	20,800

IMPORTS OF TANNING MATERIALS FOR CONSUMPTION DURING THE YEARS ENDING JUNE 30, 1891 TO 1896.

YEAR.	HEMLOCK BARK.		HEMLOCK EXTRACTS.		OTHER THAN HEMLOCK.		Hemlock and other, value.	Other articles in crude state used in tanning not specially provided for, value.
	Cords.	Value.	Pounds.	Value.	Pounds.	Value.		
1891	57,254	$274,426	768,710	$14,958	3,310	$229	.....	$2,603
1892	53,018	256,346	.....	.....	12,973	408	.....	1,918
1893	50,688	241,244	.....	.....	672	71	.....	8,361
1894	46,173	212,350	.....	.....	.....	.....	.....	10,630
1895	47,286	230,943	.....	.....	.....	.....	$3,470	16,629
1896	43,964	214,891	.....	.....	.....	.....	19,045	23,499

DOMESTIC EXPORTS OF BARK AND EXTRACTS FOR TANNING DURING THE YEARS ENDING JUNE 30, 1891 TO 1900.

YEAR.	Value.	YEAR.	Value.
1891	$241,382	1896	$354,007
1892	239,708	1897	241,979
1893	232,269	1898	329,994
1894	271,236	1899	369,693
1895	290,362	1900	376,742

LITERATURE.

Report upon Forestry, by Franklin B. Hough: Washington, Government Printing Office, 1878.

Classification de 350 matieres tannantes, by M. Bernadin: Paris, 1880.

The Tannins, by Henry Trimble, Philadelphia, Vol. I, 1892; Vol. II, 1894.

One Hundred Years of American Commerce; Hides and Leather, by Robert H. Foerderer, Vol. II, pages 494–497: New York, 1895.

The Manufacture of Leather, by Charles Thomas Davis: Philadelphia, 1897.

Organic Chemistry, V. Von Richter, Philadelphia, Vol. I, 1899; Vol. II, 1900.

GROUP XIII.—PAINTS (INCLUDING VARNISHES, AND BONE, IVORY, AND LAMP BLACK).

Although paints (including pigments), varnishes, and bone, ivory, and lampblack have been separately tabulated, a large proportion of the establishments of the first two classes make both classes of products, and the product of the last class belongs entirely to pigments; hence it is advisable to consider them together in this special treatment.

The following table gives a summary of the principal totals of the three tabulations, with a final column giving the value of that portion of the products which really belongs to this group, the remainder belonging to other groups and being there considered. To the total of this column is added the value of the paint and varnish products from other groups, Class B, and also from other categories, Class C, so far as known, the values of these last being of course reported elsewhere under their respective classes, although usually not separately.

CLASS.	Number of establishments.	Capital.	SALARIED OFFICERS, CLERKS, ETC.		WAGE-EARNERS.		Miscellaneous expenses.	Cost of materials.	Value of products.	Products belonging to this group.
			Number.	Salaries.	Average number.	Wages.				
Total	615	$60,834,921	3,731	$5,040,301	9,782	$4,971,697	$5,122,381	$44,844,229	$69,922,022	$67,376,641
Paints	419	42,501,782	2,512	3,077,318	8,151	3,929,787	3,430,061	33,799,386	50,874,995	48,440,780
Bone, ivory, and lampblack	15	782,247	21	23,650	85	46,107	75,678	105,712	359,787	359,787
Varnish	181	17,550,892	1,198	1,939,333	1,546	995,803	1,616,642	10,939,131	18,687,240	18,576,074
Total	647									71,313,392
Class B	10									541,892
Class C	22									3,394,859

The importance of considering, in this connection, the products of Class C is shown by the following list of their kinds, quantities, and values:

KIND.	Quantity.	Value.
White lead, dry, pounds	6,968,000	$289,897
Oxides of lead, pounds	11,626,033	312,403
Oxide of zinc, pounds	60,235,154	2,212,787
Dry colors, pounds	1,394,595	55,450
Paints in oil, in paste, pounds	2,594,824	255,566
Paints, ready mixed, gallons	[1]479,998	268,756
Total		3,394,859

[1]Quantities not always given; in such cases, calculated from the average value of product.

There were 23 establishments of Class A and 2 establishments of Class C reported as making white lead and oxides of lead. Including the figures of Class C, the total quantity of white lead reported as having been sold dry was 123,070,316 pounds, valued at $4,501,078, in addition to which 131,621,628 pounds were reported as having been consumed in the manufacture of other paint products, making a total of 254,691,944 pounds. The total quantity of oxides of lead reported as sold as such is 62,385,656 pounds, valued at $2,862,743, in addition to which 2,080,374 pounds were reported as being consumed, making a total of 64,466,030 pounds. The entire paint and varnish products, sold as such, from all sources are as follows:

KIND.	Quantity.	Value.
White lead, pounds	123,070,316	$4,501,078
Oxides of lead, pounds	62,385,656	2,862,743
Oxide of zinc, pounds	60,235,154	2,212,787
Lamp black, pounds	7,519,345	420,037
Fine colors, pounds	4,080,902	1,028,754
Iron oxides and other earth colors, pounds	33,772,256	324,902
Dry colors, pounds	169,128,836	4,483,478
Pulp colors, sold moist, pounds	20,060,935	861,531
Paints in oil, in paste, pounds	310,072,689	17,858,693
Paints, ready mixed, gallons	17,380,348	15,139,441
Varnishes—		
Oil and turpentine, gallons	14,286,758	14,337,461
Alcohol, gallons	563,212	943,069
Pyroxylin, gallons	204,069	237,012
Liquid dryers, etc., gallons	6,564,370	3,085,254
Putty, pounds	17,287,323	238,427
All other products		2,778,725
Total		71,313,392

While it is not possible to give an equally complete list of materials, since the reports frequently give merely an aggregate of "all other materials" or report only one or two constituents separately, the following list may be of interest:

KIND.	Quantity.	Value.
Gums, pounds	36,533,632	$3,470,695
Alcohol, grain, gallons	78,309	175,997
Alcohol, wood, gallons	310,059	285,510
Dry colors, pounds[1]		7,002,913
White lead, pounds	39,689,235	1,970,614
Whiting, pounds	10,690,441	55,157
Linseed oil, gallons	16,157,117	7,495,196
Turpentine, gallons	6,519,408	2,965,051
Benzine, gallons	10,081,945	1,045,488
Total		24,466,531

[1]Dry colors includes zinc oxide, barytes, earth colors, and other dry paint materials not otherwise specified.

The growth of this industry as shown by previous census reports is as follows, the same chemicals being included for each census as far as comparable, although the Census Report for 1850 has some remarkable figures. This report gives 51 establishments making white lead with 1,508 employes, combined capital of $3,124,800, and a total product valued at $5,242,213, while only 4 paint works and 3 varnish works are reported, with a total force of 26 employees, capital $14,550, and product valued at $92,375. These figures seem to be erroneous, unless the "white-lead works" were really paint works, although each may have corroded lead for its own use, but this too is doubtful. This view seems to be borne out by the figures of the next census, that of 1860, which gives white lead 36 establishments with 994 employees, capital $2,453,147, product $5,380,347; paints 50 establishments; varnish 48; total employees 991; and capital $3,711,450; product $286,675. Included in paints for 1860 is an establishment reported as making zinc paints, with a capital of $1,000,000, employing 100 people, the product being valued at $250,000. Also 4 establishments making zinc oxide, with a combined capital of $1,228,000, employing 141 people, the total product amounting to only $226,860. These remarkable cases show that even at that early date overcapitalization was not unknown, at least in the zinc industry, unless, as is probable, the entire capitalization of the New Jersey zinc-mining companies, which were then the sole producers, was entered as being employed in the manufacture of this by-product.

PAINT AND VARNISH: 1850 TO 1900.

YEAR.	Number of establishments.	Capital.	Wage-earners.	Value of products.
1850	68	$3,217,100	1,579	$5,466,052
1860	164	7,402,697	2,216	11,107,342
1870	224	13,949,740	3,504	22,512,860
1880	325	17,333,392	5,056	29,111,941
1890	522	45,818,146	10,588	54,233,681
1900	615	60,834,921	13,513	67,376,641

In order to make the figures for 1900 fairly comparable with those of the preceding censuses, only the establishments of Class A are taken into account, the capital, value of products, and total number of employees, office force as well as factory workers, being given. The table at the beginning of this special group report gives the true statistical position of this industry, but so far as can be learned no attempt was made in any former census to separate the products there given under Classes B and C.

The paint and varnish industry in this country had its beginning in the early part of the last century. In 1804 Samuel Wetherill & Son began the manufacture of white lead in Philadelphia, followed in 1806 by Mr. John Harrison, the founder of the present firm of Harrison Brothers & Co., of Philadelphia. At that time all of the white lead used in this country was imported, but was greatly adulterated and very high priced. A letter from Mr. W. H. Wetherill, of Wetherill & Brother, the successors of Samuel Wetherill & Son, states that the American manufacture of white lead was much opposed by the agents of the foreign manufacturers and that the factory started in 1804 was shortly after destroyed by fire and that "evidence was not wanting" that this was done "by an incendiary sent to this country for this purpose." In 1808 operations were again started against heavy foreign competition, which lasted until the War of 1812 which enabled the domestic manufacturers to get a solid footing. From that time the business rapidly increased.

According to an article by W. P. Thompson in One Hundred Years of American Commerce, 1895, page 436, by 1830 there were 12 establishments in the country, of which 8 were east of the Alleghenies. This author gives the white-lead production of the country by decades as follows:

WHITE-LEAD PRODUCTION: 1810 TO 1890.

YEAR.	Tons.	YEAR.	Tons.
1810	369	1860	15,000
1820	.....	1870	35,000
1830	3,000	1880	50,000
1840	5,000	1887	65,000
1850	9,000	1890	75,000

The manufacture of oxides of lead appears to have begun at about the same time as that of white lead, since by 1812 there were at least three establishments in Philadelphia. Both processes were very simple, litharge and red lead being made from the metal by regulated heating in a reverberatory furnace, while the white lead was made by the so-called Dutch process, which is still the favorite, the product being considered to be superior in quality to that made by any other process. While, as in everything else, skill is required to make a good grade of product in an economical manner, the process itself is so simple that the large number of white lead works reported for the census of 1850 may be explained by the development of the lead regions of Missouri and Illinois during the forties, as furnishing cheaper material, together with the idea, then probably prevalent, that anyone could make it, since it appeared to require only pots, lead, a little vinegar, and some spent tan bark.

The mixing of paints for sale naturally preceded the making of white lead, but there is no information available as to the beginning of such work. The first varnish factory, according to an article by D. F. Tiemann,[1] was founded by P. B. Smith, in New York in 1828, another early manufacturer being Christian Schrack, of Philadelphia, who began business as a maker of paints in 1816. The quality of the American varnishes proved so satisfactory that as early as in 1836 an export trade began. In 1857 D. F. Tiemann & Co. began making carmine from cochineal, and in 1860 soluble laundry blue and quicksilver vermilion, these products not having previously been made here. At present, American paint and varnish products enjoy a large and increasing foreign demand, and although the census returns for 1900 show that the great increase in the cost of materials during the census year has decreased profits, still the general condition seems to be a satisfactory one.

The foreign commerce in paints and varnishes for the United States is exhibited in the following tables, compiled from "The Foreign Commerce and Navigation of the United States," for the years ending June 30, 1891–1900.

[1] One Hundred Years of American Commerce, 1895, Vol. II, page 621.

PAINTS, PIGMENTS, AND COLORS: IMPORTS AND DOMESTIC EXPORTS, FOR THE YEARS ENDING JUNE 30, 1891–1900.

YEAR.	Imports, value.	Exports,[1] value.	YEAR.	Imports, value.	Exports,[1] value.
1891	$1,439,127	$690,698	1896	$1,309,041	$880,841
1892	1,372,052	709,857	1897	1,387,353	944,536
1893	1,466,761	700,308	1898	1,065,088	689,797
1894	980,715	825,987	1899	1,207,440	938,736
1895	1,246,924	729,706	1900	1,535,461	1,213,512

[1] Includes carbon black, gas black, lamp black, and oxide of zinc, prior to 1898

VARNISHES, SPIRITS, AND ALL OTHER, IMPORTS AND DOMESTIC EXPORTS FOR THE YEARS ENDING JUNE 30, 1891–1900.

YEAR.	IMPORTS.		EXPORTS.	
	Gallons.	Value.	Gallons.	Value.
1891	35,073	$97,298	153,365	$203,285
1892	38,737	101,692	215,266	293,059
1893	41,216	111,675	210,067	258,400
1894	20,337	54,746	226,760	282,278
1895	39,095	106,927	256,890	303,959
1896	40,644	105,551	335,979	362,975
1897	62,665	159,024	409,569	431,761
1898	32,848	79,702	398,841	422,693
1899	33,227	79,461	436,817	463,547
1900	43,743	103,985	588,545	620,104

GROUP XIV.—EXPLOSIVES.

This industry, which, as measured by the value of the output, is the fifth in importance among the industries classified under chemical products, has shown a most promising growth during the last decade, as presented by the returns of the Census of 1900, for 97 regular establishments in 21 different states were engaged in the production of explosives. These establishments employed $19,465,846 of capital and 4,502 wage-earners, and produced 215,590,719 pounds, having a value of $16,950,976. They were distributed as follows:

GEOGRAPHICAL DISTRIBUTION OF EXPLOSIVES FACTORIES: 1900.

STATES.	Number of establishments.	Value of products.	Per cent of total.
United States	97	$16,950,976	100.0
Maine, Massachusetts, Connecticut, and Vermont	5	654,862	3.9
New York, New Jersey, Pennsylvania, Delaware, Virginia, and West Virginia	54	6,846,212	40.4
Alabama, Tennessee, Missouri, and Kansas	6	1,447,100	8.5
Iowa, Indiana, Illinois, Ohio, Michigan, and Wisconsin	25	3,728,249	22.0
California	7	4,274,553	25.2

These factories were most numerous in the sections where mining or engineering operations were carried on most extensively. Though Pennsylvania had 36 factories and the largest output was in the Middle Atlantic states, yet California alone manufactured over one-fourth of the entire annual output, and was much the largest producer in the United States. In addition to these establishments 5 were reported idle, 1 in operation with less than $500 in value of products, and 2 belonging to the United States Government that were in active operation during the census year, making 80,000 pounds of explosives, having a value of $60,506.

The growth of this industry may be shown by a comparison of the returns at the various censuses for which reports have been recorded. In compiling this data it was observed that the different methods of collecting and reporting the statistics would not permit of a comparison in every detail, yet so far as it can be made it is very instructive. It was also borne in mind that while up to 1860 the data of the explosives industry were for gunpowder alone, in that year blasting powder was included, in 1870 nitroglycerine, in 1880 dynamite, in 1900 smokeless powder, and for several of these decades, variable small amounts of guncotton, fulminate of mercury, and perhaps other explosives. The returns for seven decades are as follows:

TOTAL PRODUCTION AND VALUE OF EXPLOSIVES, BY DECADES: 1840 TO 1900.

YEAR.	Number of establishments.	Capital.	Average number of wage-earners.	PRODUCTS.	
				Pounds.	Value.
1840	137	$875,875	496	8,977,348	.....
1850	54	1,179,223	579	.....	$1,590,332
1860	58	2,305,700	747	.....	3,223,090
1870	36	4,099,900	973	.....	4,237,539
1880	54	6,585,185	1,340	.....	5,802,029
1890	69	13,539,478	2,353	98,645,912	10,993,131
1900	97	19,465,846	4,502	215,980,719	[1] 16,950,976

[1] This value is for the explosive substances only. When materials of all kinds produced in these establishments are included the value is $17,125,418.

A better idea of the industry may be had by the discussion of each of the products so far as the statistics will permit. This is done for gunpowder (blasting powder being included in this term) in the following table:

PRODUCTION AND VALUE OF GUNPOWDER, BY DECADES: 1840 TO 1900.

YEAR.	Number of establishments.	Capital.	Average number of wage-earners.	PRODUCT.	
				Pounds.	Value.
1840	137	$875,875	496	8,977,348	.....
1850	54	1,179,223	579	.....	$1,590,332
1860	58	2,305,700	747	.....	3,223,090
1870	33	4,060,400	939	.....	4,011,339
1880	33	4,983,560	1,011	.....	3,348,941
1890	37	9,609,975	1,622	95,019,174	6,740,099
1900	47	8,297,773	1,708	123,314,103	5,310,351

Gunpowder.—Although since the Eleventh Census smokeless powder has come to be used for military and sporting purposes, 1 pound, speaking roughly, replacing 3 pounds of black gunpowder, yet the amount of black gunpowder produced and consumed is still large, and it bids fair to be so for some years to come. This is due to several causes, among which are the following: First, because in ordnance it is necessary to use a priming charge of black gunpowder with which to fire the smokeless powder. Second, because smokeless powder can not be efficiently substituted for black gunpowder in the older forms of small arms that are widely scattered over the country. Third, because black powder is most suitable for use in fuses and in pyrotechnics. Fourth, because smokeless powder is too expensive, and in no way superior to black gunpowder for saluting purposes. From the returns it is found that in the census year there were 10 establishments in 9 different states making black gunpowder, and that they employed $3,397,288 of capital, and 556

wage-earners, and produced 25,638,804 pounds of powder, having a value of $1,452,377. In making this there were consumed 8,614 tons of potassium nitrate (India saltpeter), 174,810 bushels of charcoal, and 1,282 tons of refined sulphur. About 6,800 tons of the potassium nitrate were made by conversion of sodium nitrate with potassium chloride, consuming 5,700 tons of sodium nitrate (Chile saltpeter). The wood employed for the making of the charcoal was willow, alder, or dogwood, and the yield of charcoal was about 25 per cent by weight of the air-dried wood.

While the composition of gunpowder may vary somewhat, the formula usually followed for black gunpowder is 75 per cent of potassium nitrate, 15 per cent of black charcoal, and 10 per cent of sulphur. In recent years brown prismatic powder has been used in heavy ordnance of the general composition of 78 per cent of potassium nitrate, 20 per cent of charcoal, and 3 per cent of sulphur, in which the "charcoal" was underburned charcoal from peat or rye straw, or in which carbohydrates were used, but such gunpowder has been almost, if not completely, displaced.

The manufacture of gunpowder is a very old one, this material having been used as a propellant in cannon at the battle of Crecy in 1346. It was manufactured in the United States prior to and during the Revolutionary War by means of stamp mills which consisted of mortars and pestles of wood and bronze by which the ingredients were pulverized and mixed, the damp material being grained by rubbing through sieves. This method produced not only a very coarsely made and irregularly acting powder but it was very dangerous, as, for instance, according to Chaptal, in France about one-sixth of the total stamps at work blew up annually. In 1787, Cossigny introduced at the Isle de France the practice of pulverizing and mixing the ingredients in wheel mills. In 1791, Carny devised the method of pulverizing in drums, wheel mills being used for incorporating the mass. During the latter part of the Eighteenth century the manufacture of gunpowder was brought to a high degree of perfection in France by the eminent chemist Lavoisier, who had supervision of the Government powder works.

The modern methods of manufacture in the United States began with the founding of the works at Wilmington, Del., in 1802, by Eleuthére Irenée du Pont de Nemours, who had learned powder making from Lavoisier, and who obtained from France the most approved machinery; and these works, constantly growing, have been in regular operation up to the present time, and the methods and kinds of machinery employed have been introduced into the mills subsequently erected elsewhere in this country.

The more recent improvements have been in the introduction of retorts for burning the charcoal, the manufacture of the saltpeter by conversion, and the devising of various forms of press mills. The method of manufacturing potassium nitrate from sodium nitrate by metathesis with potassium chloride was suggested by Longchamps, Anthon, and Kuhlmann in 1859, and was adopted at the Dupont works about 1868. With the large deposits of sodium nitrate available in Chile and potassium chloride accessible at Stassfurt, in Germany, this artificial source for saltpeter successfully competed with the native sources in India, where the supply is limited. This method of manufacture of potassium nitrate has also so reduced the cost of the article as to remove all temptation to continue the vicious system of niter plantations, which robbed the soil of one of its most valuable plant foods.

Blasting powder.—This industry, which is a development of the last century, was pursued during the last census year in 37 different establishments, located in 13 different states, the state of Pennsylvania alone having 19 separate works. There was employed $4,900,485 of capital, and 1,153 wage-earners, and the product amounted to 97,744,237 pounds of powder, having a value of $3,880,910. In the manufacture of this powder there were consumed 38,000 tons of sodium nitrate (Chile saltpeter), 746,000 bushels of charcoal, and 5,100 tons of sulphur.

Between 1802 and 1840 two large gunpowder factories, as well as a few smaller ones, were established in the United States. The active construction of canals and the exploitation of mines caused a considerable and growing demand for gunpowder for use in blasting, which eventually became so marked that to meet it the powder makers placed a "blasting powder" upon the market, which contained the same ingredients as black gunpowder except that they were not so carefully purified and the powder was less carefully made. In 1856 the material now commonly known as blasting powder was made, and it differs from the older blasting powder chiefly in the fact that the expensive potassium nitrate (India saltpeter) of the latter is replaced by the cheap sodium nitrate (Chile saltpeter). For some years prior to the above date, the idea of using sodium nitrate had obtained, but the fact that it was a deliquescent substance had proved an obstacle; yet the difficulties which were supposed to be insurmountable were overcome, and in 1856 its manufacture was begun on a large scale by the leading powder makers. A patent for a gunpowder containing sodium nitrate was granted to L. Dupont in 1857, and upon this an enormous industry, not only in the United States but throughout the world, has been built, and through it an additional impetus has been given to engineering and mining operations. Furthermore, this increased consumption of Chile saltpeter led to an increased development of the enormous deposits of this salt in the desert of Tarapaca, which so cheapened the nitrate as to benefit and stimulate the nitric acid, fertilizer, and many other industries in which this material is used.

The proportions of the ingredients in blasting pow-

der may vary widely. Thus the census returns for 1900 showed gunpowders composed of 67.3 per cent of sodium nitrate, 22.9 per cent of carbon, and 9.4 per cent of sulphur, up to powder composed of 77.1 per cent of sodium nitrate, 8.6 per cent of carbon, and 14.3 per cent of sulphur. Guttman, in his "Manufacture of Explosives," gives a powder consisting of 60.19 per cent of sodium nitrate, 21.36 per cent of charcoal, and 18.45 per cent of sulphur. From a large number of returns we find the average composition to be 74 per cent of sodium nitrate, 16 per cent of charcoal, and 10 per cent of sulphur.

Blasting powder is usually put upon the market in corrugated iron kegs, holding 25 pounds each.

Nitroglycerin.—Nitroglycerin appeared for the first time among the chemical products of the United States in the census returns for 1870, but in 1890 it disappeared under the legend "high explosives," which term usually includes dynamite, gun cotton, nitrosubstitution explosives, and fulminates. While the larger part of the nitroglycerin made is subsequently consumed in the manufacture of dynamite, blasting gelatine, and smokeless powder, there is still a quantity made and sold as such. For the census year 1900 there were 22 establishments located in 6 different states, employing $293,881 of capital and 105 wage-earners. The product amounted to 3,618,692 pounds and had a value of $783,299. There were consumed in its manufacture 1,897,448 pounds of glycerin and 12,134,869 pounds of mixed acids.

In addition to the nitroglycerin produced and sold as such, 31,661,806 pounds were made and consumed, and there were required to make it 15,043,483 pounds of glycerine and 96,092,451 pounds of mixed acids. The total production of nitroglycerin, therefore, for the census year was 35,482,947 pounds, and there were used as materials 16,983,918 pounds of glycerin and 108,227,320 pounds of mixed acids. Although all but two of the factories purchased their sulphuric acid originally, many of them regained their spent acids and some of them manufactured their nitric acid. The quantity of acid reported as regained was 15,916,907 pounds, and of nitric acid manufactured, 26,058,779 pounds. There were consumed in the manufacture of this nitric acid 19,817 tons of nitrate of soda and 28,177,000 pounds of 66° sulphuric acid, but much of the latter was regained acid.

The production of nitroglycerin for 1900 as compared with that reported in previous decades is set forth in the following table:

PRODUCTION OF NITROGLYCERIN FOR THREE DECADES, 1870, 1880, AND 1900.

YEAR.	Number of establishments.	Capital.	Average number of wage-earners.	PRODUCT.	
				Pounds.	Value.
1870	3	$39,500	34	.....	$225,700
1880	19	1,601,625	329	3,039,722	1,830,417
1900	22	293,881	105	3,618,692	783,299

Nitroglycerin was discovered by Ascanio Sobrero in Turin, Italy, in 1847, and it is interesting to note that upwards of 7 ounces of the first nitroglycerin made by Sobrero are still kept at the Nobel dynamite factory at Avigliana, in Italy, and are tested every year. Its commercial manufacture seems to have been begun by Alfred Nobel, in Sweden, in 1862, and in 1863 he received his first patent in this art for a mixture of ordinary gunpowder with nitroglycerin, he having at first employed gunpowder as a means of exploding the nitroglycerin. In 1863, however, he discovered that nitroglycerin could not only be exploded with certainty by means of a copper capsule containing mercuric fulminate (now known as a blasting cap or detonator), but that the power developed by the nitroglycerin was enormously greater than could be obtained from it by any other means, and this discovery marked an epoch, not only in the history of nitroglycerin, but in that of all high explosives, since it revealed the method of inducing explosion by detonation.

So near as can be ascertained, the manufacture of nitroglycerin in the United States began at the Giant Powder Company's works in California, in 1867, using Nobel's methods. In 1867 George M. Mowbray also began the manufacture, by independent methods, at North Adams, Mass. Mr. Dupont says:[1]

> There are two engineering works which indicate very well the era of the introduction of high explosives in this country. In the year 1870 the Nesquehoning tunnel, near Wilkesbarre, was excavated in very hard rock by the use of black powder only. The engineers in charge were unwilling to introduce the then new and untried explosive. The work was, however, completed in good form and very quickly, owing largely to the extensive use of compressed air drills. About the same time the Hoosac tunnel was completed, nitroglycerin alone being used in the work. This explosive was principally manufactured upon the ground, and was much used in the liquid state. This work was a greater one than the tunnel first mentioned, but the two serve to mark the transition period in the practical use of explosives. One of the greatest of modern engineering works, the Chicago drainage canal, is now (1895) being carried on largely by high explosives. It is an example of the magnitude of the work that is attempted with explosives.

Nitroglycerin is manufactured by mixing glycerin with a mixture of nitric acid and sulphuric acid. Each of the materials used is the most concentrated that can be made, and the demand for large quantities of nitric and sulphuric acids and glycerin of the highest grades which has been created by the high-explosives industry has had a marked effect on the development of the acid and glycerine industries. The acids are usually mixed in the proportion of 3 parts by weight of sulphuric acid to 2 parts by weight of nitric acid, and they should contain 61.9 per cent of H_2SO_4 and 34.5 per cent of HNO_3, with not more than 0.7 per cent of N_2O_3. These previously mixed acids are sent out from the acid works in iron drums holding about 1,500 pounds, and this weight of mixed acids makes a convenient charge for one run in the nitroglycerin converter, from 210 to 230 pounds of glycerin being there mixed with it.

[1] One hundred years of American Commerce, Vol. I, page 192.

The reaction goes on between the glycerin and the nitric acid, the sulphuric acid present serving chiefly to take up and retain the water which is one of the products of the reaction. When the reaction is completed the materials are run into a tank, where they rest until, owing to their differences in specific gravity, the nitroglycerin and spent acids form into separate layers; then the nitroglycerin is run off into washing and purifying tanks, and the acids are run off to be reworked. The dilute nitric acid thus obtained is sometimes used in the manufacture of ammonium nitrate for use in dynamite dopes. The diluted sulphuric acid is sometimes used in the manufacture of nitric acid, but it is more often concentrated in iron pans, and, after being mixed with strong nitric acid, again used in making nitroglycerin. This spent acid averages in composition 72 per cent of sulphuric acid, 10 per cent of nitric acid, and 18 per cent of water. Theoretically, 100 parts by weight of glycerin should yield 246 parts of nitroglycerin, but in practice the yields are from 200 to 220 parts.

Nitroglycerin is used directly in torpedoes, which are cylinders holding 20 quarts each, for "shooting" oil wells. It also is used in medicine as a heart stimulant. The principal use of nitroglycerin is in making dynamite and blasting gelatin.

Gun Cotton or Pyroxylin.—By the returns for the census of 1900 there were 10 establishments in 3 different states engaged in the manufacture and sale of cellulose nitrates, for various uses and they employed $255,343 of capital and 163 wage-earners. There were produced 922,799 pounds of the various cellulose nitrates, having a value of $486,773, and there were consumed 691,115 pounds of cotton and 8,247,668 pounds of mixed acids. Besides these there were produced and consumed in other establishments 2,739,834 pounds of cellulose nitrates, making a total product for the year of 3,662,633 pounds.

Gun cotton, or pyroxylin, is the name given to various cellulose nitrates which were discovered by Schönbein in 1846, and which result from the reaction between nitric acid and cellulose. There is a considerable number of cellulose nitrates; authorities differ as to their number. In fact, there is still doubt as to the real constitution of cellulose, and therefore nothing can be pronounced with certainty as to the constitution of the nitrates produced from it. However, it is generally accepted that the formula of cellulose is some multiple of $C_6H_{10}O_5$, and that the nitrates are produced by replacing one or more atoms of the hydrogen present by NO_2. It is also accepted, following Vieille, that, taking the formula as $C_{24}H_{40}O_{20}$, there may be at least 8 different cellulose nitrates in which from 4 to 11 groups of NO_2 have been introduced into the molecule. In the following table these different nitrates are so named as to indicate the number of NO_2 groups present, and there is also shown the per cent of N present in each.

CELLULOSE NITRATES.	Per cent of nitrogen.	Weight obtained from 100 parts of cellulose.
Cellulose endecanitrate	13.47	176.4
Cellulose decanitrate	12.75	169.4
Cellulose enneanitrate	11.96	162.5
Cellulose octonitrate	11.11	155.7
Cellulose heptanitrate	10.18	148.6
Cellulose hexanitrate	9.15	141.7
Cellulose pentanitrate	8.02	134.7
Cellulose tetranitrate	6.76	127.8

In addition to these nitrates containing different per cents of nitrogen, there are undoubtedly isomers of many of them. According to their difference in nitrogen contents, or in intermolecular arrangement, these nitrates exhibit different degrees of solubility toward organic solvents, and are in consequence put to different commercial uses. Thus the higher ones are, under ordinary conditions, insoluble in a mixture of 2 parts of strong ethyl ether and 1 part of strong ethyl alcohol, and such cellulose nitrate is called gun cotton. On the other hand, the lower nitrates are soluble in the mixed solvent named under these conditions, and these cellulose nitrates are called pyroxylin. It should be said that later researches tend to show that, according to the conditions under which they are nitrated or the conditions under which they are exposed to the solvent, the higher nitrations are acted upon by the ether-alcohol solvent.

Cellulose nitrates are prepared by immersing purified cotton in mixtures of nitric and sulphuric acid. In making gun cotton, the acid mixture consists of 1 part, by weight, of nitric acid of 1.5 specific gravity to 3 parts, by weight, of sulphuric acid of 1.845 specific gravity, and 1 pound of steam-dried cotton is immersed in and digested for twenty-four hours with 12 pounds of this acid mixture. The acid is then wrung out and the gun cotton is pulped, washed, and compressed into blocks for use. The spent acids which are thrown out in the wringing have been found to contain 79.91 per cent of H_2SO_4, 9.52 per cent of HNO_3, 1.04 per cent of N_2O_4, and 9.65 per cent of water, and they are reworked to be used again. In making the lower cellulose nitrates weaker acids are used, the strength being determined by the use to which the nitrate is to be put. Examples of such acid mixtures are given under smokeless powder and under pyroxylin plastics.

Cellulose nitrates are used for many purposes in the arts. Finely pulped, compressed material, consisting principally of the highest nitration, is known as gun cotton and is used in military mines and torpedoes, and for destructive purposes generally in military operations. Owing to the discovery by E. O. Brown, of Woolwich, in 1868, that it can be detonated when wet, it is now stored and used while saturated with water. In 1847 or 1848 Doctor Maynard, of Boston, discovered that pyroxylin was soluble in ether-alcohol and that the liquid, called "collodion," could be used as a vehicle for medicine and as a substitute for sticking

plaster. In 1851 Frederick Scott Archer invented the process of coating photographic plates with collodion. In 1869 John W. Hyatt, Jr., and Isaiah S. Hyatt, of Albany, N. Y., invented the process for manufacturing "celluloid" from cellulose nitrate. Still later, Frederick Crane invented pyroxylin varnishes, and Chardennot invented a process for making artificial silk from pyroxylin. A large use for cellulose nitrates is in the manufacture of smokeless powder, explosive gelatine, and gelatine dynamite. By the use of pyroxylin solutions a form of artificial leather is obtained.

Dynamite.—This explosive first appears in the report of the census of 1880, and then amounted in value to but one-third of that for the nitroglycerin produced. According to the census of 1900, there were 31 different establishments, located in 8 different states, employing $7,551,121 of capital, and 1,758 wage-earners engaged in the manufacture of dynamite. There were produced 85,846,456 pounds, having a value of $8,247,223, and there were consumed in making it, 31,661,806 pounds of nitroglycerin, 20,090 tons of sodium nitrate, 9,934,360 pounds of wood pulp, 82,558 pounds of pyroxylin, and 483,975 pounds of ammonium nitrate.

The production and value of dynamite for 1900, compared with that reported in previous decades, is set forth in the following table:

PRODUCTION OF DYNAMITE, BY DECADES: 1880 to 1900.

YEAR.	Number of establishments.	Capital.	Average number of wage-earners.	PRODUCT.	
				Pounds.	Value.
1880	2	.....	.....	.....	$622,671
1890	32	$3,929,503	731	30,626,738	4,253,032
1900	31	7,551,121	1,758	85,846,456	8,247,223

Dynamite was invented by Alfred Nobel in 1866, and its manufacture began shortly after at the various works established by him. In his testimony before the select committee on explosive substances of the British Parliament, in 1874, Nobel testified that there were then 13 factories, in which he was interested, engaged in this manufacture, 2 of them being in America, while there were many independent works in addition. The returns for dynamite were not so rendered in the prior census reports that the growth of this important industry can be readily ascertained, but some general idea of its growth may be gained from the following table, given by George McRobert, setting forth the annual sales of dynamite for each of sixteen years, from the factories with which Nobel was associated.

McROBERT'S TABLE.

YEAR.	Sales, tons.	YEAR.	Sales, tons.
1867	11	1875	3,500
1868	78	1876	4,300
1869	184	1877	5,500
1870	424	1878	6,200
1871	785	1879	7,000
1872	1,350	1880	7,500
1873	2,050	1881	8,500
1874	3,120	1882	9,500

Dynamite is a material of most variable composition. It consists of a solid porous absorbent which holds the liquid nitroglycerin, and its invention was a necessity, since so many frightful accidents due to the liquid state of nitroglycerin led to legislation in Europe which forbade the transportation and use of the latter explosive. Kieselguhr (known as infusorial silica) was largely used at first, and is still much used in Europe, as the absorbent, but this "dope," as the absorbent base is called, is almost entirely replaced in this country by an explosive dope, which is most frequently a mixture of wood pulp and sodium nitrate, with a very small percentage of calcium or sodium carbonate to act as a neutralizer to any acid present. Such a dynamite is known as a straight dynamite, but there are others which contain a dope of coarsely made gunpowder or of resinous compositions. In 1875 Nobel invented an explosive made by dissolving pyroxylin or soluble cellulose nitrate in nitroglycerin until, when the mixture was cool, it set to a jelly-like mass which is known as explosive or blasting gelatin. This is often mixed with wood meal or wood pulp, and then gelatin dynamite is produced. As may be inferred, dynamites vary greatly in their nitroglycerin contents, and they may be found on the market containing from 5 per cent, as in a bank blasting powder, up to 94 per cent, as in a blasting gelatin. The grade which is probably the most extensively used is that known as 40 per cent dynamite, and analysis has shown a straight dynamite of this grade to contain of nitroglycerin 39.8 per cent, sodium nitrate 46.1 per cent, wood pulp 11.5 per cent, calcium carbonate, 0.7 per cent, moisture 1.9 per cent. It can be safely assumed that 40 per cent is the average nitroglycerin content of the dynamites of all kinds put on the market.

Dynamite as sold is usually loaded into paraffined paper cases, thus making it into "sticks" or "cartridges." These sticks may vary much in size, but the average stick will be 8 inches in length by 1½ inches in diameter, and they are packed in sawdust in boxes holding 50 pounds each.

Smokeless Powder.—At the time the Eleventh Census was taken no smokeless powder was reported, nor was there then any factory in operation for its regular production, while for the census year 1900 there was an output of 3,053,126 pounds of powder having a value at the works of $1,716,101. This industry, which is wholly a growth of the last ten years, embraced 9 factories, having $2,153,958 of capital, gave employment to 730 wage-earners, and consumed 14,000,000 pounds of mixed acids, 1,600,000 pounds of cotton, 2,600,000 pounds of alcohol, 1,400,000 pounds of ether, 143,000 pounds of acetone, and 88,000 pounds of nitroglycerin. There is little doubt that the growth will be much more rapid in the immediate future, as smokeless powder is rapidly supplanting black gunpowder for military and sporting purposes, and, as a large part of the time during the last ten years has been spent in the invention of machinery for handling the materials, in planning

works so as to secure the maximum of safety with the maximum of speed and economy in manufacture and in the devising of means for the recovery and renewal of the spent acids and solvents.

The very earliest manufacture of smokeless powder in the United States was carried on by Charles Lennig, at Philadelphia, Pa., about 1850. His small-arm charges were made of long staple, fibrous gun cotton, and, as elsewhere, they were found to be so dangerous that their use was soon abandoned. The next factory to be started was erected by Carl Dittmar, at Quincy, Mass., about 1870, where a soft, granulated powder was made, but this was also abandoned.

The first of the factories erected for the manufacture of modern smokeless powder was planned, erected, and operated at the United States Naval Torpedo Station at Newport, R. I., in 1890, by Charles E. Munroe, under the direction of Commander Theodore F. Jewell, United States Navy, inspector of ordnance, in charge of the station, and it is to-day in regular operation, having been much enlarged. Following this, 4 factories were erected in 1891, 1 in 1895, 1 in 1898, and 2 in 1900, all of which were producing during at least a part of the census year. These factories were scattered through 7 states, 3 of them being in New Jersey and 2 of them being factories belonging to and operated by the United States Government. The Government factories produced military powder only, 4 of the private factories produced sporting powder only, while the remaining private works, though manufacturing largely for military purposes, produced some sporting powder also.

The earliest recorded attempt to use a smokeless explosive as a propellant is found in the experiments of Howard, who in 1800 attempted to use mercury fulminate in place of gunpowder in a firearm, with the result that he burst the piece. Immediately after the discovery of gun cotton by Schönbein in 1846, extensive trials of it as a propellant were made in Germany, France, England, and the United States, but as it was then used in the ordinary fluffy or thread-like condition of cotton it proved too violent. In 1866 Frederick A. Abel devised a method for granulating gun cotton by introducing pulped nitrocellulose containing water and a small quantity of a binding material into a vessel to which a vibrating motion was imparted, thereby producing soft grains, but this does not seem to have come into vogue.

The first person to realize any considerable degree of success was Captain Schultze of the German army, who, in 1862, made a soft-grained powder from well-purified and partly nitrated wood. The first nitrocellulose powder to approach modern requirements was the E. C. powder, invented by Reid and Johnson in 1882, in which the soft grains, produced by rolling pulped nitrocellulose containing water in barrels were superficially hardened or waterproofed after granulation. The first successful military smokeless powder was made in France by Vieille, and it consisted of a hard, dense-grained flake, or fagot powder, made from nitrocelluloses mixed with a nitrate, like barium nitrate, and with or without picric acid. This was followed in 1888 by the ballistite of Nobel, and in 1889 by the cordite of Abel and Dewar, each of which was composed of mixtures of nitrocelluloses with nitroglycerine and a restrainer of some kind. The whole was worked, by admixture with suitable solvents and by use of the proper machinery, into grains which were hardened throughout. In 1889 Richard Von Freeden discovered that gelatinized nitrocellulose, still containing the solution employed for its gelatinization, on being exposed to certain liquids, or the vapors thereof, undergoes a kind of coagulation and division into small lumps, which latter is promoted by stirring, and upon this he based a method of manufacture by which small-grained powders that are hardened throughout could be produced, and the method is now quite extensively followed.

Up to this time all gunpowders throughout the world, both black and smokeless, were made of mixtures of various ingredients, even the smokeless powders, which were made from nitrocellulose only, being made from mixtures of cellulose nitrates of different degrees of nitration; but in 1889 Charles E. Munroe proposed that smokeless powders be made of a single chemical substance in a state of chemical purity, and he pointed out that cellulose nitrate, of uniform nitration, then offered the best material from which to produce such a powder, and this is the principle which to-day governs the manufacture of military smokeless powders, at least in the United States.

Although up to 1898 the United States Army proposed to use smokeless powder composed of nitrocelluloses and nitroglycerin, the United States Navy adopted in 1890 a cellulose powder of uniform nitrogen contents, and the Army followed in 1898. As made in 1898, the nitrocellulose used contained from 12.45 to 12.80 per cent of nitrogen. Such cellulose nitrate is made by dipping 1 pound of cotton (free from oil and mechanical impurities and containing about 7 per cent of moisture) in 19 pounds of "mixed acids," containing about 57 per cent of H_2SO_4, 28.2 per cent of HNO_3, and not more than two-tenths of 1 per cent of N_2O_4. The acid has an initial temperature of 25° C., and the crock containing the mixed acids and cotton is heated to 36° C., the cotton being exposed at this temperature, with one turning over of the cotton, for sixty minutes. After purification by wringing, washing, and steaming to remove the acid, the nitrocellulose is freed from the water remaining in it by extraction with alcohol, and it is converted into a gelatinous mass by kneading or stirring in a Werner and Pfleiderer mixing machine with a mixture of ethyl ether and ethyl alcohol, 2 parts by weight of ether and 1 part by weight of alcohol being used for every 3 parts by weight of nitrocellulose. The

subsequent processes have for their object the more intimate mixing of the material and straining off of the unconverted portions, the shaping of the mass into grains, and the drying of the grains. The finished grains still contain some of the solvent, particularly alcohol, the amount varying with the thickness of the walls of the grains. In the very smallest grains this amounts to about one-half of 1 per cent, while in the larger grains there may be as much as 4 per cent of solvent present.

It is not easy to check the data in this manufacture, and for this reason round numbers are given. It may be said, however, that 100 pounds of perfectly dry cotton will yield 169 pounds of this nitrocellulose, but the cotton as used may contain as much as 7 per cent of moisture, while the final product may contain from one-half of 1 per cent to 2 per cent of solvents. The quantities of acids can not well be checked, because the spent acid is "rebuilt" and used again. The difficulty is even greater with the solvents, since most of the works manufacture the ether used from part of the alcohol purchased or supplied to them besides reusing the recovered solvents. An additional complication in comparing costs arises from the fact that, when the powder is being made in private works for the United States Government, the manufacturer is permitted to use tax-free alcohol, while if he be making such powder for other parties he must use tax-paid alcohol. Where the Government supplies the alcohol, the weight of alcohol allowed is 1.4 times the weight of the finished powder.

The foregoing description is for military powder, and though picrates and metallic salts, such as nitrates and bichromates, are used to some extent in sporting powders, yet they are to so large an extent composed of nitrocellulose that they may be regarded for purposes of census classification as composed wholly of this material. The methods of manufacture are as a rule quite different from those employed in the making of military powders, and the gelatinizing agents used are ethyl acetate, amyl acetate, and the like, in place of ether-alcohol. It is to be noted that a small portion of the smokeless powder reported for the census year was a nitrocellulose-nitroglycerin powder, which had been gelatinized by acetone. Smokeless powder is usually sold in metal canisters holding 1 bulk pound each.

Fulminates.—Although charges of dynamite and other high explosives are invariably fired by detonators or blasting caps charged with mercuric fulminate, and, although percussion caps, friction primers, and fixed ammunition are also charged with this explosive, yet the amount of this most important and essential explosive which is returned as manufactured in the United States was quite insignificant. On the other hand, as shown by the following table, compiled from the records of the Bureau of Statistics of the United States Treasury Department, the importation of fulminate is assuming greater and greater importance as our home industry in other explosives grows, and this is shown even more markedly if to the values for the fulminates there be added those for the blasting caps, percussion caps, and cartridges that are also imported:

IMPORTS, FOR CONSUMPTION, OF FULMINATES, FULMINATING POWDERS, AND LIKE ARTICLES: 1884 TO 1900, INCLUSIVE.

YEAR.	Value.	YEAR.	Value.
1884	$487	1893	$48,509
1885	5,577	1894	42,567
1886	10,647	1895	65,891
1887	10,099	1896	77,197
1888	20,984	1897	76,515
1889	10,717	1898	46,703
1890	19,460	1899	103,741
1891	44,403	1900	105,999
1892	36,278		

The fact that, notwithstanding the dangers attendant on the transportation of this violent explosive substance, its home manufacture has been almost completely superseded by the foreign product, is explained on stating that it is manufactured from grain alcohol, mercury, and nitric acid; that for every 12 parts by weight of mercury fulminate produced 110 parts by weight of 95 per cent alcohol are consumed; and that the tax levied in the United States on alcohol makes the foreign commerce in this article a very profitable one, and home competition practically impossible.

Wage-earners and wages.—There were employed in the entire explosives industry 4,349 men, 117 women, and 36 children under 16 years of age. The wages for the men varied from $365 per annum in New Jersey to $790 per annum in California, the average for the whole country being $539 per annum. The average wage for women was $263 per annum, and for children $169 per annum.

Power.—The total horsepower reported as being employed in these factories was 22,920 horsepower, of which 5,674 horsepower was supplied by 190 water wheels, 13,242 horsepower by 315 steam engines, 2,885 horsepower by 177 electric motors, and 279 horsepower from other sources. The returns are chiefly interesting in marking changes in methods, for, formerly, in erecting black gunpowder works especial care was taken to secure a location for the works where there was an abundant water supply and plenty of wood for charcoal making; whereas, in the manufacture of the modern explosives, while a sufficient isolation to obtain security for the works and limit the damage resulting from accidental explosions is sought, yet readiness and convenience in transportation of the materials used and the goods manufactured are regarded as of the first importance. The improvements in the methods for generating, conveying, and transforming the energy in steam or electricity have now rendered it relatively safe to employ these sources of energy.

Imports and Exports.—A more nearly correct idea of

the condition of this industry may be obtained if there be added to the census statistics those for the imports and exports of explosives. The imports of fulminates have already been considered, and attention is now called to the statistics for the foreign commerce in all explosives as compiled from "The Foreign Commerce and Navigation of the United States for the year ending June 30, 1900," Vol. II.

IMPORTS OF GUNPOWDER, FULMINATES, AND ALL LIKE ARTICLES: 1891 TO 1900, INCLUSIVE.

YEAR.	GUNPOWDER.		All other explosives, fulminates, etc., value.	Total value.
	Pounds.	Value.		
1891	34,312	$19,148	$124,528	$143,676
1892	31,111	29,583	100,977	130,510
1893	78,306	68,974	124,661	193,635
1894	85,481	71,285	67,342	138,627
1895	104,990	84,882	96,940	181,822
1896	68,993	49,857	77,192	127,049
1897	87,921	63,722	98,727	162,449
1898	98,708	79,992	65,123	145,115
1899	44,405	29,824	160,620	190,444
1900	31,212	15,835	169,073	184,908

DOMESTIC EXPORTS OF GUNPOWDER AND OTHER EXPLOSIVES: 1891 TO 1900, INCLUSIVE.

YEAR.	GUNPOWDER.		All other explosives, value.	Total value.
	Pounds.	Value.		
1891	733,834	$88,676	$906,870	$995,546
1892	903,077	108,276	752,079	860,355
1893	885,263	105,547	755,966	861,513
1894	495,566	66,839	935,287	1,002,126
1895	972,271	102,885	1,174,396	1,277,281
1896	1,159,935	124,823	1,256,279	1,381,102
1897	1,086,465	118,001	1,437,317	1,555,318
1898	1,202,971	139,644	1,255,762	1,395,406
1899	1,504,624	181,642	1,350,247	1,531,889
1900	1,612,822	197,438	1,694,166	1,891,604

LITERATURE.

Powder and Explosives, by Francis G. Du Pont. One Hundred Years of American Commerce, I, 192.

The Manufacture of Explosives, Oscar Guttmann: Macmillan & Co., New York, 1895.

Report and Proceedings of the Select Committee on Gun Cotton, etc., 1871–1874: London, 1874.

Ascanio Sobrero, by Vincenzo Fino: Turin, 1889.

On the Manufacture of Dynamite, G. E. Barton. Jour. Amer. Chem. Soc., 19, 500–509. 1897.

Notes on Nitroglycerine, Dynamite, and Blasting Gelatine, George McRoberts. Philosophical Soc. of Glasgow, April 25, 1883.

Lectures on Chemistry and Explosives, Charles E. Munroe: Torpedo Station Print, 1888.

On the Development of Smokeless Powder, Charles E. Munroe. Jour. Amer. Chem. Soc., 18, 819–846. 1896.

Specifications for United States Navy Smokeless Powder. Proceedings U. S. Naval Inst., 24, 477–480. 1898.

Smokeless Powder, Lieut. Joseph Strauss, U. S. N. Proceedings U. S. Naval Inst., 27, 733–738. 1901.

Geschichte der Explosivstoffe, S. J. Von Romocki: Berlin, 1895.

Christian Friedrich Schönbein 1799–1868, by Kohlbaum & Schaer. Monographieen aus der Geschichte der Chemie IV Heft 1900, VI Heft 1901, Leipzig.

Group XV.—Plastics.

During the census year 8 establishments manufactured cellulose plastics and also engaged in the further manufacture of these plastics into articles of various sorts. The value of the plastics produced was $2,099,400. The total value of the plastics and of the finished articles was $3,063,673. There were employed a capital of $7,558,720, and 1,221 wage-earners. The growth of the industry can be shown only for the pyroxylin plastics, including the finished article as displayed in the following table:

PRODUCTION OF PYROXYLIN PLASTICS, BY DECADES, 1880 TO 1900, INCLUSIVE.

YEAR.	Number of establishments.	Capital.	Number of employees.[1]	Value of products.
1880	6	$1,214,000	736	$1,261,540
1890	12	3,158,487	1,023	2,575,736
1900	7	7,210,548	1,176	2,864,044

[1] For 1900 this means wage-earners only.

Pyroxylin Plastics.—The best known of all the pyroxylin plastics is "celluloid." The art of making pyroxylin plastics was begun in England when Alexander Parkes discovered, in 1855, that a solution of pyroxylin, mixed with other substances, could, after the solvent was evaporated, be made into a substance having the qualities of horn or ivory, and could then be easily molded or worked or colored as desired. He entered vigorously upon the manufacture of this substance, which he called "parkesine," and put on exhibition various articles made from it, but the enterprise did not succeed and was abandoned in 1867. About this time Daniel Spill began the making of what he styled "zylonite" from pyroxylin or zyloidin by treatment with solvents and admixture with other materials, but owing to the fact that quite fluid solutions were employed, and to the difficulty of getting rid of the excess of the solvents, the operations were not commercially practicable.

In 1869, John W. Hyatt, Jr., and Isaiah S. Hyatt, of Albany, N. Y., made the important discovery that camphor by itself is a solvent for pyroxylin, if, after the camphor has been mixed with the pyroxylin, the mixture be heated to from 150° to 200° F. and subjected at the same time to a heavy pressure, and that the product can be worked like rubber. To this discovery, for which United States Patent No. 105338, July 12, 1870, and its reissues were granted, to the process which those inventors based on it, and to the knowledge and skill which were developed by its practice, is due the present commercial success of pyroxylin plastics.

The Hyatt Brothers began the manufacture of celluloid in a small way at Albany, N. Y., in 1869, but capital was soon interested in the venture, and in 1870 the business was removed to Newark, N. J., where the Cel-

luloid Manufacturing Company has since remained in active operation. It had so expanded in 1896 that the floor space occupied at the factory was nearly eight acres in extent, and it is claimed that over 6,000 persons throughout the country were employed, either in producing the celluloid, or shaping the product of this factory into various articles.

The manufacturing operations at the factory involve the production of the pyroxylin, its conversion into celluloid, and the manufacture of part of the product into wearing apparel and toilet and fancy articles. According to Field, the pyroxylin is made by dipping cotton or tissue paper into a mixture of sulphuric acid 66 parts, nitric acid 17 parts, and water 17 parts, 100 pounds of the acid mixture being used for 1 pound of the paper, and the immersion being continued from twenty to thirty minutes at 30° C. The pyroxylin used in this art is of low nitration, containing about 10.18 per cent of nitrogen.[1] The purified pyroxylin is mixed with camphor by sprinkling it with a solution of camphor in wood alcohol, and incorporating the mass with other desired ingredients on steam-heated maxillating rolls. The solid celluloid which is thus obtained, and which is a composition of pyroxylin with camphor, an ant-acid, and coloring matter, is then shaped by cutting into sheets, stuffing through die plates, molding under pressure while hot, turning, and the like, into various objects.

Celluloid is used in making collars and cuffs; piano and organ keys; billiard balls; paper cutters; combs; backs for brushes and hand mirrors; handles for canes, umbrellas, whips, and cutlery; mouthpieces for pipes, cigarette and cigar holders; chessmen; dolls' heads and other toys; electrotype plates, and a great variety of other articles of adornment and use.

Viscose.—This body represents the most recent development in the production of plastic bodies from cellulose, and was invented by C. F. Cross, E. J. Bevan, and C. Beadle, to whom United States Patent No. 520770, of June 5, 1894, was issued. In the manufacture, purified cotton is treated with an excess of a 15 per cent solution of sodium hydroxide and squeezed until it retains about three times its weight of the solution. It is then placed in a vessel with carbon disulphide, the quantity used being about 40 per cent of the weight of the cotton. After digestion for about three hours at the ordinary temperature, sufficient water to cover the mass is added and digestion allowed to proceed overnight, when, on stirring, a homogeneous liquid is obtained, which is a solution of cellulose thiocarbonate, or xanthate, and from which a jelly or coagulum of cellulose is produced by spontaneous decomposition, by precipitation with dehydrating agents, or by heating the solution. By incorporating viscose with mineral matters, hydrocarbons, and like substances, solid aggregates are produced which may be cast or molded into convenient forms, and after purification and sufficient aging made available for various structural uses. More recently these investigators have found the cellulose tetracetate to be especially suitable for the formation of viscose.

Other Plastics.—Many plastic substances are now made from caoutchouc, gutta-percha, casein, fibrin, gluten, and like bodies which act as gelatinizing or cementing agents, by which the zinc oxide, antimony sulphide, kaolin, and other fillers are held in solid aggregations which may be molded or shaped with lathes and other tools as desired.

The foreign commerce in the pyroxylin plastics, as compiled from the Foreign Commerce and Navigation of the United States for the year ending June 30, 1900, Vol. II, is set forth in the following table:

IMPORTS AND EXPORTS OF PYROXYLIN PLASTICS, 1891 TO 1900, INCLUSIVE.

YEAR.	Imports, value.	Exports, value.
1891	$10,595	.....
1892	43,353	$39,004
1893	57,062	86,597
1894	96,977	85,234
1895	371,873	72,926
1896	337,862	146,354
1897	262,675	149,631
1898	160,836	155,444
1899	249,619	173,771
1900	378,583	174,310

LITERATURE.

Pyroxylin, Its Manufacture and Applications, by Walter D. Field, J. Am. Chem. Soc., vols. 15 and 16, 1893 and 1894.

Das Celluloid, by Fr. Böckmann, Leipzig, 1880.

Cellulose, by Cross and Bevan, London, 1895.

Researches on Cellulose, 1895–1900, by Cross and Bevan, London, 1901.

Group XVI.—Essential Oils.

Though one of the less important, as measured by the value of the product, this is one of the oldest of the chemical industries, and it received recognition as a distinct industry in census statistics so long ago as 1860. It appears, however, that there have been varying views at the several censuses as to what substances should properly be placed under this classification. For the census of 1900, there are included in this report, under this title, all those bodies reported as having been manufactured in the United States during the census year, that are usually included in the text-books and treatises under the legends "volatile oils" or "essential oils," except vanillin, and oil or spirits of turpentine, which was made the subject of a special census report, while in addition witch-hazel is included. In this classification, then, there are, for the year ending June 1, 1900, 100 establishments in 14 states, engaged wholly or chiefly in the production or refining of these oils. Of these, 30 establishments produced a product of less than

[1] See Explosives: Gun Cotton or Pyroxylin, ante, page 73.

$500 in value. These 100 establishments employed $622,385 of capital and 201 wage-earners, and the value of their products was $850,133. In addition, there were 3 establishments which produced $9,268 of essential oils as a subordinate product. As pointed out, there is included here the refined natural oils and the crude natural oils, and in addition the artificial oils. These last named are manufactured by 4 establishments, employing $33,720 of capital and 13 wage-earners, and they reported $54,450 in value of products. The vanillin industry, which is classified with "fine chemicals," returned 124,874 ounces of the product, having a value of $113,050. This was manufactured in 4 establishments, and gave employment to 26 wage-earners and $65,689 of capital. The product of refined natural oils for 1900 amounted in value to $370,500. The establishments for the production of the crude natural oils were distributed as follows:

GEOGRAPHIC DISTRIBUTION OF CRUDE ESSENTIAL OIL FACTORIES: 1900.

STATES.	Number of establishments.	Average number of wage-earners.	Capital.	Product.	Per cent of total.
United States	97	167	$426,892	$434,451	100.0
Connecticut	5	8	65,500	45,530	10.5
New York	11	15	183,675	249,150	57.4
Virginia	15	31	15,149	38,165	8.8
Indiana	10	14	20,050	14,893	3.4
Michigan	28	91	107,509	70,126	16.1
New Hampshire, Vermont, Massachusetts, Pennsylvania, North Carolina, Florida, Tennessee, Illinois, Wisconsin, and California	28	8	35,009	16,587	3.8

This tabular view shows that though this industry was widely distributed, it did not attain to any magnitude except in the states of New York, Michigan, Connecticut, and Virginia, and that in these states, as elsewhere, it was carried on by a large number of persons in a very small way. In fact it is usually carried on as an employment accessory to farming, the farmers taking advantage of the idle time between seasons to gather roots, herbs, bark, and leaves, and by means of a simple and often portable still (which is frequently erected for the time being in the woods near where the material is gathered) extracting their essential oils. This accounts for the small number of wage-earners in proportion to the number of establishments reported, as the farmer, in a large number of instances, carries out all the operations without hired labor. The character of the industry and the methods employed are especially illustrated by the great variety of products reported, for there are, among others, returned and combined in the values given in the table, the natural oils of peppermint, spearmint, erigeron (fleabane), pennyroyal, wormwood, tansy, fireweed, golden rod, wintergreen, black birch, sassafras, spruce, cedar, juniper, and witch-hazel.

The peppermint-oil industry was confined principally to Michigan, Indiana, and New York, there having been 95,000 pounds produced in these three states; the sassafras-oil industry was located principally in Virginia, where 104,931 pounds of this oil were produced; the wintergreen-oil industry was located chiefly in Pennsylvania, where 2,075 pounds were reported as having been produced; and the witch-hazel industry was located chiefly in Connecticut and New York, where 110,260 gallons of this substance, having a value of $54,649, were produced.

As previously stated, the methods of classifying this industry, as well as the methods used for collecting the statistics, have varied somewhat in the different censuses, but they have been sufficiently consistent for the last three decades to admit of the comparison made in the following table:

TOTAL PRODUCTION OF ESSENTIAL OILS (CRUDE) BY DECADES, 1880 TO 1890, INCLUSIVE.

YEAR.	Number of establishments.	Capital.	Average number of wage-earners.	Value of product.
1880	124	$67,755	278	$248,858
1890	67	102,223	191	255,847
1900	97	426,892	167	434,451

The increase in the value of the product for 1890 over the value for 1880 was but 2.8 per cent, while the increase for 1900 over 1890 was 69.8 per cent. It is not possible to state how great a part of this increase for 1900 is due to a more complete collection of the returns for this rural industry. There is an apparent falling off in the number of wage-earners, but if, since these operations are usually conducted by the owner of the establishment, there were added one man for each establishment to the number of wage-earners, there would be a total of 264, which is probably not far from the truth. Another method of reckoning the number of wage-earners would be to take into account those engaged in the cultivation of the herbs, like mint, which are grown for the production of essential oils, and it is probable that at the census of 1870, where the number of hands employed is reported as 2,365, a method such as this has been followed. It is necessary to recall that the essential-oil distilleries would, as a rule, be in operation but a part of each year.

The *essential oils* are those volatile oils which exist ready formed in animal and vegetable organisms, and they are called essential because they possess, in a concentrated form, certain of the characteristic properties of the plants from which they are derived. They are also known as the *volatile oils*, because they are easily evaporated, and as *distilled oils*, from the method by which a number of them are usually extracted from the plant. They exist in all odoriferous vegetation, sometimes pervading the plant, and in other cases being confined

Pages 602 through 651 were inadvertently omitted during scanning.

TABLE 8.—BONE, IVORY, AND LAMP BLACK: SUMMARY BY STATES, 1900.

	United States.[1]
Number of establishments	15
Character of organization:	
Individual	2
Firm and limited partnership	8
Incorporated company	5
Capital:	
Total	$782,247
Land	$149,103
Buildings	$196,422
Machinery, tools, and implements	$300,571
Cash and sundries	$136,151
Proprietors and firm members	17
Salaried officials, clerks, etc.:	
Total number	21
Total salaries	$23,650
Officers of corporations—	
Number	5
Salaries	$6,360
General superintendents, managers, clerks, etc.—	
Total number	16
Total salaries	$17,290
Men—	
Number	15
Salaries	$16,990
Women—	
Number	1
Salaries	$300
Wage-earners, including pieceworkers, and total wages:	
Greatest number employed at any one time during the year	92
Least number employed at any one time during the year	80
Average number	85
Wages	$46,107
Men, 16 years and over—	
Average number	85
Wages	$46,107
Miscellaneous expenses:	
Total	$75,678
Rent of works	$6,625
Miscellaneous expenses—Continued.	
Total—Continued.	
Taxes, not including internal revenue	$2,260
Rent of offices, insurance, interest, and all sundry expenses not hitherto included	$65,902
Contract work	$891
Materials used:	
Total cost	$105,712
Components of products	$66,776
Fuel	$2,663
Mill supplies	$1,771
All other materials	$32,126
Freight	$2,376
Products:	
Total value	$359,787
Pigments—	
Lamp and other blacks, pounds	6,454,345
Value	$359,787
Comparison of products:	
Number of establishments reporting for both years	15
Value for census year	$359,787
Value for preceding business year	$250,816
Power:	
Number of establishments reporting	13
Total horsepower	365
Owned—	
Engines—	
Steam, number	18
Horsepower	345
Gas or gasoline, number	1
Horsepower	20
Establishments classified by number of persons employed, not including proprietors and firm members:	
Total number of establishments	15
Under 5	7
5 to 20	7
21 to 50	1

[1] Includes establishments distributed as follows: Pennsylvania, 12; Connecticut, 1; New York, 1; Ohio, 1.

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900.

STATES AND TERRITORIES.	ESTABLISHMENTS: NUMBER, AND CHARACTER OF ORGANIZATION.				CAPITAL.				
	Total number.	Individual.	Firm and limited partnership.	Incorporated company.	Total.	Land.	Buildings.	Machinery, tools, and implements.	Cash and sundries.
United States	1,740	515	405	820	$238,529,641	$22,947,444	$35,270,850	$46,116,451	$134,194,896
Alabama	19	2	9	8	1,514,791	20,118	239,050	212,824	1,042,799
California	53	16	7	30	6,807,440	590,615	1,509,294	1,236,298	3,471,233
Colorado	4	.....	.....	4	392,865	15,700	81,200	148,550	147,415
Connecticut	31	9	6	16	3,254,506	128,772	429,881	790,778	1,905,075
Delaware	15	8	1	6	2,139,856	95,100	238,467	223,814	1,582,475
District of Columbia	8	4	2	2	111,606	22,000	11,800	29,585	48,221
Florida	10	4	1	5	778,319	95,164	139,185	136,298	407,672
Georgia	46	13	11	22	6,764,918	141,762	1,049,304	672,634	4,901,218
Illinois	88	15	9	64	10,245,146	1,359,232	1,141,727	1,715,112	6,029,075
Indiana	42	14	8	20	2,527,306	151,985	480,112	663,238	1,231,971
Iowa	8	2	3	3	621,171	38,442	103,150	84,013	395,566
Kansas	5	2	.....	3	291,278	24,000	74,450	57,648	135,180
Kentucky	18	3	2	13	740,484	50,522	82,975	98,546	508,441
Louisiana	10	.....	2	8	1,439,153	70,394	313,956	215,419	839,384
Maine	13	5	2	6	1,107,261	71,585	76,594	528,459	430,623
Maryland	63	18	21	24	9,148,474	1,282,011	1,241,469	1,702,628	4,922,366
Massachusetts	83	25	21	37	7,887,795	467,045	979,209	1,149,955	5,291,586
Michigan	97	55	14	28	10,684,794	1,286,685	2,048,160	3,565,983	3,783,966
Minnesota	8	1	2	5	371,083	7,829	37,085	50,374	275,795
Mississippi	4	1	.....	3	372,797	20,322	50,000	57,362	245,113
Missouri	39	6	5	28	6,256,327	496,359	742,024	948,877	4,069,067
Nebraska	5	.....	.....	5	945,517	70,500	382,319	111,576	381,122
Nevada	4	.....	4	.....	53,075	5,000	2,050	7,525	38,500
New Jersey	160	41	30	89	34,307,300	3,350,787	5,015,423	5,838,209	20,102,881
New York	285	104	56	125	46,913,165	4,931,561	6,274,907	8,986,573	26,720,124
North Carolina	23	2	9	12	2,878,088	110,269	411,432	228,823	2,127,564
Ohio	137	34	38	65	13,083,173	1,392,119	1,810,967	2,213,587	7,666,500
Oregon	5	2	2	1	176,332	5,000	6,500	21,247	143,585
Pennsylvania	306	89	102	115	43,964,862	4,602,488	6,979,953	11,928,088	20,454,333
Rhode Island	12	5	2	5	1,165,565	58,700	178,583	162,911	765,371
South Carolina	22	2	1	19	10,505,043	109,441	1,642,600	487,117	8,265,885
Tennessee	14	3	3	8	1,258,373	108,947	356,519	177,114	615,793
Texas	7	2	3	2	50,550	700	5,000	26,225	18,625
Vermont	5	2	.....	3	316,422	8,200	34,685	82,132	191,405
Virginia	64	20	22	22	8,158,747	1,706,496	973,308	1,242,299	4,236,644
West Virginia	9	2	2	5	313,292	27,050	48,900	74,049	163,293
Wisconsin	12	3	4	5	817,341	18,000	8,500	208,759	582,082
All other states[1]	6	1	1	4	165,426	6,544	70,112	31,822	56,948

[1] Includes establishments distributed as follows: Arizona, chemicals, 1; New Hampshire, chemicals, 1, Washington, fertilizers, 1; paints, 3,

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	Proprietors and firm members, number.	SALARIED OFFICIALS, CLERKS, ETC.									
		Total.		Officers of corporations.		General superintendents, managers, clerks, etc.					
						Total.		Men.		Women.	
		Number.	Salaries.	Number.	Salaries.	Number.	Salaries.	Number.	Salaries.	Number.	Salaries.
United States	1,189	8,605	$11,340,385	1,263	$3,160,458	7,342	$8,179,927	6,637	$7,841,490	705	$338,437
Alabama	32	74	69,640	17	24,984	57	44,656	55	43,856	2	800
California	30	199	269,283	42	57,700	157	211,583	144	203,693	13	7,890
Colorado	.....	18	20,520	8	8,300	10	12,220	9	11,500	1	720
Connecticut	20	108	164,481	29	68,200	79	96,281	71	93,586	8	2,695
Delaware	10	36	60,194	9	32,450	27	27,744	26	27,264	1	480
District of Columbia	8	9	5,433	1	2,500	8	2,933	8	2,933	.....	.....
Florida	6	33	31,031	8	9,166	25	21,865	22	20,565	3	1,300
Georgia	42	126	156,188	17	44,025	109	112,163	107	111,203	2	960
Illinois	37	683	912,841	93	227,373	590	685,468	511	645,656	79	39,812
Indiana	34	134	163,763	24	45,272	110	118,491	104	116,611	6	1,880
Iowa	10	34	28,980	1	2,400	33	26,580	27	24,880	6	1,700
Kansas	2	8	9,940	3	3,640	5	6,300	5	6,300	.....	.....
Kentucky	9	63	61,564	13	20,350	50	41,214	42	38,860	8	2,354
Louisiana	5	43	66,969	13	36,460	30	30,509	29	29,729	1	780
Maine	8	22	28,533	7	16,200	15	12,333	12	9,733	3	2,600
Maryland	64	280	330,116	55	129,622	225	200,494	213	195,673	12	4,821
Massachusetts	64	422	526,540	53	150,463	369	376,077	323	355,610	46	20,467
Michigan	90	431	558,934	55	123,910	376	435,024	322	413,788	54	21,236
Minnesota	8	32	31,878	7	10,258	25	21,620	21	20,160	4	1,460
Mississippi	1	18	20,714	6	6,150	12	14,564	12	14,564	.....	.....
Missouri	16	334	412,916	50	107,682	284	305,234	262	294,682	22	10,552
Nebraska	.....	43	62,156	2	9,000	41	53,156	34	50,120	7	3,036
Nevada	9	1	600	.....	.....	1	600	1	600	.....	.....
New Jersey	106	1,226	1,599,059	149	432,682	1,077	1,166,377	999	1,126,193	78	40,184
New York	113	1,619	2,411,586	201	620,554	1,418	1,791,032	1,286	1,727,171	132	63,861
North Carolina	21	51	65,838	11	29,823	40	36,015	40	36,015	.....	.....
Ohio	112	820	1,036,692	128	293,570	692	743,122	609	701,410	83	41,712
Oregon	6	10	15,080	2	4,800	8	10,280	7	9,800	1	480
Pennsylvania	200	1,260	1,606,571	173	457,626	1,087	1,148,945	987	1,098,245	100	50,700
Rhode Island	8	46	72,941	7	17,000	39	55,941	31	51,277	8	4,664
South Carolina	5	85	164,716	9	35,976	76	128,740	75	128,500	1	240
Tennessee	9	67	84,243	18	45,800	49	38,443	47	37,483	2	960
Texas	10	2	3,900	.....	.....	2	3,900	2	3,900	.....	.....
Vermont	2	15	8,468	4	1,600	11	6,868	4	4,360	7	2,508
Virginia	71	153	182,861	29	64,586	124	118,275	121	117,325	3	950
West Virginia	8	10	9,830	5	6,680	5	3,150	5	3,150	.....	.....
Wisconsin	10	83	78,691	12	10,656	71	68,035	61	62,020	10	6,015
All other states	3	7	6,695	2	3,000	5	3,695	3	3,075	2	620

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	WAGE-EARNERS, INCLUDING PIECEWORKERS.									
	Total.				Men, 16 years and over.		Women, 16 years and over.		Children, under 16 years.	
	Greatest number employed at any one time during the year.	Least number employed at any one time during the year.	Average number.	Wages.	Average number.	Wages.	Average number.	Wages.	Average number.	Wages.
United States	61,553	37,939	46,765	$21,799,251	44,635	$21,214,066	1,952	$554,423	178	$30,762
Alabama	887	289	460	99,782	456	99,334	4	448		
California	1,973	1,259	1,547	982,378	1,511	967,922	36	14,456		
Colorado	91	54	67	31,430	63	30,200	4	1,230		
Connecticut	869	525	662	356,532	630	347,583	32	8,949		
Delaware	665	304	403	186,005	399	185,391	1	138	3	476
District of Columbia	57	32	27	11,298	27	11,298				
Florida	283	85	144	49,161	141	48,711			3	450
Georgia	2,159	654	1,149	304,731	1,140	302,591	1	600	8	1,540
Illinois	2,294	1,602	1,880	987,870	1,679	927,622	180	56,563	21	3,685
Indiana	891	630	651	317,968	614	311,717	36	6,146	1	105
Iowa	183	137	160	71,451	152	70,022	6	1,229	2	200
Kansas	318	135	197	95,644	197	95,644				
Kentucky	286	129	190	83,324	184	81,824	6	1,500		
Louisiana	456	200	300	97,827	279	93,655	21	4,172		
Maine	187	73	108	38,810	105	37,710	3	1,100		
Maryland	2,699	1,281	1,613	754,907	1,587	748,166	19	5,741	7	1,000
Massachusetts	1,669	1,101	1,337	717,043	1,257	693,670	75	22,531	5	842
Michigan	4,386	2,966	3,626	1,451,730	3,469	1,421,425	145	28,571	12	1,734
Minnesota	77	62	62	27,466	52	24,717	10	2,749		
Mississippi	176	50	98	35,200	98	35,200				
Missouri	1,315	991	1,143	513,293	1,018	485,588	75	17,915	50	9,790
Nebraska	199	137	174	100,686	163	97,256	11	3,430		
Nevada	50	37	22	8,670	20	8,180	2	490		
New Jersey	7,211	5,069	6,091	3,095,868	5,674	2,963,539	407	130,419	10	1,910
New York	11,180	7,657	8,940	4,691,897	8,615	4,599,067	313	90,455	12	2,375
North Carolina	805	256	441	113,860	440	113,785			1	75
Ohio	3,035	1,837	2,218	1,112,593	2,085	1,069,151	130	43,053	3	389
Oregon	48	46	46	26,136	43	24,876	3	1,260		
Pennsylvania	8,713	7,287	7,814	3,883,218	7,459	3,787,584	331	91,443	24	4,191
Rhode Island	330	218	258	132,205	242	129,697	16	2,508		
South Carolina	3,066	754	1,772	479,449	1,772	479,449				
Tennessee	922	310	594	143,619	582	142,019	3	600	9	1,000
Texas	88	26	48	18,376	48	18,376				
Vermont	121	44	73	28,809	50	22,271	23	6,538		
Virginia	3,452	1,379	2,154	626,159	2,114	620,809	33	4,350	7	1,000
West Virginia	111	103	87	33,469	87	33,469				
Wisconsin	232	190	165	65,440	140	59,751	25	5,689		
All other states	69	30	44	24,947	43	24,797	1	150		

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	AVERAGE NUMBER OF WAGE-EARNERS, INCLUDING PIECEWORKERS.											
	Men, 16 years and over.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
United States	45,847	47,271	48,974	46,876	43,598	42,520	40,620	42,231	43,880	43,344	45,065	45,384
Alabama	744	786	773	587	351	267	196	184	268	319	407	590
California	1,469	1,453	1,422	1,549	1,387	1,402	1,523	1,559	1,485	1,586	1,678	1,615
Colorado	56	55	56	53	52	52	85	67	68	72	63	67
Connecticut	520	570	617	659	700	676	665	649	683	642	624	546
Delaware	290	304	351	415	407	365	396	521	594	489	373	289
District of Columbia	21	23	31	36	36	23	29	29	30	24	19	19
Florida	182	220	242	142	126	119	115	105	100	94	109	128
Georgia	1,863	1,987	1,947	1,177	630	498	510	527	582	928	1,469	1,563
Illinois	1,648	1,692	1,751	1,753	1,805	1,683	1,600	1,691	1,759	1,583	1,605	1,567
Indiana	542	566	573	649	635	611	715	718	686	571	547	551
Iowa	142	203	140	139	141	154	144	156	153	150	148	141
Kansas	192	199	181	161	149	143	149	184	224	246	282	259
Kentucky	144	150	195	200	182	194	175	204	244	207	163	146
Louisiana	344	410	420	335	267	247	175	174	234	221	263	259
Maine	58	78	86	171	172	119	119	92	114	86	103	63
Maryland	1,395	1,407	1,525	1,677	1,597	1,456	1,526	1,828	2,199	1,631	1,423	1,407
Massachusetts	1,253	1,297	1,339	1,337	1,210	1,189	1,130	1,229	1,246	1,253	1,309	1,286
Michigan	3,435	3,460	3,559	3,777	3,663	3,767	3,236	3,285	3,332	3,250	3,283	3,584
Minnesota	52	57	55	56	58	57	52	48	49	47	48	48
Mississippi	176	176	161	109	57	39	31	41	51	88	111	139
Missouri	962	981	1,011	1,009	1,036	1,058	1,086	1,056	1,071	1,026	990	913
Nebraska	164	144	133	157	141	164	168	174	185	185	174	173
Nevada	30	16	22	19	14	19	18	18	17	36	17	14
New Jersey	5,537	5,528	5,907	6,000	5,764	5,701	5,479	5,711	5,723	5,578	5,578	5,564
New York	8,644	8,821	9,097	9,218	9,069	8,971	7,995	8,076	8,258	8,355	8,395	8,502
North Carolina	557	629	692	619	406	283	282	257	292	416	436	417
Ohio	1,883	1,946	2,116	2,191	2,103	2,028	2,039	2,307	2,374	2,049	1,983	2,011
Oregon	43	43	43	43	43	43	43	45	45	44	43	43
Pennsylvania	7,282	7,315	7,518	7,648	7,564	7,427	7,329	7,408	7,585	7,535	7,397	7,501
Rhode Island	234	236	239	241	234	231	201	261	263	261	247	254
South Carolina	2,876	2,993	2,985	1,537	808	776	744	741	787	1,443	2,756	2,824
Tennessee	675	772	868	656	464	444	331	520	887	614	365	384
Texas	32	29	38	42	35	47	59	81	57	57	50	48
Vermont	72	62	76	33	37	30	35	38	48	52	55	68
Virginia	2,036	2,375	2,500	2,186	1,958	1,982	1,993	2,000	1,930	1,984	2,278	2,149
West Virginia	85	83	84	83	87	88	88	86	87	85	104	83
Wisconsin	164	160	170	173	174	136	119	120	124	97	116	123
All other states	45	45	51	39	36	31	40	41	46	40	54	46

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	AVERAGE NUMBER OF WAGE-EARNERS, INCLUDING PIECEWORKERS—continued.											
	Women, 16 years and over.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
United States	1,911	2,000	2,066	2,063	2,052	1,986	1,823	1,830	1,876	1,945	1,944	1,927
Alabama	2	2	2	3	3	4	4	5	6	7	7	5
California	36	36	36	37	37	37	37	37	37	36	36	36
Colorado	4	4	4	4	4	4	4	4	4	4	4	4
Connecticut	27	29	32	34	36	27	30	31	37	37	36	27
Delaware	1	1	1	1	1	1	1	1	1	1	1	2
District of Columbia												
Florida												
Georgia	3	2	2	2	1	1	1	1	1	1	1	1
Illinois	185	193	197	199	188	180	155	155	157	169	176	192
Indiana	29	29	33	37	41	43	44	41	41	40	30	27
Iowa	6	7	7	9	8	14	3	3	3	3	3	3
Kansas												
Kentucky	6	6	6	6	6	6	5	5	8	8	8	6
Louisiana	24	32	31	30	19	18	18	15	15	15	14	16
Maine	2	6	6	3	3	2	2	2	2	6	6	2
Maryland	19	19	19	19	20	24	21	20	20	17	16	17
Massachusetts	61	64	70	74	74	71	74	79	85	90	79	75
Michigan	169	175	173	176	151	125	113	103	106	137	152	165
Minnesota	10	11	11	11	11	11	8	7	8	8	11	11
Mississippi												
Missouri	73	72	73	72	74	75	82	80	81	79	68	70
Nebraska	11	11	11	11	11	11	11	11	11	11	11	11
Nevada	1	1	2	2	2	2	2	2	2	1	2	1
New Jersey	359	404	392	369	410	441	420	428	435	428	417	395
New York	308	320	336	350	354	323	294	291	303	298	300	288
North Carolina												
Ohio	122	131	153	174	157	129	98	105	110	135	117	117
Oregon	3	3	3	3	3	3	3	3	3	3	3	3
Pennsylvania	346	340	350	346	344	338	313	306	308	314	332	338
Rhode Island	18	17	18	17	15	13	1	11	15	16	24	27
South Carolina												
Tennessee	2	2	2	3	3	3	3	3	3	3	3	2
Texas												
Vermont	28	27	33	12	17	18	20	21	19	23	28	31
Virginia	30	30	35	31	31	36	30	35	30	35	35	35
West Virginia												
Wisconsin	26	26	26	26	26	26	26	25	25	25	24	20
All other states			2	2	2							

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	AVERAGE NUMBER OF WAGE-EARNERS, INCLUDING PIECEWORKERS—continued.											
	Children, under 16 years.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
United States	177	180	191	186	178	174	174	183	180	165	166	182
Alabama												
California												
Colorado												
Connecticut												
Delaware	3	3	3	3	3	4	4	4	3	2	2	2
District of Columbia												
Florida	9	8	10	2	2	2	1	1	1	1	1	2
Georgia	13	13	13	13	3	3	3	3	3	3	13	13
Illinois	15	18	18	20	21	21	21	27	24	21	19	31
Indiana							1	2	1	4	2	2
Iowa	2	2	2	2	2	2	2	2	2	2	2	2
Kansas												
Kentucky												
Louisiana												
Maine												
Maryland	7	7	7	7	7	7	7	7	7	7	7	7
Massachusetts	3	3	4	7	3	6	5	6	7	4	4	4
Michigan	12	9	13	12	15	15	14	13	13	8	7	7
Minnesota												
Mississippi												
Missouri	49	54	49	50	47	45	47	54	56	51	45	48
Nebraska												
Nevada												
New Jersey	9	9	11	11	11	11	11	9	9	9	9	9
New York	11	11	13	13	14	12	12	12	11	11	11	11
North Carolina					1	1	1	1	2	2		
Ohio	4	4	3	4	5	4	4	4	2	1	1	1
Oregon												
Pennsylvania	25	25	29	26	25	25	22	21	24	23	26	28
Rhode Island												
South Carolina												
Tennessee	9	9	9	9	9	9	9	9	9	9	9	9
Texas												
Vermont												
Virginia	6	5	7	7	10	7	10	8	6	7	8	6
West Virginia												
Wisconsin												
All other states												

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MATERIALS USED.												
	Aggregate cost.	Purchased in raw state.											
		Total cost.	Fish.		Gums.	Kainit.		Limestone.		Phosphate rock.		Pyrites.	
			Thousands.	Cost.	Cost.	Tons.	Cost.	Tons.	Cost.	Tons.	Cost.	Tons.	Cost.
United States	$124,043,837	$15,702,216	4,589,632	$183,542	$3,817,112	54,700	$520,833	790,456	$717,910	797,772	$3,620,262	633,837	$3,101,075
Alabama	1,428,452	438,888				13,048	132,172			23,940	244,216	9,520	62,500
California	5,502,254	100,360			22,714			1,600	8,000	1,456	16,362	6,331	34,658
Colorado	158,716	15,597			3,597							4,800	12,000
Connecticut	1,615,099	680,308	17,500	25,189	109,668	200	7,500			17	143	2,597	13,585
Delaware	738,041	63,556	200,000	40,000		1,461	15,235	2,106	752	2,062	7,569		
District of Columbia	55,050	1,552				154	1,552						
Florida	341,681	62,290				723	8,640			8,040	32,177	3,177	17,473
Georgia	2,462,109	735,084			6,400	10,205	98,181			102,413	417,037	37,879	213,466
Illinois	7,981,328	542,974			455,359			9,250	1,330	10,480	60,320	4,337	25,965
Indiana	1,513,769	197,661			48,872							18,867	108,789
Iowa	519,376												
Kansas	521,979												
Kentucky	659,350	79,506			49,102					5,625	17,804		
Louisiana	700,380	95,158			640	1,858	17,416	21	54	15,180	64,015	2,457	13,033
Maine	214,666	20,000	5,000	1,500	12,000	150	1,500					1,000	5,000
Maryland	4,726,232	908,867	12,000	16,500	3,204	6,895	58,547			126,757	582,626	55,182	247,990
Massachusetts	4,996,442	563,863			232,861			38	133	18,722	131,734	34,894	147,470
Michigan	5,362,671	714,539			222,950			315,690	274,161	3,465	16,807	5,238	31,791
Minnesota	235,787	2,337			2,337								
Mississippi	349,689	85,800				3,234	35,800			9,000	22,000	4,000	28,000
Missouri	5,496,347	30,848			28,629	40	400			630	1,819		
Nebraska	572,898												
Nevada	9,500												
New Jersey	16,297,390	1,733,693	14,118	9,765	698,672	486	4,382			86,630	409,998	85,782	390,645
New York	24,756,424	2,942,580			1,344,871	1,263	15,075	324,919	316,745	22,104	155,401	54,379	227,458
North Carolina	1,057,430	287,849	4,215,500	18,668		967	9,587	1,815	2,400	38,858	160,554	16,684	88,818
Ohio	8,006,959	568,408	700	2,800	234,901	2,530	21,360	175	1,150	28,515	114,172	42,421	194,025
Oregon	163,143	5,480			5,480								
Pennsylvania	18,230,605	2,462,198			317,180	1,265	11,479	62,429	74,109	33,491	200,710	97,579	500,777
Rhode Island	631,859	118,105			5,450			168	728			4,183	25,470
South Carolina	3,107,710	1,026,097				9,114	71,226			141,464	555,861	83,272	399,010
Tennessee	1,054,022	284,770								36,431	118,067	20,668	155,428
Texas	64,524	9,261	15,000	9,169						10	92		
Vermont	320,287	1,200											
Virginia	3,055,220	803,350	104,754	57,451	12,000	1,107	10,781	72,245	38,348	82,482	290,778	35,988	147,312
West Virginia	205,200	106,900											
Wisconsin	862,991	225			225								
All other states	68,257	12,912	5,000	2,500								2,602	10,112

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MATERIALS USED—continued.													
	Purchased in raw state—Continued.				Purchased in partially manufactured form.									
	Wood.					Acids.						Acid phosphate.		Argols.
	For alcohol.		For extracts.		Total cost.	Sulphuric.		Nitric.		Mixed.				
	Cords.	Cost.	Tons.	Cost.		Tons.	Cost.	Pounds.	Cost.	Pounds.	Cost.	Tons.	Cost.	Cost.
United States	495,073	$1,255,794	261,384	$2,485,688	$87,323,152	280,028	$1,946,742	3,131,894	$154,144	69,566,011	$1,560,133	287,147	$2,182,316	$2,204,800
Alabama					702,434	500	5,000			433,266	11,844	58,385	169,820	
California			3,172	18,626	4,283,386	2,961	56,418	319,987	13,359	12,498,500	151,904	1,550	27,000	245,000
Colorado					110,743									
Connecticut			18,801	524,223	659,230	231	1,736					3,226	28,248	
Delaware					525,778	1,972	11,824					21,262	154,292	
District of Columbia					47,555							1,550	14,500	
Florida			3,300	4,000	234,591	300	1,800					5,547	48,447	
Georgia					1,334,190	24,202	133,207					30,305	276,183	
Illinois					6,383,225	16,077	147,993	25,000	1,000			5,366	48,352	
Indiana	15,000	40,000			1,082,731	2,570	44,515			3,020,000	86,449	1,105	12,180	
Iowa					406,239									
Kansas					444,986	3,000	34,440					750	7,110	
Kentucky			600	12,600	514,155	4,314	32,187					1,910	20,700	
Louisiana					522,265							17,419	154,627	
Maine					150,946							330	4,500	
Maryland					3,088,179	28,119	164,658					29,571	237,541	
Massachusetts	880	6,480	4,477	45,185	3,753,550	4,138	54,103	774,930	31,416			6,553	62,368	
Michigan	82,694	124,830	15,450	44,000	2,994,372	3,869	47,921			6,694,964	189,276			
Minnesota					208,681									
Mississippi					204,564	500	5,000					7,892	67,178	
Missouri					4,393,443	1,054	9,714			5,966,091	251,600	175	1,748	
Nebraska					487,039									
Nevada					7,805									
New Jersey	3,208	12,364	12,326	207,867	12,198,674	75,317	436,625	1,692,610	97,496	21,526,726	380,970	12,551	119,061	1,044,800
New York	108,885	271,681	34,734	611,349	17,479,548	21,064	172,641	15,400	656	2,183,744	39,986	18,127	155,137	915,000
North Carolina	3,134	7,822			605,982	3,402	19,051					10,256	87,276	
Ohio					6,409,486	21,576	147,333	26,000	802	6,208,183	164,207	8,774	82,519	
Oregon					137,533									
Pennsylvania	280,872	791,417	74,899	566,526	12,193,055	42,836	288,697	193,600	6,641	9,926,537	249,454	15,795	141,167	
Rhode Island			3,277	86,457	421,950	554	2,853			100,000	7,000	200	1,696	
South Carolina					1,699,892	4,459	24,632					12,702	121,141	
Tennessee			6,433	11,275	487,503	310	2,412					1,200	9,000	
Texas					45,139	92	576							
Vermont	400	1,200			300,792									
Virginia			48,215	246,680	1,378,984	16,498	104,936	34,000	1,540			14,646	130,525	
West Virginia			35,700	106,900	66,062	113	1,470	50,367	1,284	1,008,000	27,443			
Wisconsin					728,801									
All other states					34,664									

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MATERIALS USED—continued.										
	Purchased in partially manufactured form—Continued.										
	Ammonia.				Alcohol.				Bones, tankage, and offal.	Common salt.	
	Aqua.		Sulphate.		Grain.		Wood.				
	Pounds.	Cost.	Pounds.	Cost.	Gallons.	Cost.	Gallons.	Cost.	Cost.	Tons.	Cost.
United States	417,488,626	$1,137,307	16,985,013	$657,726	331,207	$510,375	3,692,803	$1,751,345	$10,313,661	42,189	$142,398
Alabama									340,611		
California	89,158,596	12,542	2,502,000	64,959	8,652	19,500	2,773	3,766	232,955	454	1,639
Colorado	90,000	4,050			185	416	185	162		120	360
Connecticut			328	11	10,100	24,070	690	1,400	88,514	17	76
Delaware	1,492,366	60,277	1,127,729	28,193					51,708		
District of Columbia	3,258,864	2,444							24,123		
Florida			500,000	15,000	10	24			96,926	6	48
Georgia			30,000	900					534,781	40	100
Illinois			1,130,268	35,056	3,310	6,483	100,916	84,170	603,783	5,058	19,120
Indiana	127,703	3,788			601	1,396	591	591	123,705	3,048	10,494
Iowa									1,000	1	60
Kansas									296,496		
Kentucky									56,059		
Louisiana					53	103			215,218	140	560
Maine							1,965	2,161	5,580		
Maryland			478,521	13,939					1,160,985	190	950
Massachusetts	1,227,436	73,646	200,000	5,500	1,095	2,641	56,071	45,320	402,020	1,580	2,382
Michigan	29,431,188	490,162			9,434	21,698	200	200	415,154	1,462	6,014
Minnesota											
Mississippi									93,046		
Missouri	41,049,931	116,538	1,133,931	136,561	36,937	82,086	14,149	9,812	64,815	509	2,124
Nebraska									15,770		
Nevada											
New Jersey	99,289,132	56,140	5,025,724	138,578	160,624	127,156	311,229	204,658	1,104,361	6,547	28,677
New York	180,000	9,000	580,377	164,504	52,425	122,964	3,111,592	1,330,284	596,733	13,713	38,361
North Carolina			50,000	1,500					354,015		
Ohio	43,017,000	25,810	19,549	579	6,745	15,314	12,360	16,403	344,183	5,234	13,180
Oregon					300	696	217	184	1,893		
Pennsylvania	105,440,790	200,337	1,062,458	29,468	38,336	80,328	75,765	47,359	1,096,756	4,060	18,168
Rhode Island			2,414,128	1,078	2,400	5,500	1,600	2,800	204,401		
South Carolina									1,061,977		
Tennessee	1,964,640	2,400							141,576		
Texas									25,875		
Vermont	360	22									
Virginia	536,620	64,851	730,000	21,900					558,642	10	85
West Virginia	1,224,000	15,300									
Wisconsin							2,500	2,075			
All other states											

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MATERIALS USED—continued.													
	Purchased in partially manufactured form—Continued.													
	Cotton seed and meal.	Dry colors.	Glycerine.		Lead.		Lime.		Linseed oil.		Nitrate of potash.		Nitrate of soda.	
	Cost.	Cost.	Pounds.	Cost.	Tons.	Cost.	Bushels.	Cost.	Gallons.	Cost.	Tons.	Cost.	Tons.	Cost.
United States	$167,410	$9,476,333	34,635,822	$3,419,406	104,401	$8,618,097	7,428,885	$442,252	16,157,117	$7,495,196	6,084	$300,199	147,020	$4,899,622
Alabama	80,218		63,119	8,058									490	19,236
California		130,476	5,765,997	681,840	1,908	152,650	3,509	700	205,784	118,083			26,912	837,022
Colorado		33,367					1,318	224	75,042	37,521			180	6,300
Connecticut		23,666							71,496	34,963			2,577	91,099
Delaware		11,096					7,080	1,213	10,400	4,660			2,616	78,331
District of Columbia		245					1,190	203	800	500			15	675
Florida													269	9,619
Georgia	78,192	48,943							49,551	29,997			1,333	50,035
Illinois		1,772,237	617,195	57,642	11,866	991,042	4,459	546	2,121,711	935,511	257	19,826	3,172	106,444
Indiana		71,819	1,407,659	157,945			18,432	3,090	142,264	59,815			8,957	313,198
Iowa		84,170							182,856	73,947			4,795	150,101
Kansas		445							3,500	1,400			1,759	68,253
Kentucky		106,826					1,854	315	268,625	120,857			89	4,600
Louisiana	9,000	25,338					557	160	66,604	33,302			46	1,702
Maine		37,054							30,168	15,729	95	6,000	1,468	44,700
Maryland		88,474					190,000	22,000	112,376	54,943			3,669	132,450
Massachusetts		784,389			3,641	327,718	27,283	10,708	489,339	219,896	492	38,511	5,187	182,975
Michigan		431,054	1,152,501	142,873			134,256	22,452	913,022	417,099			2,203	76,342
Minnesota		75,449							164,519	80,159				
Mississippi		3,500							6,000	3,600			150	5,400
Missouri		684,637	1,787,311	199,741	15,447	1,332,088	50,474	8,095	1,201,716	526,632			2,530	90,263
Nebraska		92,510			2,901	242,666			213,779	102,773				
Nevada									1,800	1,080				
New Jersey		488,219	3,866,604	434,101	3,000	275,500	98,664	15,467	844,341	399,581	28	2,780	31,276	1,026,282
New York		2,252,264	10,073,575	839,197	29,389	2,152,933	5,805,537	255,271	4,199,414	1,970,463	633	54,453	7,663	254,274
North Carolina		1,180							750	300			745	28,609
Ohio		911,684	7,849,186	624,274	9,831	817,413	27,979	4,413	1,806,071	909,189	384	31,342	14,585	486,636
Oregon		37,271							95,452	45,218				
Pennsylvania		847,617	1,914,237	258,507	26,418	2,326,087	1,045,814	94,299	2,235,619	993,028	3,318	115,407	16,599	557,481
Rhode Island		51,812					6,085	1,826	34,338	15,182			229	7,524
South Carolina													2,169	82,569
Tennessee		47,902							48,093	24,047			2,550	88,098
Texas		11,434							11,822	5,811				
Vermont		6,378					3,425	1,086						
Virginia		46,649					357	62	27,737	13,868	877	31,880	1,786	65,246
West Virginia			138,438	15,228			612	122						
Wisconsin		256,949							493,575	236,945			857	26,250
All other states		11,279							28,553	9,097			144	7,903

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MATERIALS USED—continued.											
	Purchased in partially manufactured form—Continued.							Fuel.	Rent of power and heat.	Mill supplies.	All other materials.	Freight.
	Potash salts.	Sulphur.		Tallow and fats.	Wood ashes.		All other components of products.					
	Cost.	Tons.	Cost.	Cost.	Bushels.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.	Cost.
United States	$3,891,818	83,530	$1,724,857	$380,517	801,047	$39,507	$23,906,991	$5,515,636	$297,568	$779,814	$11,281,479	$3,143,972
Alabama	31,270	827	18,690				17,687	20,284	1,032	10,886	136,102	118,826
California	106,984	10,199	235,383				1,191,206	275,557	9,302	63,481	484,502	285,666
Colorado							28,343	5,980	780	950	12,802	11,864
Connecticut	27,725	1,997	43,487				294,235	95,995	160	60,557	80,751	38,098
Delaware	62,906	516	10,937				50,341	13,364	262	4,854	87,978	42,249
District of Columbia	3,530						1,335	2,056	260	255	2,379	993
Florida	54,300						8,427	9,749	360	2,488	23,866	8,337
Georgia	136,905	350	8,750				36,197	53,185	460	11,706	200,007	127,477
Illinois	81,075	2,588	53,401				1,419,544	200,325	11,306	22,814	718,979	101,705
Indiana	1,628	198	6,773		25,200	1,280	184,065	65,565	51	4,296	133,908	29,557
Iowa		694	13,198				83,763	22,552		1,652	58,292	30,641
Kansas	17,647	281	9,218				9,977	21,643	13,500	3,767	38,083	
Kentucky	5,400						167,211	8,647	1,101	2,305	43,543	10,095
Louisiana	15,644	2,627	51,527				15,084	20,072	14	4,017	56,846	2,008
Maine	4,769	250	5,000	3	21,960	2,044	23,406	4,468	1,055	3,368	27,048	7,781
Maryland	568,019	7,214	162,581				481,639	153,866	350	67,366	377,230	130,374
Massachusetts	235,613	3,358	63,010				1,211,334	150,780	4,938	21,252	426,915	75,144
Michigan	67,905	51	1,002		584,617	29,440	635,780	863,430	813	27,785	544,325	217,407
Minnesota							53,073	3,726	1,020	596	14,808	4,619
Mississippi	18,560						8,280	3,375		5,150	34,200	16,600
Missouri	6,740	1,003	22,021				1,448,228	81,316	5,801	10,915	366,864	7,160
Nebraska							33,320	22,414		2,055	48,372	13,018
Nevada							6,725	535		130	1,030	
New Jersey	781,154	17,010	311,325				4,725,743	587,230	4,553	89,474	1,378,452	305,314
New York	337,931	14,986	307,581	9,700			5,500,215	1,355,502	228,897	146,813	2,509,999	93,085
North Carolina	105,866						8,185	23,703	600	13,683	89,827	35,786
Ohio	61,682	3,816	81,875	274,314	169,270	6,743	1,389,591	184,879	1,917	46,368	651,345	144,556
Oregon	1,900						50,371	820	820	250	11,790	6,450
Pennsylvania	517,046	13,956	282,929	96,500			3,950,779	826,449	2,758	115,856	1,858,441	771,848
Rhode Island	9,950	937	18,186				92,142	29,692	965	2,428	41,786	16,933
South Carolina	310,118						99,455	88,786		5,909	223,276	63,750
Tennessee	114,224	419	12,164				45,680	34,279		4,975	118,248	124,247
Texas							1,443	1,822	72	355	6,500	1,375
Vermont							293,306	3,632		1,425	12,622	616
Virginia	205,327						133,473	252,736	1,423	13,848	315,673	289,206
West Virginia							5,265	9,528	578	1,702	20,401	29
Wisconsin		142	3,694				197,888	11,136		3,803	116,179	7,347
All other states		111	2,125				4,255	6,558	2,420	280	8,110	3,313

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS CONSUMED.											
	Acids.			Acid phosphate (tons).	Charcoal (bushels).	Ether (pounds).	Lead oxides (pounds).	Nitrate of ammonia (pounds).	Nitroglycerine (pounds).	Pyroxyline (pounds).	White lead (pounds).	All other products consumed (pounds).
	Sulphuric (tons).	Nitric (pounds).	Mixed (pounds).									
United States	764,355	32,123,221	20,902,371	88,964	1,719,675	1,193,264	374,061	158,307	31,661,806	1,964,345	24,922,647	545,121,097
Alabama	22,020								135,324			18,230,512
California	27,153	3,600,000	12,000,000			799,579			10,895,803		162,000	3,374,875
Colorado	600											
Connecticut	1,210	570,139			16,798							21,000
Delaware					29,200							2,647,281
District of Columbia												
Florida	7,065											380,000
Georgia	78,655											
Illinois	6,594	155,484										1,317,031
Indiana	13,795	8,185,736	148,671					81,115	2,254,788	4,310		428,729
Iowa												1,426,207
Kansas												
Kentucky												
Louisiana	17,718			3,025								
Maine												
Maryland	98,240											5,823,200
Massachusetts	45,305	855,500	8,734,700							239,842		5,215,478
Michigan	10,205	586,105			267,825			77,192	2,547,820			55,817,010
Minnesota												
Mississippi	9,000			9,000								
Missouri	744	8,074							3,906,248			306,576
Nebraska											7,251,300	
Nevada												
New Jersey	62,775	13,787,691	19,000	17,527		393,125			8,877,764	1,720,193		21,079,070
New York	34,123	2,469,682			294,000				182,000			399,834,890
North Carolina	33,047			5,545	155,400							1,003,283
Ohio	10,314	953,422		13,050					105,350			1,463,080
Oregon												
Pennsylvania	42,378	951,388		35,746	939,500	560	374,061		2,756,709		17,509,347	24,312,375
Rhode Island												
South Carolina	138,973											
Tennessee	35,495			5,071	16,887							40,500
Texas												
Vermont					65							
Virginia	68,946											2,400,000
West Virginia												
Wisconsin												
All other states												

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	MISCELLANEOUS EXPENSES.					PRODUCTS.							
							Group I.—Acids.						
								Sulphuric.					
								50° Baumé.		60° Baumé.		66° Baumé.	
	Total.	Rent of works.	Taxes.	Rent of offices, interest, etc.	Contract work.	Aggregate value.	Total value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
United States	$14,825,112	$625,891	$973,585	$12,963,054	$262,582	$202,582,396	$13,150,258	189,084	$1,024,091	17,012	$246,284	382,279	$6,035,069
Alabama	97,677	1,100	22,969	72,850	758	2,123,102	25,000	2,934	25,000				
California	386,899	10,770	21,846	354,166	117	8,279,243	667,440	3,537	44,091	2,369	33,460	6,071	116,124
Colorado	28,649	1,370	3,749	23,530		299,954	74,800					3,000	60,000
Connecticut	175,944	5,160	10,429	159,945	400	2,544,714	279,804					9,126	162,815
Delaware	112,986	250	4,678	108,058		1,356,416							
District of Columbia	3,521	1,560	138	1,823		88,137							
Florida	34,890	1,545	2,397	30,948		533,789	833	90	623				
Georgia	416,841	6,981	37,534	372,201	125	3,549,632	5,436	856	5,436				
Illinois	743,905	58,636	43,353	640,096	1,820	12,422,227	407,263					12,450	224,130
Indiana	155,204	5,536	11,662	134,506	3,500	2,686,427	574,962					19,419	231,487
Iowa	49,311	20	3,402	45,889		696,022							
Kansas	59,144	280	2,644	56,220		733,818							
Kentucky	29,676	4,180	4,894	20,602		1,054,008							
Louisiana	123,352	265	1,961	121,126		1,049,653	25,910			149	5,960	208	8,736
Maine	17,431	500	3,229	13,702		389,631	17,542	402	3,214	1,034	14,328		
Maryland	483,898	45,030	44,884	393,984		7,260,580	300,739	51,555	294,754			399	5,985
Massachusetts	649,776	37,658	51,604	555,514	5,000	8,088,698	900,968	37,395	35,110			27,634	414,211
Michigan	1,015,881	8,979	46,059	952,853	7,990	9,757,084							
Minnesota	64,650	7,415	843	54,192	2,200	403,101							
Mississippi	40,866		6,647	34,219		505,072							
Missouri	374,174	30,149	34,711	304,662	4,652	7,588,090	81,830					2,869	54,500
Nebraska	74,315	480	2,845	70,990		954,840							
Nevada	2,382	96	176	2,110		27,225							
New Jersey	1,604,323	48,320	107,506	1,415,215	33,282	26,763,856	3,554,662	9,123	60,564			116,398	1,575,802
New York	2,992,743	197,888	203,297	2,583,408	8,150	40,998,911	1,831,942	1,426	15,050	84	1,488	50,641	988,354
North Carolina	109,043	39	17,810	91,180	14	1,523,030							
Ohio	1,165,268	40,027	70,327	993,412	61,502	13,307,431	1,386,325					40,147	527,944
Oregon	8,313	2,940	794	4,579		239,359							
Pennsylvania	2,309,431	72,249	106,215	2,007,652	123,315	32,154,223	2,583,491	39,188	303,122	13,356	190,756	84,574	1,473,339
Rhode Island	104,859	8,319	5,116	83,636	7,788	1,127,329	153,994	28	2,500	20	292	7,092	148,952
South Carolina	675,589	1,050	53,200	621,339		4,882,506	225,698	41,036	225,698				
Tennessee	143,653	996	3,942	138,715		1,917,985							
Texas	4,089	1,540	215	2,334		125,170							
Vermont	39,591	265	200	39,126		408,737							
Virginia	421,586	12,325	37,871	369,579	1,811	5,059,465	8,929	1,514	8,929				
West Virginia	15,990	410	870	14,552	158	334,003							
Wisconsin	84,591	11,100	3,117	70,374		1,280,838							
All other states	4,671	463	441	3,767		117,190	42,690					2,251	42,690

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.													
	Group I.—Acids—Continued.									Group II.—Sodas.				
	Nitric.		Mixed.		Tartaric.		Acetic.		Other.	Total value.	Sal soda.		Soda ash.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Value.		Tons.	Value.	Tons.	Value.
United States	30,961,501	$1,454,909	42,368,819	$1,111,158	2,677,004	$781,603	26,660,565	$426,892	$2,070,252	$11,638,051	63,249	$779,443	386,361	$4,768,383
Alabama														
California	3,380,340	158,293			90,000	27,000			288,472	666,025	3,870	68,370	1,320	17,160
Colorado	180,000	10,800							4,000	3,500				
Connecticut	1,592,280	79,871	1,466,044	36,600					518	7,038				
Delaware														
District of Columbia														
Florida									210					
Georgia														
Illinois	508,758	35,600					867,920	11,120	136,413	303,771	5,061	67,489		
Indiana	491,454	18,344	6,434,418	240,510					84,621	299,463	3,487	34,874		
Iowa														
Kansas														
Kentucky														
Louisiana									11,214	840				
Maine														
Maryland										39,905	2,500	25,000		
Massachusetts	3,082,046	86,741					8,303,885	110,872	254,034	118,182	232	2,900		
Michigan										2,826,377			188,165	2,158,969
Minnesota														
Mississippi														
Missouri							652,573	10,650	16,680	30,129				
Nebraska														
Nevada										20,950			600	8,800
New Jersey	14,256,680	684,773	10,981,134	259,583	1,680,000	487,000	6,478,443	123,846	363,094	170,640	52	687		
New York	4,100,541	222,740	6,392,516	159,800	720,000	208,000	4,127,162	68,320	168,190	4,921,144	28,095	357,303	167,552	2,066,422
North Carolina														
Ohio	1,377,291	72,248	17,094,707	414,665					371,468	122,820	4,100	42,640		
Oregon														
Pennsylvania	1,972,111	83,999			187,004	59,603	6,230,582	102,084	370,588	1,010,167	12,756	132,990		
Rhode Island	20,000	1,500							750	1,800				
South Carolina														
Tennessee														
Texas														
Vermont														
Virginia										920,999			28,724	517,032
West Virginia														
Wisconsin										174,301	3,096	57,190		
All other states														

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.													
	Group II.—Sodas—Continued.							Group III.—Potashes.		Group IV.—Alums.		Group V.—Coal-tar products.		
	Bicarbonate of soda.		Caustic soda.		Borax.		Other soda products.	Pounds.	Value.	Pounds.	Value.	Total value.	Coal-tar distillery products.	Chemicals made from coal-tar distillery products.
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Value.						Value.	Value.
United States	68,185	$1,324,843	78,779	$2,917,955	5,637	$502,480	$1,344,947	3,764,806	$174,476	179,465,871	$2,446,576	$1,338,810	$826,546	$512,264
Alabama														
California	225	9,000	3	125	5,502	490,330	91,040					80,632	11,415	19,217
Colorado							3,500							
Connecticut							7,038							
Delaware														
District of Columbia														
Florida														
Georgia														
Illinois			2,458	221,325			14,957	820,000	53,349	10,180,000	95,600			
Indiana							264,589	135,200	6,350					
Iowa														
Kansas														
Kentucky														
Louisiana							840							
Maine								88,290	2,935					
Maryland							14,905							
Massachusetts							115,282			19,766,415	306,754	27,513	27,513	
Michigan	10,000	150,000	18,000	500,000			17,408	1,869,116	77,609	1,480,000	39,500			
Minnesota														
Mississippi														
Missouri			111	8,679			21,450					394,400	94,400	300,000
Nebraska														
Nevada					185	12,150								
New Jersey			20	820			169,183					231,000	227,400	3,600
New York	43,812	885,003	40,499	1,518,464			93,952			46,211,951	593,070	44,016	29,716	14,300
North Carolina														
Ohio							80,180	852,200	34,283			243,000	243,000	
Oregon														
Pennsylvania	7,700	154,000	11,754	460,845			262,332			101,877,505	1,411,652	354,249	179,102	175,147
Rhode Island							1,800							
South Carolina														
Tennessee												14,000	14,000	
Texas														
Vermont														
Virginia	6,425	122,079	5,934	207,697			74,191							
West Virginia														
Wisconsin	23	4,761					112,350							
All other states														

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.												
	Group VI.—Cyanides.						Group VII.—Wood distillation.						
	Total value.	Potassium cyanide.		Yellow prussiate of potash.		Other cyanides.	Total value.	Wood alcohol.				Acetate of lime.	
								Crude.		Refined.			
		Pounds.	Value.	Pounds.	Value.	Value.		Gallons.	Value.	Gallons.	Value.	Tons.	Value.
United States	$1,595,505	2,317,280	$601,362	6,165,406	$994,014	$129	$5,675,616	4,191,379	$1,660,061	3,038,218	$2,297,008	43,413	$981,286
Alabama													
California													
Colorado													
Connecticut													
Delaware													
District of Columbia													
Florida													
Georgia													
Illinois													
Indiana							125,000			100,000	65,000	1,000	30,000
Iowa													
Kansas													
Kentucky													
Louisiana													
Maine	120,700			700,000	120,700								
Maryland	13,020	50,000	13,020										
Massachusetts							38,607			29,652	35,973		
Michigan							514,106	116,010	32,225	504,196	319,553	3,396	43,265
Minnesota													
Mississippi	18,216	24,099	3,813	96,024	14,403								
Missouri													
Nebraska													
Nevada	1,053,472	2,235,945	582,482	2,847,556	470,990								
New Jersey							83,331			90,000	67,500		
New York							2,548,109	1,056,083	431,064	2,207,230	1,762,812	11,285	250,211
North Carolina	86,852			518,822	86,852		22,437	170,960	13,677	62,238	7,570		
Ohio							4,000			3,000	4,000		
Oregon	303,245	7,236	2,047	2,003,004	301,069	129							
Pennsylvania							2,339,066	2,848,326	1,183,095	41,902	34,600	27,732	657,810
Rhode Island													
South Carolina													
Tennessee													
Texas													
Vermont							960						
Virginia													
West Virginia													
Wisconsin													
All other states													

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.											
	Group VII—Continued.			Group VIII—Fertilizers.								
	Charcoal.		All other products in this group.	Total value.	Superphosphates.				Complete.		All other.	
					From minerals, bones, etc.		Ammoniated.					
	Bushels.	Value.	Value.		Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
United States	17,155,440	$726,809	$10,452	$41,014,685	925,008	$8,492,360	142,898	$2,449,388	1,454,389	$25,796,143	299,910	$4,276,794
Alabama				1,942,708	38,246	369,587	2,000	35,000	92,253	1,433,355	6,670	104,766
California				636,687					19,570	591,187	2,561	45,500
Colorado												
Connecticut				313,610			1,000	23,000	7,325	205,931	2,752	84,679
Delaware				634,213	2,385	28,250			17,180	283,873	30,377	322,090
District of Columbia				71,480					3,160	64,800	449	6,680
Florida				496,642	9,394	93,950			15,435	377,535	1,315	25,167
Georgia				3,240,304	131,503	1,075,581	14,603	229,271	101,219	1,563,653	26,605	371,799
Illinois				1,754,905	26,108	313,850	4,150	58,100	43,483	835,335	25,333	547,620
Indiana	750,000	30,000		235,836	365	10,006	27	500	5,750	116,280	5,431	109,050
Iowa				3,075							155	3,075
Kansas				549,943	8,978	160,498	6,858	125,745	10,000	200,000	4,535	63,700
Kentucky				295,520					17,315	295,520		
Louisiana				856,201	29,244	263,821	13,037	221,599	22,842	367,181	300	3,600
Maine				27,902					828	21,602	1,000	6,300
Maryland				5,188,925	124,696	1,178,367	48,608	690,671	184,095	2,985,015	27,734	334,872
Massachusetts	15,000	1,200	1,434	2,060,575	1,282	12,820			76,571	1,940,605	4,280	107,150
Michigan	2,831,120	119,063		353,608	1,528	17,699			14,753	279,588	2,767	56,321
Minnesota				7,285							1,471	7,285
Mississippi				492,772	7,200	50,400			30,504	442,372		
Missouri				139,395	2,766	44,248			2,774	39,039	2,354	56,108
Nebraska				58,914					4,532	58,914		
Nevada												
New Jersey	152,500	10,800	5,031	3,804,162	105,165	887,470	7,283	159,580	125,839	2,629,511	8,039	127,601
New York	2,310,653	103,390	632	2,445,375	9,810	105,645	10,300	338,400	87,862	1,623,638	45,814	377,692
North Carolina	1,138	137	1,053	1,48[illegible],333	48,820	397,397	3,400	51,000	53,528	841,632	14,345	197,304
Ohio				1,562,518	24,728	285,698	23,805	380,936	43,351	700,606	11,918	195,278
Oregon				6,500							120	6,500
Pennsylvania	11,079,029	461,259	2,302	2,712,767	22,975	310,273	2,846	53,271	120,715	2,178,334	11,272	170,889
Rhode Island				105,755			681	10,215	2,097	48,231	2,938	47,309
South Carolina				4,656,808	173,183	1,404,569			207,860	3,146,915	7,497	105,324
Tennessee				1,464,788	35,959	456,568			36,695	704,220	20,400	304,000
Texas				69,800	40	780			25	500	4,036	68,520
Vermont	16,000	960										
Virginia				3,324,979	120,683	1,024,893	4,300	72,100	106,828	1,820,771	26,692	407,215
West Virginia				5,400							350	5,400
Wisconsin												
All other states				8,000							400	8,000

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.									
	Group IX.—Bleaching materials.				Electro-chemical products.	Group XI.—Dyestuffs.				
	Total value.	Hypochlorites.		Other bleaching agents.		Total value.	Natural.		Artificial.	
		Tons.	Value.	Value.	Value.		Pounds.	Value.	Pounds.	Value.
United States	$492,086	2,143	$115,608	$376,478	$1,305,368	$4,914,686	49,019,074	$2,658,008	11,168,308	$2,256,678
Alabama										
California										
Colorado										
Connecticut						36,325	808,175	36,325		
Delaware										
District of Columbia										
Florida						5,650	59,325	5,650		
Georgia										
Illinois	38,649	297	38,649			13,894			11,200	13,894
Indiana										
Iowa										
Kansas										
Kentucky										
Louisiana										
Maine					9,631	30,000			4,412	30,000
Maryland										
Massachusetts	912			912		1,191,560	4,045,302	320,347	2,123,816	871,213
Michigan	62,387	1,782	62,387		193,256					
Minnesota										
Mississippi										
Missouri	21,196			21,196						
Nebraska										
Nevada										
New Jersey	12,972	56	12,972			668,068	6,100,000	206,240	3,846,908	461,828
New York	340,612			340,612	1,102,481	1,897,834	9,723,797	1,104,858	2,497,162	792,976
North Carolina										
Ohio	3,500			3,500						
Oregon										
Pennsylvania	11,858	8	1,600	10,258		889,213	23,831,150	816,135	1,162,450	73,078
Rhode Island						168,453	4,391,325	168,453		
South Carolina										
Tennessee										
Texas										
Vermont						2,300			230,000	2,300
Virginia										
West Virginia						11,389			1,292,360	11,389
Wisconsin										
All other states										

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.						
	Group XII.—Tanning materials.						
	Total value.	Natural.				Artificial.	
		Ground or chipped.		Extracts.			
		Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
United States	$1,790,118	49,002,037	$465,956	62,012,788	$1,259,007	2,454,084	$65,155
Alabama							
California	31,500	300,000	1,500	1,050,000	30,000		
Colorado							
Connecticut							
Delaware							
District of Columbia							
Florida	20,000			1,050,900	20,000		
Georgia							
Illinois	2,500			12,500	2,500		
Indiana							
Iowa							
Kansas							
Kentucky	21,000	1,344,000	21,000				
Louisiana							
Maine							
Maryland							
Massachusetts	16,000					376,470	16,000
Michigan	100,684			8,444,600	100,684		
Minnesota							
Mississippi							
Missouri							
Nebraska							
Nevada							
New Jersey	181,800	13,872,000	98,600	719,228	46,684	1,460,664	36,516
New York	300,756			7,024,440	295,356	36,000	5,400
North Carolina							
Ohio							
Oregon							
Pennsylvania	364,701	415,117	7,783	19,108,020	349,679	580,950	7,239
Rhode Island							
South Carolina							
Tennessee	48,589			2,776,500	48,589		
Texas							
Vermont							
Virginia	470,223	25,145,920	180,158	17,936,725	290,065		
West Virginia	282,365	7,925,000	156,915	3,889,875	75,450		
Wisconsin							
All other states							

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.									
	Group XIII.—Paints, colors, and varnishes.									
	Aggregate value.	A.—Pigments.								
		Total value.	White lead.		Oxides of lead.		Lamp and other blacks.		Fine colors.	
			Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
United States	$67,918,533	$13,824,773	116,102,316	$4,211,181	50,759,623	$2,550,340	7,519,345	$420,037	4,080,902	$1,028,754
Alabama										
California	969,779	278,825	4,800,000	237,180	500,000	25,895				
Colorado	188,500									
Connecticut	579,334	7,840					224,000	7,840		
Delaware	32,873	200							1,000	200
District of Columbia	2,500									
Florida										
Georgia	182,279									
Illinois	8,129,967	880,368	11,037,475	531,962					201,000	32,000
Indiana	403,327	18,250					365,000	18,250		
Iowa	335,367	96,316	250,000	24,750						
Kansas	4,875									
Kentucky	673,063									
Louisiana	140,102									
Maine	117,991									
Maryland	460,852	68,947	80,000	4,000						
Massachusetts	2,439,254	594,432	110,496	5,525	3,725,279	197,440	700,000	42,000	345,000	35,000
Michigan	3,391,773	40,737								
Minnesota	395,816									
Mississippi	13,200									
Missouri	4,388,644	509,364	4,942,814	243,681	3,581,604	183,189				
Nebraska	838,151	61,889			1,125,262	61,889				
Nevada	3,875									
New Jersey	5,984,881	1,540,921	14,471,171	717,047					1,135,284	190,893
New York	18,762,564	4,812,435	39,109,000	547,440	12,426,000	663,176	15,000	2,550	1,937,116	734,713
North Carolina	2,468									
Ohio	6,702,884	619,377	8,822,814	383,475	1,508,000	79,792	550,000	40,000	254,000	19,900
Oregon	186,931									
Pennsylvania	10,725,579	4,111,190	32,478,546	1,516,121	27,893,478	1,338,959	5,665,345	309,397	207,502	16,048
Rhode Island	181,818	500								
South Carolina										
Tennessee	147,790	30,640								
Texas	89,880									
Vermont	401,077									
Virginia	201,972	146,499								
West Virginia										
Wisconsin	881,717	6,043								
All other states	57,500									

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.										
	Group XIII.—Paints, colors, and varnishes—Continued.										
	A.—Pigments—Continued.						B.—Paints.				
	Iron oxides and other earth colors.		Dry colors.		Pulp colors, sold moist.		Total value.	Paints in oil, in paste.		Paints already mixed for use.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.		Pounds.	Value.	Gallons.	Value.
United States	33,772,256	$324,902	167,734,241	$4,428,028	20,060,935	$861,531	$32,473,812	306,477,865	$17,603,127	16,900,350	$14,870,685
Alabama											
California			2,100,000	15,750			557,149	2,411,622	207,797	355,837	349,352
Colorado							160,000	83,330	10,000	153,325	150,000
Connecticut							99,385	1,428,868	68,009	34,020	31,376
Delaware							21,876	215,846	8,496	16,725	13,380
District of Columbia							2,500			1,000	2,500
Florida											
Georgia							149,779	870,683	56,065	91,394	93,714
Illinois	1,183,565	14,617	9,853,710	300,789	10,000	1,000	4,629,569	45,021,424	2,634,159	2,594,474	1,995,410
Indiana							153,215	1,734,600	121,136	34,612	32,079
Iowa			3,042,000	71,566			209,051	1,405,000	74,150	181,485	134,901
Kansas							4,875			6,500	4,875
Kentucky							353,135	1,022,640	70,610	387,575	282,525
Louisiana							132,102	189,834	50,686	94,017	81,416
Maine							60,406	822,600	47,133	13,000	13,273
Maryland	130,000	400	1,533,509	33,505	558,300	31,042	293,259	1,101,227	87,519	232,544	205,740
Massachusetts	2,278,000	28,435	3,445,701	218,607	789,312	67,425	1,103,380	10,402,389	635,551	479,011	467,829
Michigan			417,418	40,787			1,659,034	9,761,345	684,716	847,205	974,318
Minnesota							357,816	796,282	100,084	298,661	257,732
Mississippi							13,200			12,000	13,200
Missouri			8,455,000	82,494			3,578,173	45,796,923	2,282,924	1,542,268	1,295,249
Nebraska							773,662	8,850,306	553,950	221,712	219,712
Nevada							3,375			2,700	3,375
New Jersey	500,000	25,000	4,764,207	445,425	5,156,948	162,556	1,132,641	8,672,911	552,452	622,542	580,189
New York	15,602,000	127,134	42,933,177	2,156,799	12,941,596	580,623	6,918,338	68,999,820	4,009,897	2,922,134	2,908,441
North Carolina							2,377	2,803	2,377		
Ohio	80,000	1,200	1,441,781	95,010			4,118,491	30,595,967	1,752,553	2,578,218	2,365,938
Oregon							135,731	30,576	7,644	114,991	128,087
Pennsylvania	6,318,691	96,976	63,817,766	820,847	594,379	12,842	4,562,252	59,138,990	3,052,644	2,174,014	1,509,608
Rhode Island	20,000	500					104,604	629,800	70,775	35,554	33,829
South Carolina											
Tennessee	7,660,000	30,640					117,150	142,000	28,400	116,073	88,750
Texas							89,580	241,429	15,600	26,200	23,930
Vermont							170,207	108,650	5,300	232,059	164,907
Virginia			25,929,972	146,499							
West Virginia											
Wisconsin					60,400	6,043	800,050	6,000,000	412,500	430,000	387,550
All other states							57,500			48,500	57,500

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.												
	Group XIII.—Paints, colors, and varnishes—Continued.										Group XIV.—Explosives.		
	C.—Varnishes and japans.												
	Total value.	Oil and turpentine varnishes.		Alcohol varnishes.		Pyroxyline varnishes.		Liquid dryers, japans, and lacquers.	All other products in this group.	Total value.	Gunpowder.	
		Gallons.	Value.	Gallons.	Value.	Gallons.	Value.	Value.	Value.		Pounds.	Value.
United States	$18,602,796	14,286,758	$14,337,461	563,212	$943,069	204,069	$237,012	$3,085,254	$3,017,152	$17,036,897	123,314,103	$5,310,351
Alabama										54,940	247,525	8,511
California	130,805	123,670	120,392	2,670	5,300			5,113	3,000	4,274,553	500,000	80,000
Colorado	28,500	30,000	28,500									
Connecticut	390,092	137,679	307,462	175	404	28,810	36,012	46,214	82,017	312,400	7,282,750	312,400
Delaware	2,200			500	1,200			1,000	8,597	443,971	8,794,779	443,971
District of Columbia												
Florida												
Georgia	7,500							7,500	25,000			
Illinois	2,136,496	1,617,053	1,621,154	148,943	203,538	16,000	16,000	295,804	483,534	289,735	6,358,250	270,974
Indiana	221,372	263,624	195,260	1,210	3,509	383	594	21,949	10,490	970,944	4,925,000	214,324
Iowa									30,000	353,315	12,618,400	353,315
Kansas										179,000	4,477,575	179,000
Kentucky	315,978	454,550	314,603	100	145			1,230	3,950			
Louisiana	8,000	8,310	7,904					96				
Maine	46,000	50,000	46,000						11,585	170,000	4,000,000	170,000
Maryland	44,646	55,800	23,825					20,821	54,000			
Massachusetts	593,353	436,532	442,600	4,400	11,360			139,393	148,089	171,062	1,227,775	147,330
Michigan	1,668,549	1,632,963	1,629,437	3,575	8,451			30,661	23,453	691,766		
Minnesota	28,000	27,754	28,000						10,000			
Mississippi												
Missouri	227,468	110,169	127,640	2,106	3,277	6,500	16,000	80,551	23,639	992,842		
Nebraska									2,600			
Nevada									500			
New Jersey	2,826,391	1,668,752	2,258,228	67,673	124,743	49,308	69,181	374,239	484,928	3,493,197	5,477,900	240,027
New York	6,271,755	4,928,208	4,665,714	231,205	432,928	102,777	99,000	1,074,113	700,036	367,998	5,939,200	263,594
North Carolina	91							91				
Ohio	1,739,803	1,245,565	1,177,397	43,304	50,107			512,299	225,213	1,330,489	21,627,675	927,098
Oregon	51,200	32,000	51,200									
Pennsylvania	1,779,950	1,408,656	1,236,672	47,901	83,473	291	225	459,580	272,187	2,571,368	34,961,649	1,507,807
Rhode Island	11,250			6,950	11,250				65,464			
South Carolina												
Tennessee										220,318	2,500,000	100,000
Texas	300							300				
Vermont									230,870	1,400		
Virginia	55,473	55,473	55,473							3,500		
West Virginia										52,099		
Wisconsin	17,624			2,500	3,324			14,300	58,000	92,000	2,375,625	92,000
All other states												

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.											
	Group XIV.—Explosives—Continued.									Group XV.—Plastics.		
	Nitroglycerine.		Gun cotton, or pyroxyline.		Dynamite.		Smokeless powder.		All other explosives.	Total value.	Pyroxyline plastics.	All other products in this group.
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Value.		Value.	Value.
United States	3,618,692	$783,299	369,499	$189,623	85,846,456	$8,247,223	2,973,126	$1,655,948	$850,453	$2,099,400	$1,970,387	$129,013
Alabama					496,861	46,429						
California			50,000	30,000	27,055,910	2,895,703	1,361,000	816,600	452,250			
Colorado												
Connecticut												
Delaware												
District of Columbia												
Florida												
Georgia												
Illinois									18,761			
Indiana	675,000	118,750			6,456,041	614,934	68,938	22,936				
Iowa												
Kansas												
Kentucky												
Louisiana												
Maine												
Maryland												
Massachusetts									28,732	231,509	111,641	119,868
Michigan	4,000	2,000			6,643,975	652,174			87,592			
Minnesota												
Mississippi												
Missouri					10,464,235	992,842						
Nebraska												
Nevada												
New Jersey	14,199	2,191	284,499	124,623	25,550,543	2,185,365	1,477,633	765,991	175,000	1,862,496	1,858,746	3,750
New York			35,000	35,000	671,215	69,404						
North Carolina												
Ohio	1,455,113	351,970					61,555	49,021	2,400			
Oregon												
Pennsylvania	1,163,918	256,289			8,507,676	790,372			16,900	5,395		5,395
Rhode Island												
South Carolina												
Tennessee									120,318			
Texas												
Vermont							4,000	1,400				
Virginia									8,500			
West Virginia	306,462	52,099										
Wisconsin												
All other states												

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.														
	Group XVI.—Essential oils.						Group XVII.—Compressed and liquefied gases.				Group XVIII.—Fine chemicals.				
	Total value.	Natural.		Witch-hazel.		Artificial.	Total value.	Anhydrous ammonia.	Carbon dioxide.	Compressed and liquefied gases not otherwise enumerated.	Total value.	Alkaloids.		Gold salts.	
		Pounds.	Value.	Gallons.	Value.	Value.		Value.	Value.	Value.		Ounces.	Value.	Ounces.	Value.
United States	$846,605	882,554	$737,496	110,260	$54,649	$54,460	$1,215,011	$448,157	$696,164	$70,690	$4,229,431	3,387,522	$1,743,264	8,594	$90,145
Alabama															
California	2,490	3,330	2,490				44,488	20,488	24,000						
Colorado															
Connecticut	45,530	300	480	91,000	45,050										
Delaware							77,786	77,786							
District of Columbia															
Florida	500	400	500												
Georgia															
Illinois	110	32	100			10	180,350		180,350		100,060				
Indiana	14,180	17,683	14,180												
Iowa															
Kansas															
Kentucky															
Louisiana															
Maine															
Maryland											12,000				
Massachusetts	4,395	2,930	4,395				13,700		500	13,200	9,390				
Michigan	202,258	218,453	202,258				2,976	2,976							
Minnesota															
Mississippi															
Missouri							142,586	79,742	62,844		234,056			5,226	53,448
Nebraska															
Nevada															
New Jersey							151,600	92,375	59,225		406,854	288,672	98,213	803	9,917
New York	533,400	517,462	469,351	19,260	9,599	54,450	226,452		173,962	52,490	484,590			65	780
North Carolina	500	500	500												
Ohio							52,905	47,905		5,000	1,650				
Oregon															
Pennsylvania	2,595	1,993	2,595				239,713	126,885	112,828		2,930,831	3,098,850	1,645,051	2,500	26,000
Rhode Island											50,000				
South Carolina															
Tennessee															
Texas															
Vermont							3,000		3,000						
Virginia	37,772	117,721	37,772												
West Virginia															
Wisconsin	2,875	1,750	2,875				79,455		79,455						
All other states															

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.										
	Group XVIII.—Fine chemicals—Continued.										
	Silver salts.		Platinum salts.		Chloroform.		Ether.		Acetone.		All other.
	Ounces.	Value.	Ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Value.
United States	1,252,604	$499,345	7,312	$54,600	396 540	$98,070	263,238	$129,876	1,638,715	$178,666	$1,435,465
Alabama											
California											
Colorado											
Connecticut											
Delaware											
District of Columbia											
Florida											
Georgia											
Illinois											100,060
Indiana											
Iowa											
Kansas											
Kentucky											
Louisiana											
Maine											
Maryland											12,000
Massachusetts											9,390
Michigan											
Minnesota											
Mississippi											
Missouri	103,576	37,719	6,380	46,678			116,350	56,211			40,000
Nebraska											
Nevada											
New Jersey	173,000	63,890	932	7,922	334,000	66,800	56,000	18,650	63,593	6,359	135,103
New York	325,121	120,104			62,540	31,270	74,500	45,700	1,455,865	158,712	128,024
North Carolina											
Ohio											1,650
Oregon											
Pennsylvania	650,907	277,632					16,388	9,315	119,257	13,595	959,238
Rhode Island											50,000
South Carolina											
Tennessee											
Texas											
Vermont											
Virginia											
West Virginia											
Wisconsin											
All other states											

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.												
	Group XIX.—Chemicals not otherwise specified.												
	Total value.	Glycerin.		Cream of tartar.		Epsom salts.		Blue vitriol.		Copperas.		Phosphates of soda.	
		Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
United States	$5,189,992	15,383,798	$2,012,886	10,620,000	$2,081,500	7,559,809	$57,966	7,500,000	$375,000	19,884,305	$87,927	3,478,350	$104,554
Alabama													
California	326,000			1,610,000	326,000								
Colorado													
Connecticut													
Delaware													
District of Columbia													
Florida													
Georgia													
Illinois	182,391	1,403,506	169,695							2,086,400	12,696		
Indiana													
Iowa													
Kansas													
Kentucky													
Louisiana													
Maine													
Maryland	116,215					1,421,500	14,215					3,400,000	102,000
Massachusetts	30,191												
Michigan													
Minnesota													
Mississippi													
Missouri	2,554											78,350	2,554
Nebraska	31,655	372,418	31,655										
Nevada													
New Jersey	1,120,977			4,210,000	795,500					871,902	5,231		
New York	2,133,275	8,000,000	1,120,000	4,800,000	960,000	20,000	1,000			67,403	675		
North Carolina													
Ohio	726,211	5,607,874	691,536							10,158,600	34,675		
Oregon													
Pennsylvania	520,523					6,118,309	42,751	7,500,000	375,000	6,700,000	34,650		
Rhode Island													
South Carolina													
Tennessee													
Texas													
Vermont													
Virginia													
West Virginia													
Wisconsin													
All other states													

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	PRODUCTS—continued.			COMPARISON OF PRODUCTS.			POWER.							
	Group XIX.—Chemicals not otherwise specified—Continued.		All other.	Number of establishments reporting for both years.	Census year 1900.	Preceding business year.	Number of establishments reporting.	Total horsepower.	Owned.					
	Tin salts.								Engines.				Water wheels.	
									Steam.		Gas or gasoline.			
	Pounds.	Value.	Value.		Value.	Value.			Number.	Horsepower.	Number.	Horsepower.	Number.	Horsepower.
United States	4,677,471	$470,159	$18,510,292	1,473	$180,675,706	$156,604,049	1,354	198,338	2,682	158,646	86	1,669	311	9,273
Alabama			100,454	13	1,817,640	1,562,913	19	1,630	34	1,515				
California			629,649	48	7,863,041	6,981,138	42	3,653	65	2,553	6	47	7	200
Colorado			33,154	4	299,954	190,952	4	199	6	167				
Connecticut			970,673	26	2,485,964	2,313,213	21	2,692	38	1,731			33	911
Delaware			167,573	13	1,077,926	1,098,490	12	2,602	30	1,360			40	1,082
District of Columbia			14,157	7	85,637	83,855	3	94	1	65			1	9
Florida			10,164	10	533,789	469,492	7	527	10	515				
Georgia			121,613	23	1,516,461	1,409,770	36	3,913	56	3,855				
Illinois			869,683	74	10,886,616	9,567,420	66	6,726	76	6,086	8	139	1	15
Indiana			56,365	36	2,546,039	2,270,170	34	2,441	49	2,008	3	73		
Iowa			4,265	8	696,022	566,051	7	753	22	753				
Kansas				4	728,943	554,593	4	1,105	6	730	1	5		
Kentucky			64,425	15	953,730	829,686	15	969	17	902	1	10		
Louisiana			26,600	9	1,036,453	808,938	8	927	12	835	1	36		
Maine			13,630	10	366,000	374,600	8	2,644	10	196			17	2,420
Maryland			1,021,244	54	4,921,377	4,513,513	47	4,487	78	4,056	5	87	2	44
Massachusetts	179,587	30,191	515,106	79	8,027,083	6,526,099	60	6,190	89	4,890	1	10	6	470
Michigan			1,300,784	89	9,362,568	7,664,301	52	23,774	179	23,494			6	150
Minnesota				6	377,031	310,500	6	271	4	201				
Mississippi				4	505,972	441,000	3	415	4	415				
Missouri			1,192,242	35	7,026,687	6,868,038	29	2,805	49	2,599	3	37		
Nebraska			26,120	5	954,840	841,650	5	380	4	360				
Nevada			2,400	4	27,225	25,900	3	59	5	57	1	2		
New Jersey	3,130,578	320,246	3,983,744	131	23,823,809	20,281,702	120	17,817	321	16,293	3	47	2	30
New York	257,329	51,600	2,465,293	246	38,930,455	35,058,082	224	49,974	538	28,784	10	228	67	1,201
North Carolina			10,292	15	1,152,111	1,084,357	16	1,292	29	1,153	16	56		
Ohio			1,050,044	115	12,414,903	10,501,736	103	10,017	156	7,657	7	267	12	603
Oregon			45,928	5	229,359	158,794	4	90	2	60				
Pennsylvania	1,109,977	68,122	3,177,810	277	30,791,552	26,031,791	272	30,855	559	27,372	17	598	102	1,582
Rhode Island			465,509	12	1,127,329	999,561	5	730	15	647			2	60
South Carolina				7	865,429	792,863	18	3,940	36	3,940				
Tennessee			22,500	13	1,577,587	971,818	11	2,105	23	1,833	1	22	6	250
Texas			15,540	5	39,830	28,060	6	180	6	175				
Vermont				3	404,337	267,368	4	380	6	380				
Virginia			91,091	47	3,756,967	3,129,320	57	9,782	127	9,292	1	2	7	246
West Virginia			32,750	7	303,503	257,168	8	550	8	500				
Wisconsin			490	9	1,074,347	694,383	11	1,090	11	1,087	1	3		
All other states			9,000	5	77,190	74,764	4	280	1	130				

TABLE 9.—CHEMICALS AND ALLIED PRODUCTS: DETAILED STATEMENT BY STATES AND TERRITORIES, 1900—Continued.

STATES AND TERRITORIES.	POWER—continued.							FACTORIES.									
	Owned—Continued.				Rented.		Furnished to other establishments.	Total number of establishments.	No employees.	Under 5.	5 to 20.	21 to 50.	51 to 100.	101 to 250.	251 to 500.	501 to 1,000.	Over 1,000.
	Electric motors.		Other power.														
	Number.	Horsepower.	Number.	Horsepower.	Electric, horsepower.	Other kind, horsepower.	Horsepower.										
United States	399	6,849	15	542	19,445	1,914	875	1,740	43	413	655	319	143	122	34	6	5
Alabama	1	25			30	60		19		1	6	5	4	3			
California	37	570	2	45	173	65	40	53		12	28	9	4	4		1	
Colorado			3	15	15	2		4			2	1	1				
Connecticut	2	8	1	25	17			31		9	13	4	3	1	1		
Delaware	5	140				20		15		1	10	1	1	1	1		
District of Columbia						20		8		3	4	1					
Florida					12			10	1	1	1	6		1			
Georgia	2	28			30			46		3	18	10	8	6	1		
Illinois	9	159			23	304	161	88		19	31	22	10	5	1		
Indiana	35	337			23			42		9	22	7	2	2			
Iowa								8	2	2	1	2		1			
Kansas	3	70				300		5		2			1	2			
Kentucky					57			18		6	6	3	3				
Louisiana	2	31				25		10	1		4	2	1	2			
Maine	3	19			9			13	2	2	5	3	1				
Maryland	8	210				90		63		10	23	17	3	8	2		
Massachusetts	26	645	1	50	30	95		83	1	27	37	10	4	2	2		
Michigan	15	115			5	10	140	97	6	48	19	10	5	6	1		2
Minnesota					70			8		1	5	2					
Mississippi								4			1	2	1				
Missouri	3	6			123	40		89		10	13	10	2	2	2		
Nebraska					20			5			2		3				
Nevada								4		1	2	1					
New Jersey	74	1,171	2	55	20	201	10	160	5	36	56	27	12	18	5		1
New York	63	989			18,435	337	146	285	5	67	106	56	28	14	6	2	1
North Carolina					83			23	3	4	7	3	3	3			
Ohio	66	1,376			57	57	208	137	6	33	61	22	6	6	3		
Oregon					30			5		1	3	1					
Pennsylvania	40	893	4	302	28	80	155	306	9	70	126	66	17	13	2	2	1
Rhode Island	1	15				8	15	12		4	3	1	3	1			
South Carolina								22		2	3	1	2	11	3		
Tennessee								14	1	1	5	3	2		2		
Texas					5			7		3	3		1				
Vermont								5		1	3			1			
Virginia	3	27	1	40		175		64		15	20	7	11	8	2	1	
West Virginia	1	15	1	10		25		9		4	4		1				
Wisconsin								12	1	3	4	3		1			
All other states					150			6		2	3	1					