ELECTRICAL MACHINERY, APPARATUS, AND SUPPLIES

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The first complete record made by any government of the manufacture of electrical apparatus and supplies was that included in the Twelfth Census of the United States. Prior to this, general and miscellaneous figures had been secured, which, however, had reference rather to specific industries and developments than to the electrical arts as a whole.

At the censuses of 1880 and 1890 general statistics were obtained as to the number of electrical manufacturing establishments, their gross products, capital invested, number of wage-earners, wages paid, cost of materials, and a few other items. But Census Bulletin No. 245, of August 25, 1902, was the first to summarize or to analyze the entire product of American electrical factories and to discuss the conditions of electrical manufacturing as a great and growing field of American inventiveness, industry, and investment. That bulletin was followed in due sequence by a series of reports on the generation and utilization of electric current employing the machinery and apparatus furnished by the electrical manufacturing industries. One of these reports dealt exhaustively with street and electric railways; another with central electric light and power stations; and a third with telephones and telegraphs, including municipal fire alarm and police patrol systems. In fact, with the issuance of the Report on Telephones and Telegraphs, January 23, 1906, the Bureau of the Census closed the first and only census ever taken of the group of arts and industries dealing with the employment of the electric current for transportation, illumination, distribution of power, the long distance transmission of speech, and the instantaneous communication of messages and intelligence. The present bulletin, dealing with figures of electrical manufacturing for the census of 1905, begins in reality the new series of reports on these allied industries, as hereafter the census of street railways, lighting plants, and telephone and telegraph systems will be taken in five-year instead of ten-year periods. The rapidity of growth in these fields is probably unsurpassed in any other branch of human activity, and the more frequent record of these statistics adds greatly, therefore, to their value and utility.

In the report on electrical industries for 1900 a large quantity of products for which an electrical use could be predicated was excluded; these figures are, however, included within the scope of other Census inquiries. Among the products excluded then and now, were poles, whether of wood, iron, or steel; a large amount of glass and porcelain ware made only for electrical purposes; bare iron and copper wire; and the whole group of electro-chemical and electro-metallurgical products.

The extent of items of this character excluded may be gathered from the fact that the electrical conduits reported by the pottery, terra cotta, and fire clay industry for 1905 reached a value of $602,682 in the class of terra cotta, fire and other clay products. The products reported as of the nature of porcelain electrical supplies reached a value of $1,500,283, as compared with a total of only $470,355 at the census of 1900. The product of electrical conduits in 1900 was reported as valued at $685,273, so that while the conduit showed a slight decrease in the period, the porcelain electrical supplies showed apparently an enormous increase. It would not be safe, however, to take these figures on their face, and the great gain in porcelain may be attributed to the inclusion of goods or supplies which might more strictly have been included within the statistics of electrical industries in 1900. Some of the largest electrical manufacturers have purchased or equipped separate porcelain factories, and one of them has an extensive porcelain department carried on in close connection with its other shops of an entirely different nature. As will be seen, however, these two items for 1905 make a total of $2,102,965, not included in the electrical returns, but obviously bearing a very intimate relationship to that generic class of apparatus and supplies. It is to be observed that in Table 17, relating to electrical conduits, almost the entire product reported deals with interior conduits, which are of a metallic or textile nature in general; only short sections, such as those for running through floors or penetrating exterior walls, being of porcelain. Apparently the porcelain sections are not here included, as they are not regarded as conduits in the electrical trade, but are usually spoken of as "tubes." Undoubtedly a large quantity of this material is therefore embraced in the porcelain item just referred to, while in like manner none of the terra cotta and other clay conduits has been brought to account in the small amount of underground conduits enumerated in Table 17.

Table 1 presents the comparative figures of electrical machinery, apparatus, and supplies for 1880, 1890, 1900, and 1905.

TABLE 1.—COMPARATIVE SUMMARY, WITH PER CENT OF INCREASE: 1880 TO 1905.

	CENSUS.				PER CENT OF INCREASE.		
	1905	1900 [1]	1890	1880	1900 to 1905	1890 to 1900	1880 to 1890
Number of establishments	784	581	189	[2] 76	34.9	207.4	148.7
Capital	$174,066,026	$83,659,924	$18,997,337	$1,509,758	108.1	340.4	1,158.3
Salaried officials, clerks, etc., number	10,619	5,067	[3] 683	(4)	109.6	641.9	....
Salaries	$11,090,885	$4,631,723	[3] $849,138	(4)	139.5	445.5	....
Wage-earners, average number	60,466	42,013	8,802	1,271	43.9	377.3	592.5
Total wages	$31,841,521	$20,579,194	$4,517,050	$683,164	54.7	355.6	561.2
Men 16 years and over	48,976	34,462	7,289	1,132	42.1	372.8	543.9
Wages	$28,316,772	$18,513,653	$4,082,847	(4)	53.0	353.4	....
Women 16 years and over	10,902	6,956	1,469	72	56.7	373.5	1,940.3
Wages	$3,410,081	$1,943,220	$426,660	(4)	75.5	355.4	....
Children under 16 years	588	595	44	67	[5] 1.2	1,252.3	[5] 34.3
Wages	$114,668	$122,321	$7,543	(4)	[5] 6.3	1,521.6	....
Miscellaneous expenses	$17,948,708	$6,804,633	$1,154,462	(6)	163.8	489.4	....
Cost of materials used	$66,836,926	$49,458,272	$8,819,498	$1,116,470	35.1	460.8	689.9
Value of products, including amount received for custom work and repairing	[7] $140,809,369	[8] $92,434,435	$19,114,714	$2,655,036	52.3	383.6	619.9

[1] The totals for 1900 do not agree with those published at the Twelfth Census because of a reclassification.
[2] Includes 36 establishments reported as "electrical apparatus and supplies," and 40 reported as "telegraph and telephone apparatus."
[3] Includes proprietors and firm members, with their salaries; number only reported in 1900 and 1905, but not included in this table.
[4] Not reported separately.
[5] Decrease.
[6] Not reported.
[7] Exclusive of electrical machinery, apparatus, and supplies, valued at $18,742,033, made by establishments engaged primarily in the manufacture of other products.
[8] Exclusive of electrical machinery, apparatus, and supplies, valued at $13,397,430, made by establishments engaged primarily in the manufacture of other products.

In spite of the general tendency toward the consolidation of manufacturing establishments there was a gain in number of 34.9 per cent between 1900 and 1905, while the capital increased 108.1 per cent. Other large increases will be noted in the number of salaried officials and wage-earners, and particularly in the amounts paid out to employees. Throughout the last five years labor has been actively and remuneratively employed in all the electrical industries and no single strike of any serious magnitude has been recorded.

The increase in the total value of products, 1900 to 1905, was 52.3 per cent, which is a good indication of the capacity of the field at large for consumption, although various factors have come in to establish wide differences in the increase in the respective departments of the electrical business. In many instances, moreover, while the general trend of prices has been upward the cost of electrical apparatus to the consumer has been less, owing to large production and greater refinements in the processes. This has been affected, however, by the higher cost of such raw material as copper, the price of which has risen steadily throughout the entire term.

The growth of the industry since 1880, as shown by the census figures, is a remarkable illustration of the ingenuity of inventors, and the enterprise of manufacturers, in creating and supplying, during the past twenty-five years, an ever-enlarging demand for electrical machinery, apparatus, and supplies. The increase in number of establishments has been over ninefold, and in average number of wage-earners more than forty-six fold. The wages paid, amounting in 1880 to a little less than $700,000, reached, at the census of 1905, a total of nearly thirty-two millions, the gain being greater than forty-five fold. In value of products the increase has been over fifty-two fold.

Table 2 compares the general statistics, by states, for 1900 and 1905.

TABLE 2.—COMPARATIVE SUMMARY, BY STATES: 1905 AND 1900.

STATE.	Census.	Number of establishments.	Capital.	Salaried officials, clerks, etc.: Number.	Salaried officials, clerks, etc.: Salaries.	Wage-earners and wages: Total: Average number.	Wage-earners and wages: Total: Wages.	Men 16 years and over: Average number.	Men 16 years and over: Wages.	Women 16 years and over: Average number.	Women 16 years and over: Wages.	Children under 16 years: Average number.	Children under 16 years: Wages.	Miscellaneous expenses.	Cost of materials used.	Value of products, including amount received for custom work and repairing.
United States	1905	784	$174,066,026	10,610	$11,090,885	60,466	$31,841,521	48,976	$28,316,772	10,902	$3,410,081	588	$114,668	$17,948,708	$66,836,926	[1]$140,809,369
	[2]1900	581	83,659,924	5,067	4,631,723	42,013	20,579,194	34,462	18,513,653	6,956	1,943,220	595	122,321	6,804,633	49,458,272	[3]92,434,435
California	1905	24	716,440	112	112,836	403	244,123	364	232,164	32	10,483	7	1,476	74,523	434,241	1,004,284
	1900	11	181,474	29	28,638	238	129,906	228	127,826	...	...	10	2,080	11,771	359,135	555,735
Colorado	1905	7	141,800	14	18,450	89	54,574	48	37,074	41	17,500	...	...	10,900	65,480	178,759
	1900	4	77,000	6	6,000	84	41,720	56	30,120	27	11,200	1	400	8,027	51,608	121,000
Connecticut	1905	32	4,183,535	225	278,011	1,707	724,426	1,197	593,872	403	112,210	107	18,344	431,226	2,754,122	4,939,831
	1900	17	2,513,812	142	170,490	961	405,604	690	336,112	270	69,307	1	185	222,400	1,973,715	3,167,842
Illinois	1905	104	21,644,783	1,631	1,406,868	6,131	3,203,435	4,941	2,780,370	1,186	422,187	4	878	1,969,790	7,649,446	16,700,027
	1900	82	11,641,177	1,142	637,933	6,048	2,818,274	4,699	2,440,344	1,246	356,927	103	21,003	1,565,404	4,675,961	12,169,425
Indiana	1905	34	3,174,505	384	382,421	1,416	663,834	1,232	615,925	184	47,909	...	...	459,061	1,066,634	2,857,174
	1900	24	1,453,356	134	133,693	881	340,355	715	304,922	166	35,433	...	...	89,172	784,393	1,586,229
Kentucky	1905	3	203,701	9	8,348	73	34,518	60	31,273	13	3,245	...	...	14,033	84,406	169,788
	1900	4	76,077	7	6,379	56	24,396	37	21,801	18	2,461	1	134	11,526	66,285	117,680
Maryland	1905	6	191,315	23	26,248	161	65,813	139	62,198	14	2,600	8	1,015	20,679	92,600	224,859
	1900	6	236,710	26	26,925	155	54,303	137	50,967	13	2,736	5	600	28,156	112,464	266,811
Massachusetts	1905	72	12,735,427	871	962,650	8,798	5,003,190	7,107	4,437,918	1,499	521,185	192	44,087	1,448,091	7,324,167	15,882,216
	1900	54	8,259,612	565	556,703	5,202	2,714,449	4,256	2,445,100	843	244,221	103	25,128	454,008	5,250,293	10,490,361
Michigan	1905	14	413,732	60	58,588	529	176,817	372	148,852	143	25,366	14	2,599	97,031	294,374	702,102
	1900	12	547,319	29	28,962	184	86,188	170	81,269	11	4,513	3	406	38,314	182,452	438,144
Minnesota	1905	15	389,211	32	35,960	170	103,015	168	102,040	2	975	...	...	30,146	186,561	423,933
	1900	12	79,935	13	7,976	86	45,340	86	45,340	...	...	...	...	9,585	121,782	228,076
Missouri	1905	20	1,644,031	183	193,244	795	411,804	546	327,999	239	81,565	10	2,240	227,048	606,424	1,740,583
	1900	17	981,975	59	68,650	533	186,216	405	156,646	111	26,245	17	3,325	144,966	355,475	910,602
New Hampshire	1905	5	162,486	14	12,359	83	32,224	44	22,235	39	9,989	...	...	14,496	88,388	149,871
	1900	5	183,233	11	7,056	94	32,956	53	22,331	41	10,625	...	...	3,704	81,614	181,793
New Jersey	1905	42	18,457,821	1,012	1,002,693	6,268	2,894,139	3,833	2,203,102	2,353	676,246	82	14,791	1,581,525	6,872,638	13,803,476
	1900	36	7,909,120	623	666,622	3,916	1,903,183	2,817	1,575,016	1,016	311,154	83	17,013	785,454	3,538,740	7,532,700
New York	1905	175	30,643,167	1,668	1,730,441	16,301	9,286,912	14,405	8,700,862	1,854	578,405	42	7,645	3,263,950	17,846,213	35,348,276
	1900	134	17,697,352	1,113	904,201	10,370	5,666,702	9,266	5,341,834	1,023	309,044	81	15,824	893,038	12,538,790	22,695,024
Ohio	1905	92	10,408,184	1,023	1,079,006	5,114	2,268,497	3,747	1,874,381	1,352	391,776	15	2,340	1,685,514	4,699,140	11,019,235
	1900	64	7,036,103	394	399,202	3,773	1,502,270	2,956	1,315,376	794	181,569	23	5,325	568,201	3,338,978	6,504,847
Pennsylvania	1905	80	58,393,011	2,746	3,089,535	9,404	5,299,668	8,252	4,909,121	1,069	375,709	83	14,838	5,580,353	11,365,212	26,257,569
	1900	63	20,967,587	646	836,960	7,817	4,002,737	6,600	3,677,780	1,054	294,236	163	30,721	1,647,426	11,372,739	19,112,665
Rhode Island	1905	11	3,608,034	119	153,096	1,409	557,065	1,002	442,441	398	112,524	9	2,100	201,343	4,017,178	5,435,474
	1900	13	2,652,135	50	64,524	864	328,691	586	254,318	278	74,373	...	...	257,774	4,134,980	5,113,292
Wisconsin	1905	23	6,329,351	396	450,644	1,204	672,812	1,140	655,891	59	15,844	5	1,077	758,306	1,020,359	3,194,132
	1900	7	981,553	56	63,744	527	221,501	489	213,701	38	7,800	...	...	48,245	358,976	923,587
All other states	[4]1905	25	625,492	97	89,487	411	144,655	379	139,054	22	4,363	10	1,238	80,693	369,343	777,780
	[5]1900	16	184,394	22	17,065	224	74,403	216	72,850	7	1,376	1	177	17,462	159,892	318,622

[1] Exclusive of electrical machinery, apparatus, and supplies, valued at $18,742,033, made by establishments engaged primarily in the manufacture of other products. This value was distributed as follows: California, $81,600; Connecticut, $591,094; Illinois, $1,056,263; Indiana, $252,208; Maryland, $400; Massachusetts, $14,900; Michigan, $217,131; Missouri, $205,745; New Hampshire, $28,185; New Jersey, $5,130,814; New York, $5,494,909; Ohio, $1,557,660; Pennsylvania, $2,683,549; Rhode Island, $339,666; Wisconsin, $599,000; and "all other states," $488,909.

[2] The totals for 1900 do not agree with those published at the Twelfth Census because of a reclassification.

[3] Exclusive of electrical machinery, apparatus, and supplies, valued at $13,397,430, made by establishments engaged primarily in the manufacture of other products.

[4] Includes establishments distributed as follows: Delaware, 1; District of Columbia, 2; Georgia, 2; Iowa, 2; Louisiana, 2; Maine, 2; Nebraska, 2; Oregon, 2; South Carolina, 1; Tennessee, 2; Texas, 3; Virginia, 2; Washington, 1; West Virginia, 1.

[5] Includes establishments distributed as follows: Delaware, 1; Georgia, 1; Iowa, 2; Louisiana, 2; Maine, 2; Nebraska, 3; North Carolina, 2; South Carolina, 1; Tennessee, 1; Texas, 1.

The distribution of electrical manufacturing throughout the states has remained the same in all essential respects at the two censuses. New York, Illinois, Ohio, Pennsylvania, and Massachusetts reported at the census of 1905, 523 out of 784 establishments making electrical apparatus, or two-thirds (66.7 per cent). If to these be added the 32 establishments in Connecticut, the 34 in Indiana, and the 42 in New Jersey, it will be seen that 631 out of 784 establishments are concentrated in these eight states. Incandescent lamps are made all over the country, but the largest output is from a plant in New Jersey, which also makes many of the best electrical instruments (although in this respect Massachusetts is also well to the front). The manufacture of insulated wires and cables has had its center on the Atlantic seaboard, particularly in the states of Massachusetts, Connecticut, Rhode Island, New York, and New Jersey, but such material was also produced in large quantities farther west. While the production of telephonic apparatus has always been large in Illinois, this industry has undergone development in several other of the Western states, due to the "independent" telephone movement; and in the Middle states one or two of the largest plants being in New York. A few of the plants enumerated were brought into being by their proximity to lumber regions, affording a supply of insulating pins, cross-arms, etc.

The gross values of the output at the census of 1905, as shown by Table 2, were in close proportion to the number of establishments, but the states do not come in quite the same order. New York led, followed by Pennsylvania, Illinois, Massachusetts, New Jersey, and Ohio, in the order given. If the amounts for these states be totaled, it will be seen that the great bulk of all products, or over five-sixths of the whole (84.5 per cent) came from these 6 states.

The great increase in the amount of capital invested in the period has been referred to. In 1900 the $83,659,924 of capital invested had, so to speak, reproduced itself during the year with a margin of almost $9,000,000, the value of the products being $92,434,435. In the year 1905, however, the capitalization of $174,066,026 returned was associated with a production valued at $140,809,369—an indication of an undue increase in the capitalization. According to Table 2 this increase was distributed uniformly throughout the country, but was greatest by far in the state of Pennsylvania, where the increase was from $20,967,587 to no less a sum than $58,393,011; in other words, there was an increase of capital in that state of 178.5 per cent, although the value of products increased only from $19,112,665 to $26,257,569. In New York state the capitalization increased from $17,697,352 to $30,643,167, but the value of the products rose from $22,695,024 to $35,348,276. Another notably large increase in capitalization was that in Illinois, where it rose from $11,641,177 to $21,644,783, while the products increased only from $12,169,425 to $16,700,027. In New Jersey the capitalization increased 133.4 per cent, namely, from $7,909,120 to $18,457,821, but the value of the products exhibited a similarly large increase, namely, from $7,532,700 to $13,803,476. Ohio exhibited a more normal ratio of increase in capital and product, as the capital increased from $7,036,103 to $10,408,184, while the products rose from $6,504,847 to $11,019,235. In Massachusetts also the ratio ran about the same, the capitalization increasing from $8,259,612 to $12,735,427, while the value of the products rose from $10,490,361 to $15,882,216. These are the larger figures, while at the other end of the scale, as shown by Table 2, were several states in which the electrical product as well as the invested capital was insignificant. Fourteen states in 1905, with a total of 25 manufacturing establishments, reported a capital of only $625,492 and products valued at $777,780. There was, however, a noteworthy increase in Minnesota, where the capitalization increased 386.9 per cent in the period, namely, from $79,935 to $389,211, with a product valued at $423,933.

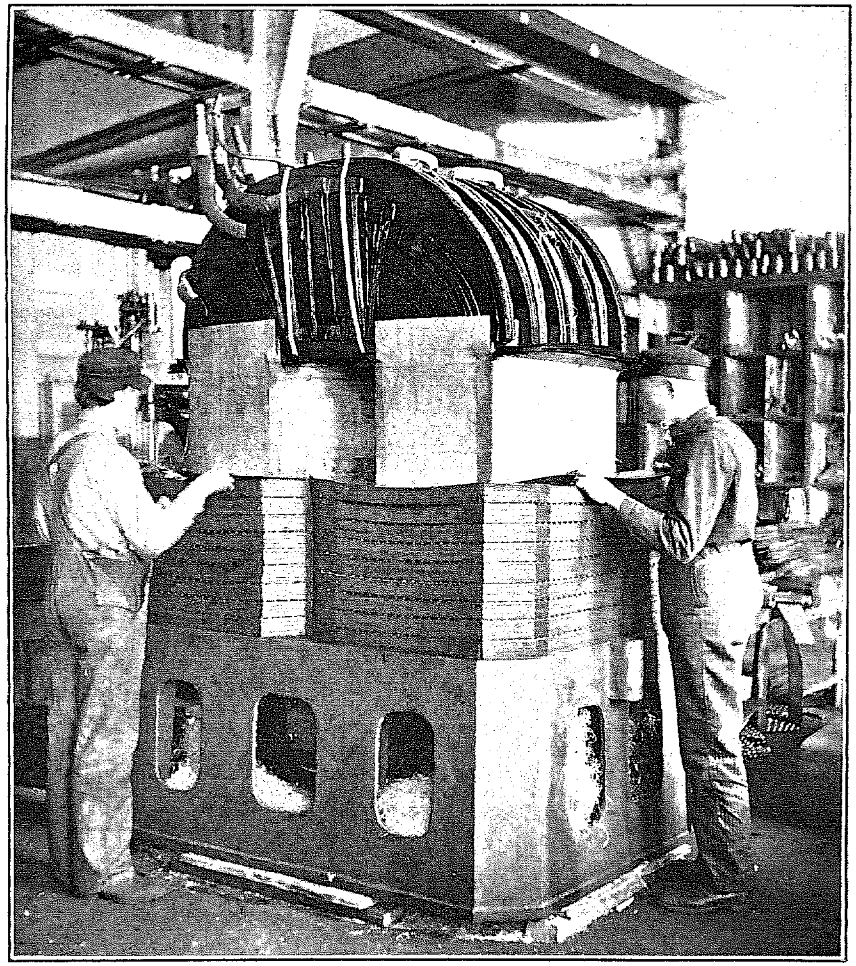
PRODUCTS IN DETAIL.

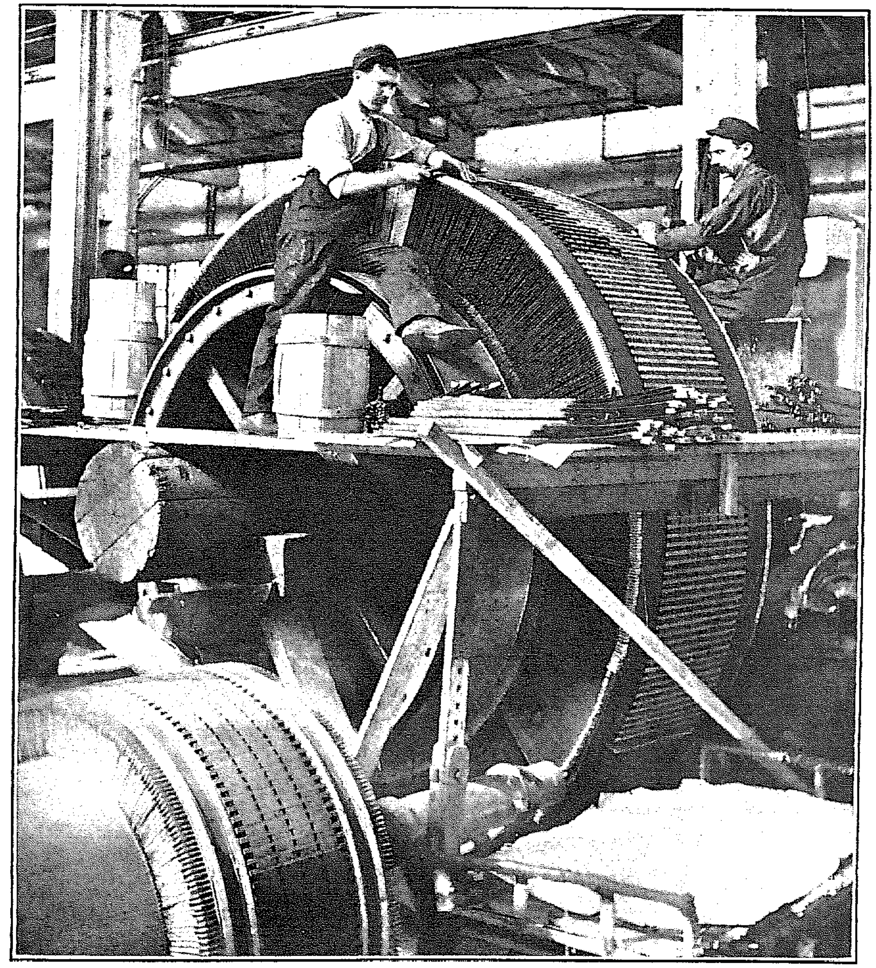
Practically little of the vast production of electrical machinery, apparatus, and supplies goes across the counter directly into the hands of individual consumers. The great bulk of it is purchased and consumed by public service corporations. There are relatively few electrical stores or jobbing houses for retail trade, and even these find their patronage mostly among the electrical contractors. There are no large department stores or other agencies of retail trade through which this vast aggregate of electrical apparatus and supplies can be distributed, but, on the other hand, there were in 1902, 987 operating and lessor street railway companies which constituted the only market for street railway apparatus, and 3,620 private or municipal central station lighting plants, which with some 50,000 isolated plants constituted almost the entire market for electric lamps of all kinds. The third large field of public service electrical consumption was afforded by 25 large telegraph systems and 4,151 telephone systems, in which was used an overwhelming proportion of the telegraphic and telephonic apparatus. Supplementing these intelligence systems there were also in 1902, 764 municipal electric fire alarm systems and 148 electric police patrol systems. It will be readily understood, therefore, that after these large channels of consumption had been filled very little of the apparatus or material was left for the retail purchaser whose average wants, indeed, are limited to an occasional incandescent lamp, a fan motor, a push button, or a few feet of wire. All of these departments, except perhaps that of telegraphy, have made gigantic strides in the last five years, and to their prosperity, therefore, must be attributed the general well-being of electrical manufacturing as exhibited in Tables 1 and 2.

In addition to the electrical products manufactured by the 784 establishments in 1905 and the 581 in 1900, shown in Tables 1 and 2, a large quantity of electrical machinery and apparatus was made by establishments engaged primarily in the manufacture of other products. The value of such products as reported at the censuses of 1900 and 1905 was $13,397,430 and $18,742,033, respectively. The distribution by states of the total for 1905 is shown in a footnote to Tables 2 and 27. The magnitude of this electrical manufacturing carried on in establishments in which it is not the chief product or sole business, is illustrated by the fact that the total of $18,742,033 at the census of 1905 was produced by no fewer than 128 establishments located in 25 states, giving an average value per establishment of $146,422.

The above partial products for both 1905 and 1900, while not included in Tables 1, 2, and 27 of this report, are included in their respective groups in the detailed tables, which present the products by kind, quantity, and value.

Tables 3 to 26, inclusive, give in detail the statistics


CONSTRUCTING A LARGE ALTERNATING CURRENT TRANSFORMER.


BUILDING UP THE ARMATURE OF A LARGE ELECTRIC GENERATOR.

for the different varieties of electrical apparatus and supplies manufactured. Comparative figures for the total for the United States are presented for the comparable products that were reported separately at the censuses of 1900 and 1905. In a number of the states there were only one or two establishments engaged in the manufacture of some of these different classes of products, and to present the statistics for them would result in disclosing the operations of individual establishments. Therefore the totals for 1905 are given by states only in cases where such a presentation does not result in giving figures for less than three establishments engaged in the manufacture of any distinct class of products.

Dynamos.—The statistics with regard to the production of dynamos are presented in Table 3.

TABLE 3.—DYNAMOS—NUMBER, HORSEPOWER, AND VALUE: 1905 AND 1900.

STATE.	TOTAL.			DIRECT CURRENT.			ALTERNATING CURRENT.		
	Number.	Horsepower.	Value.	Number.	Horsepower.	Value.	Number.	Horsepower.	Value.
United States, 1905	15,080	1,328,243	$11,084,234	13,756	853,800	$6,973,130	1,324	474,443	$4,111,104
1900	10,527	770,832	10,472,576	9,182	428,601	6,297,925	1,345	342,231	4,174,651
States, 1905:									
Illinois	2,301	384,015	881,625	2,301	384,015	881,625	(1)	(1)	(1)
Indiana	370	8,953	149,821	370	8,953	149,821	(1)	(1)	(1)
Massachusetts	781	81,485	202,738	781	81,485	202,738	(1)	(1)	(1)
Michigan	358	3,433	58,712	358	3,433	58,712			
Missouri	126	612	18,028	126	612	18,028	(1)	(1)	(1)
New Jersey	1,109	45,451	761,062	1,109	45,451	761,062	(1)	(1)	(1)
New York	2,774	146,375	1,237,737	2,774	146,375	1,237,737	(1)	(1)	(1)
Ohio	2,005	95,482	1,129,794	1,829	49,544	727,626	176	45,938	402,168
Pennsylvania	2,443	93,995	2,537,802	2,443	93,995	2,537,802	(1)	(1)	(1)
Wisconsin	1,225	20,146	294,483	1,225	20,146	294,483	(1)	(1)	(1)
All other states	1,588	448,296	3,812,432	[2]440	[2]19,791	[2]103,496	[3]1,148	[3]428,505	[3]3,708,936

[1] Included in "all other states."
[2] Includes states as follows: California, Connecticut, Kentucky, Maine, Minnesota, New Hampshire, Texas, Virginia, and Washington.
[3] Includes states as follows: Illinois, Indiana, Massachusetts, Minnesota, Missouri, New Hampshire, New Jersey, New York, Pennsylvania, and Wisconsin.

Before proceeding to a detailed discussion of dynamos as a class, it may be well, in view of the importance of the generic group of dynamo electrical machinery, to point out that the total value of dynamos and motors produced was $33,454,860. This does not include dynamotors, etc., which may be classed with transformers. Dynamos and motors constitute the largest single class of apparatus dealt with, and go into service in every department of electrical industry, either as the source of electrical energy or as the means of power distribution. These machines are employed chiefly in the three great departments, traction, lighting, and power, which are to-day frequently supplied from one power house, the electrical energy generated being manipulated by subsidiary devices to render it available for its specific use at the point of consumption. It is true that the value returned for insulated wire and cable was $34,519,699, but this material was supplied to all the electrical arts in varying proportions and no small part was required for use with the dynamos and motors, the installation of which demands these arteries of connection. In like manner the carbons, valued at $2,710,935, the arc lamps, valued at $1,574,422, and the incandescent lamps, valued at $6,953,205, were to a very large degree necessary supplies for the lighting arts that could not be carried on without the modern dynamo. Incidentally, also, it may be noted that no less an amount than $77,539,359 remained for other electrical products, exclusive of "amount received for custom work and repairing." This large amount embraced much apparatus dependent upon or associated with dynamo electrical machinery.

It will be seen from Table 3 that the value of dynamos reported in 1905 was very little in excess of that reported at the previous census, being $11,084,234 as compared with $10,472,576. As the other figures with regard to this class of apparatus indicate, the slight increase in value was associated with a very large increase in number and in horsepower; the number of machines built increasing from 10,527 in 1900 to 15,080 in 1905, while the capacity nearly doubled, rising from 770,832 horsepower to 1,328,243 horsepower. It is obvious from even a cursory consideration of these figures that a relatively small increase in the average size of the machines was accompanied by an enormous decrease in the cost per horsepower to the purchaser. The average size of machines reported in the earlier census was 73 horsepower, and this had risen in 1905 to 88 horsepower. Meantime, however, the cost had decreased from $13.59 per horsepower to $8.35. This change is due entirely to the great increase in the number of large machines in the power plants of central stations and electric railways. In earlier years the work of these plants was done chiefly with machines of very moderate capacity—50 horsepower being a respectable size for an arc lighting dynamo and 500 horsepower for incandescent lighting or electric railway work. The growing demand for current for all classes of service, and the greater distances and larger areas for which this current must be supplied, led to the adoption of alternating current dynamos generally associated with transforming apparatus to which the electrical energy could be delivered at the point of consumption, in order that, if necessary, direct current could be furnished to trolley cars, storage batteries, arc lamps, etc. The whole process of the change is exemplified in the fact that, whereas the direct current machines averaged 47 horsepower in 1900, the 13,756 reported in 1905 had risen to an average of but 62 horsepower per machine, and the average size of the alternating current dynamos had risen from 254 to 358 horsepower. Moreover, while the direct current machines were ten times as numerous, they had not quite twice the total capacity of the 1,324 alternating current machines.

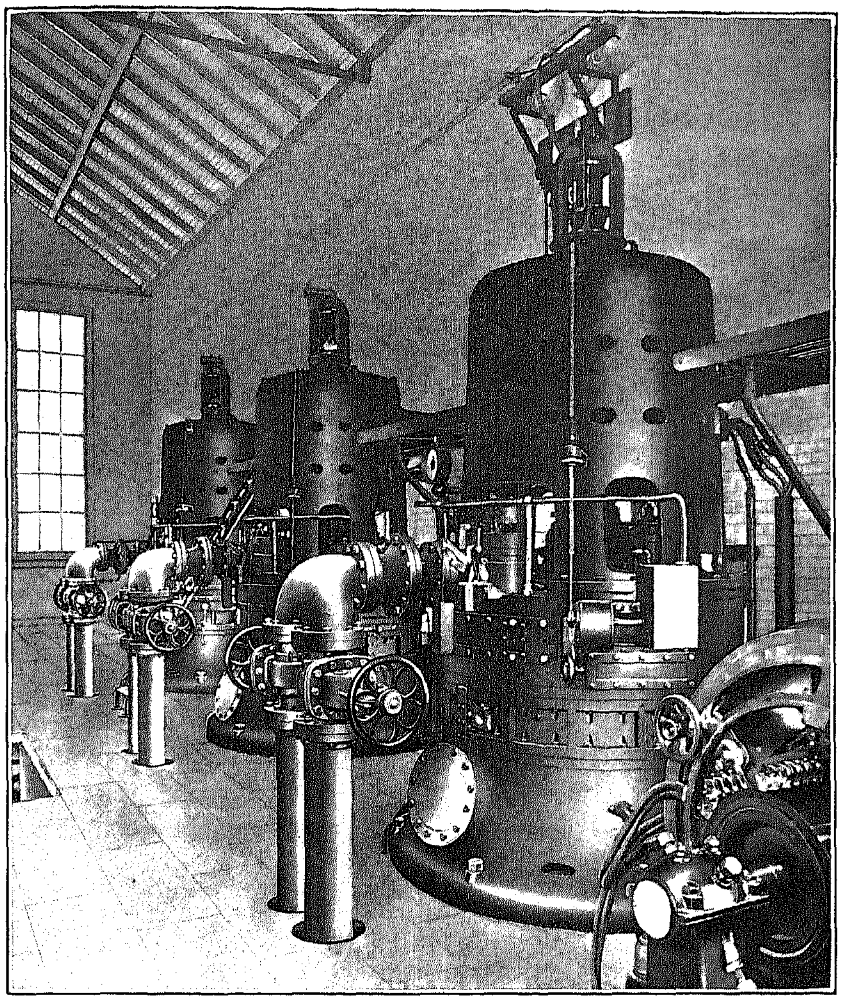
As these figures indicate, while the dynamo art as a whole has already undergone a great revolution with regard to its apparatus for producing current in bulk for great public utilities, and resorts increasingly to the use of alternating current, there is still an insistent demand for large numbers of small dynamos of the direct current type. Ten or fifteen years ago machines of from 50 to 100 horsepower were popular for arc lighting, but now the current for arc lamps is supplied quite generally from the gigantic machines which at the same time furnish current for incandescent lighting and for power. On the other hand, the adoption of electric lighting for steamships, large office buildings, isolated country estates, and scattered mills, factories, etc., has maintained a steady demand for direct current dynamos for incandescent lighting, many of them being employed also in the daytime to furnish electrical energy for motive power purposes. There is a marked tendency in the great cities to abandon the isolated plants in large buildings and to connect with the service mains of the central station companies, but at the same time many of these plants have capacity enough to supply an ordinary town, and being economically self-sufficient are likely to remain in operation indefinitely. A few plants in recent years have been installed on farms to be operated by wind or water power, but the number of these plants during the census year was too insignificant to warrant special inquiry. In many instances central stations have annexed large sections of rural territory to their circuits, thus supplying not only a city or large town, but a great number of farmers, dairymen, etc. Frequently the country districts secure current from the circuits of the interurban trolleys which now constitute so large a network in many of the more thickly settled regions of the country.

Probably a large proportion of the capacity of direct current dynamos is manufactured and employed especially for electro-chemical processes. Electroplating work is done with this type of current at such low voltages that the ordinary city current can not be employed for the purpose unless it is used to drive a motor which in turn operates the low voltage plating machines. It is, however, in electro-deposition and electro-chemical operations that such apparatus in its largest units finds the greatest demand. This is particularly true of the refining of copper. The first electrolytic copper refining process employed for industrial purposes was that of James Elkington, in Wales, in 1869, with an output of about 250 pounds of copper. A few years later the work was taken up in Germany, while in the United States only one plant is recorded as having been in operation as late as 1878. Until 1890 the development of this work was relatively slow, but since that time it has undergone enormous development, so that in 1905 nine large plants for the electro-deposition of copper were recorded as in operation in the United States, all of them employing large capacity, low voltage, direct current dynamos. The largest of these American plants has a capacity of refining 350 tons of copper per day. Not only is the economy of the process such as to explain this extension of electrical methods, but the value of the by-product is enormous, it being stated that at the Anaconda refinery alone over $200,000 monthly is recovered in gold and silver from the slimes of the copper vats.

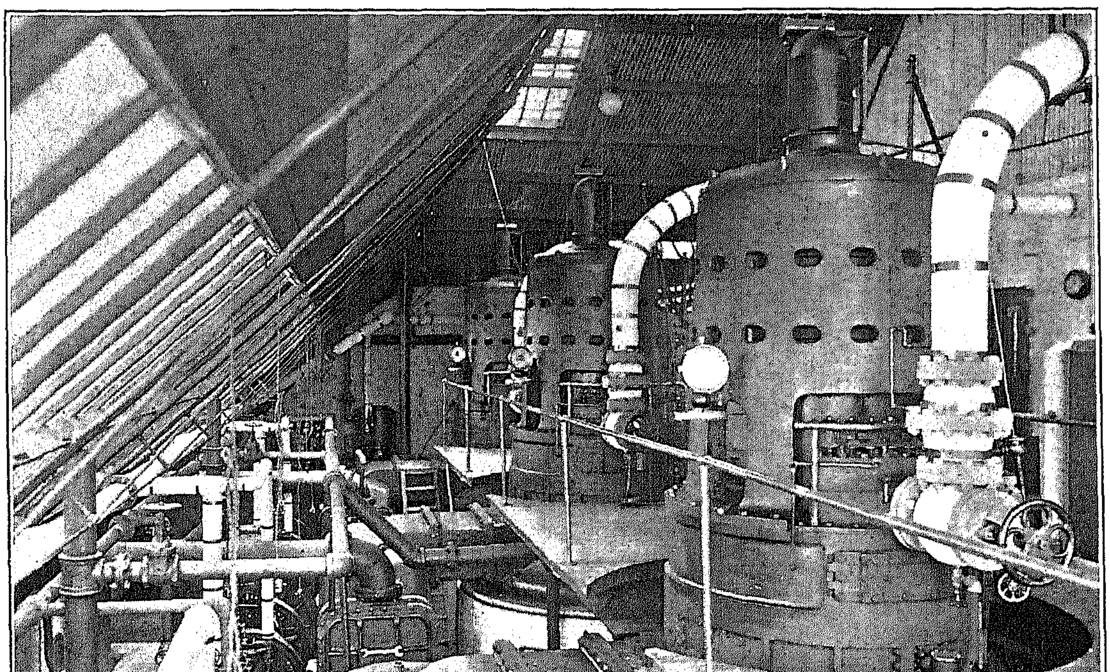
The alternating current dynamos included in Table 3 are of three types, their nature depending somewhat on the uses to which they have to be applied, namely, single phase, 2-phase, and 3-phase. In outward appearance and general characteristics these machines present a uniform appearance, but their style of construction depends upon whether they are to be operated by steam engines, gas engines, or driven by water turbines, and is modified again by the use of steam turbines instead of reciprocating engines.

In the earliest days of electric lighting, single phase alternating current dynamos were employed, but being utilized in a desultory way fell into unpopularity, which lasted until the great revival of alternating current methods about 1885. Then the increased use of incandescent lighting rendered it desirable to cover circuits of much larger area than was possible with the direct current apparatus of low voltage, as this current could not be delivered economically much more than a mile from the central station. The alternating current dynamo, generating current at high pressure and delivering its product to transformers miles apart, where it could be lowered in pressure for the consumption circuits of the customer, leaped swiftly into prominence and importance at this juncture. This created such a revolution in the art that to-day, for example, not one of the great Edison systems, in such cities as New York, Boston, Chicago, Philadelphia, etc., hesitates to restrict the employment of direct current dynamos to generate current at a pressure of 250 volts, or less, and generates alternating current in huge power houses only, transmitting this at pressures of 6,000 or 7,000 volts to substations where it is converted into low pressure direct current for distribution and use.

The earlier single phase apparatus was practically available for lighting purposes only and was usually employed with a large number of reversals of current per minute, the frequencies running from 60 cycles per second upward. Such current could not be used for



THREE 500 KILOWATT TURBINE DIRECT CONNECTED GENERATORS INSTALLED IN A RAILROAD REPAIR SHOP.



FACTORY EQUIPPED WITH STEAM TURBINE DYNAMO ELECTRIC UNITS FOR SUPPLYING LIGHT AND POWER.

electroplating or for charging storage batteries, and as no good motors of the alternating current type were available, the system lacked in flexibility and general availability, so that its advantages of being able to cover large areas were minimized. The difficulties thus encountered at this stage of the art were first settled in a large way in the electric railway field. The new trolley systems limited at first to small urban districts with a few cars and short run of track began to reach out for the suburbs, while the process of consolidation within urban limits brought large and successive increases of mileage to be energized with electric current from the same plant. The solution of the difficulty of supplying electrical energy in continuous volume over large areas for the propulsion of cars was found to consist in the abandonment of smaller direct current dynamos and their substitution by very large alternating current dynamos, whose current could be transmitted with slight loss for several miles and rectified or converted at substations, which in turn delivered the current to the lines at the voltage required for the operation of the motor. Analogous methods were immediately found to be economical in electric lighting, and the revolution was very quickly accomplished in both fields, the process of transition, however, being accompanied by the abandonment of single phase alternators in favor of the 2-phase, and more particularly the 3-phase type.

One of the modifications of manufacture in nearly all dynamos of this type has been their self excitation and compounding with alternating current. In the earlier practice small direct current machines were employed, driven by separate engines or by turbines to furnish the current in exciting the field of single phase or polyphase alternators. A further step was illustrated in the Niagara plant, where the current for exciting the fields of the generators was obtained directly from synchronous converters, which in turn were supplied with alternating current from the generators—static transformers, however, being interposed to reduce the potential. In this manner alternating current at about 125 volts potential was delivered to the collector of the rotary converter, and from the direct current commutator of the other converter current was delivered at a potential of 175 volts to the generator fields. The next step has been to lead the current generated by the machine directly to the field windings for excitation and compounding by means of a peculiar commutator device. By the interposition and suitable interconnection of transformers, or by certain circuit arrangements in a single transformer, the exciting current of the machine is taken off in shunt to the main winding and the compounding current in wattless series, and so conducted to the commutator that the exciting current remains approximately constant for all loads, while the compounding increases and decreases with the wattless component of the main current. The main feature of the machine is the commutator and the connection of the field windings to it. At the time of this report the self-excitation of the alternators has become a general practice, but their compounding within the machine itself, while regarded as effective, is an expensive process. There are other devices for large alternators which are altogether outside of the machine, and which do not increase the cost of the machine itself.

With the introduction of the steam turbine in place of the reciprocating engine, as will be further noted below, there has come into vogue a new class of dynamo electrical machinery, whose characteristics are determined largely by the fact that the turbine operates at a high speed and thus permits large amounts of power to be produced and handled within a very small space. The dynamos in this class become so much an essential and integral part of the machine that a new name has been coined to designate them and they have become universally known as "turbo-generators." It will be readily understood that where a type of apparatus running at approximately 300 revolutions per minute undergoes a change by which it is operated economically and efficiently at 3,000 revolutions per minute, economic and engineering advantages present themselves, and these will explain the rapid development of the product in the turbo-generator field during the census year. It is significant of the pertinent relations of these advantages to dynamo construction that in the United States the construction of these turbo-generator units has been begun and fostered almost wholly by dynamo electrical manufacturers, and up to the present moment has remained in their hands to such an extent that two or three of the leading steam turbine manufacturers, who also build dynamos, may be said to control the production of certainly not less than 75 per cent of the steam turbine output, whether for dynamo operation or simply for the other purposes to which steam engines have hitherto been applied.

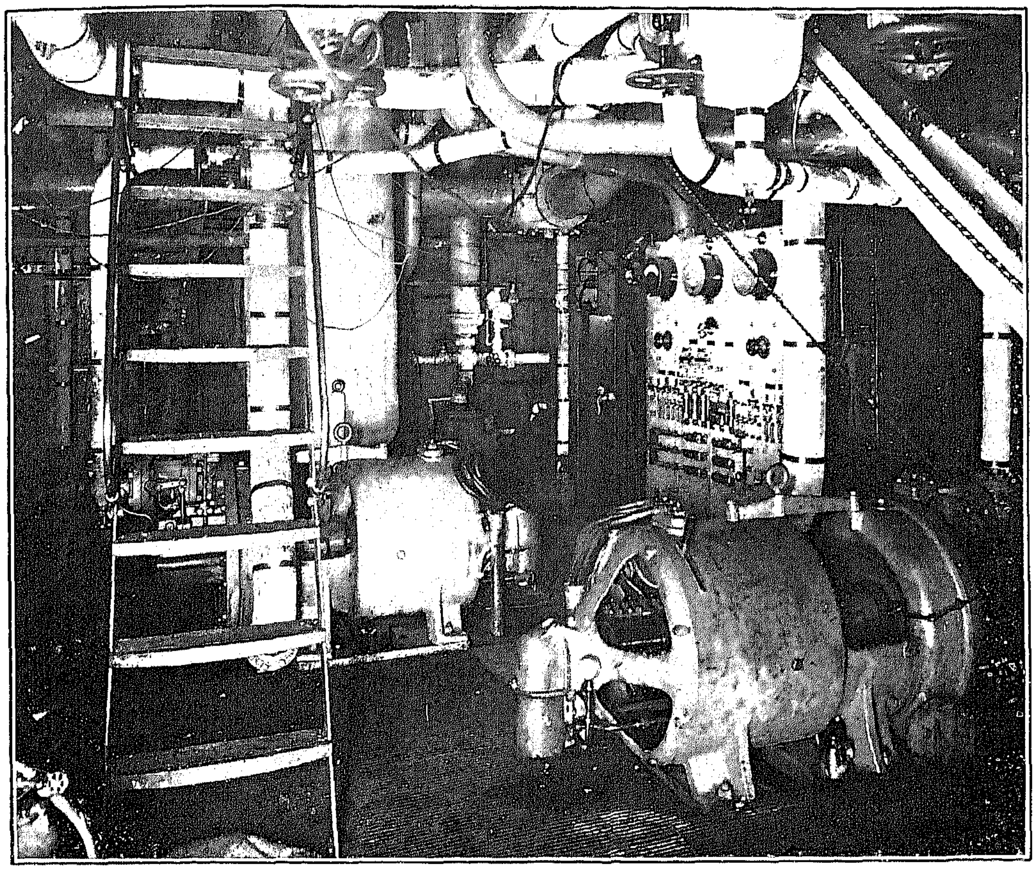
The best illustration of the use of 2-phase alternators is to be found in the power transmission field, particularly at Niagara Falls and on the Pacific coast. The first large utilization of Niagara power was made in a plant of 50,000 horsepower, composed of 10 vertical shaft turbines, each directly connected, by means of a long shaft in the wheel pit, to a 2-phase alternating current generator of 5,000 horsepower capacity. This was supplemented in 1904 by another power house containing 11 generating units of the same type and capacity, affording a total output for the plants of 145,000 electrical horsepower. Each machine is made for generating electrical energy in the condition of 2-phase, 25-cycle current with a potential of 2,300 volts in the machine and operating at a speed of 250 revolutions per minute. In the earlier plants the alternating dynamos were all of the external revolving field or umbrella type. In other words, contrary to the ordinary practice of the time, the armatures were made stationary and the field magnets revolved and inclosed the armature. In the second power house several of the machines are of the internal field-magnet construction; that is, the field magnet has been placed within the armature.

The next step was the design and construction in America of even larger apparatus of this type for the development of power on the Canadian side by the Dominion branch of the American corporation known as the Niagara Falls Power Company. The unit adopted for this was of double the size and capacity, namely, 10,000 horsepower, and wound for 12,000 volts 3-phase instead of 2-phase. The rapid advance in the art is shown in the fact that not only was the unit thus doubled in size within a year or two, but the voltage generated within the machine was increased from 2,300 to 12,000, an enormous stride in manufacturing skill. The new 10,000-horsepower unit occupies only slightly more space than that of one of half the capacity, which results, for a given plant output, in great reduction in length of wheel pit, power house, and fore bay, and a consequent reduction in expense of construction of the hydro-electric plant as a whole. This latest type of large generator driven by waterpower is of the internal field vertical shaft type, the turbine being at the lower extreme end of the long shaft in the wheel pit. The revolving field ring is built up of laminations bolted together with lapping joints, a method which gives a uniform and definite strength of ring with a high magnetic permeability. On account of the high speed of 250 revolutions per minute the generator is small compared with some large steam engine driven units, its over-all diameter being only about 19 feet. The weight of the revolving part of the machine, namely, the field magnets, is 141,000 pounds. The change from 2-phase to 3-phase in these later machines was made at Niagara for the reason that in distributing large amounts of power underground from a 2,300-volt 2-phase plant it becomes cheaper to transform, after a radius of about one mile is exceeded, to 12,000-volt 3-phase and distribute at that voltage. Hence it follows that greater economy of plant construction and operation is secured by the employment of these larger units, directly generating the useful current within themselves at the higher voltage and thus dispensing with transformers. It will be understood, of course, that for the delivery of electrical power at such distant places as Buffalo, Rochester, Syracuse, Toronto, etc., long distance step-up transformers are still employed, raising the voltage to 22,000, 40,000, or 60,000 volts.

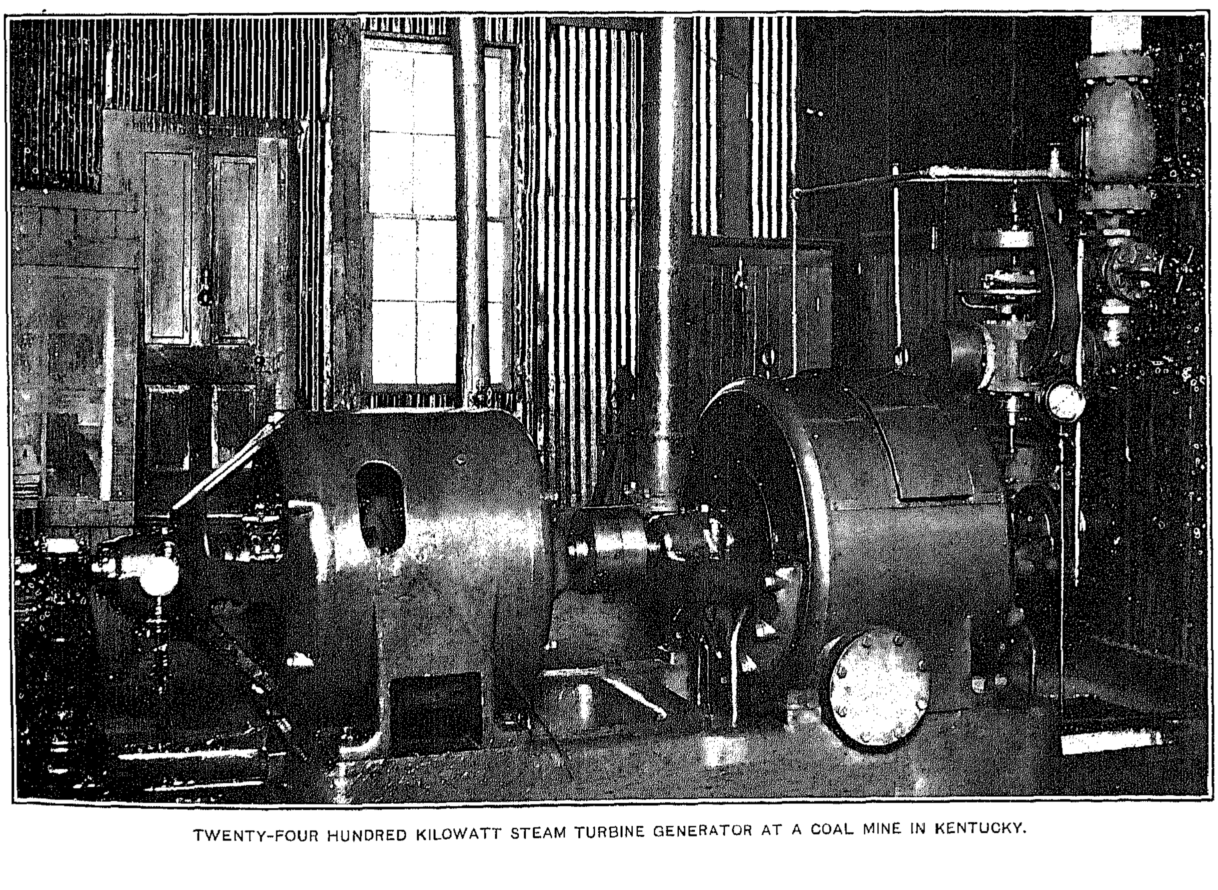
An altogether new departure in dynamo construction has been introduced by the adoption of steam turbines as the prime moving agent, the new practice giving rise to many special problems of a mechanical and electrical nature. Briefly stated, it may be said that the essential feature of a steam turbine consists in a set of nozzles or blades through or against which steam at high pressure passes so as to strike upon another series of angularly placed plates, vanes, or cuts mounted upon a rotating shaft, the whole being inclosed in an outer case or chamber, and the rotating shaft of the turbine carrying the rotor member of the dynamo-electric machine. The arrangement of the turbine or of its parts is such that the steam which has impinged upon a first set of plates or vanes is led through a second set of orifices so as to encounter a second set of plates or vanes during a further expansion, this process being repeated until the steam has virtually lost its useful driving power. The steam in expanding in this manner, adiabatically, acquires a great velocity, the potential energy of its heat being converted into kinetic energy in movement, which is transferred to the device upon which it impinges, so that the potential energy of the steam is converted into work through the rotation of the shaft upon which the receptive plates or vanes are mounted. There is already a variety of constructions of the steam turbine type upon the market, almost all of them designed primarily for the operation of dynamo-electric machines. It is not necessary here to enter into the principles of steam turbine construction, but it is essential to note the main features of the electrical constructions that have resulted from the adoption of the turbine as a prime motor.

Some idea of the extent of the new development may be formed from the fact that during the year ending in April, 1906, the two largest concerns in the American field of dynamo construction received orders to manufacture in one case a total of 188 steam turbines with a total capacity of 220,250 kilowatts, and in the other case 323 turbo-units with an aggregate capacity of 221,175 kilowatts, a total of not less than 441,425 kilowatt capacity. As these were not the only ones produced in the field, it will at once be perceived how enormous a proportion of the addition to the aggregate capacity of American dynamo-electrical machinery the turbo-generators represented in the year of the Census report. The average turbine appears to have been of about 1,000 kilowatt capacity, although the units ran down to as small sizes as 15 kilowatts, or about 20 horsepower.

As already noted, these turbo-generators are of two types, the horizontal and the vertical. In the case of the leading horizontal type made in the United States, the dynamo end of the turbo-generating unit may be said to follow with fair closeness the precedent methods of construction. Two frequencies of current are standard, one of 25 cycles per second for railway and power work, and one of 60 cycles per second for lighting. The character of the generator determines the speed of



STEAM TURBINE GENERATOR SETS IN ENGINE ROOM OF A HUDSON RIVER STEAMBOAT.



TWENTY-FOUR HUNDRED KILOWATT STEAM TURBINE GENERATOR AT A COAL MINE IN KENTUCKY.

the turbine units, and vice versa. For instance, the 25-cycle generator, which at 1,500 revolutions per minute has 2 poles, has 4 poles at 750 revolutions. The generator has a revolving field structure, small in diameter and finished smooth, to minimize windage, ventilation being secured by ducts cut in solid steel. The standard construction of laminated armature is employed and the structure is well ventilated by air ducts between the laminations, to communicate with the interior air by means of slots or openings in the frame. According to the voltage and current capacity of the machine the windings are of wire, bar, or strap copper, and they are thoroughly protected by embedding them in closed slots in the laminations of the armature. The largest types of such machines are exemplified by the 1,250-kilowatt units furnished for the Interborough Rapid Transit plant in New York city. There the horizontal turbo-generator units are of the revolving field type, delivering 3-phase, 60-cycle current directly to the distributing system at a pressure of 11,000 volts. Each unit operates at a speed of 1,200 revolutions per minute, therefore requiring a 6-pole magnetic field. The capacity at full load is 1,250 kilowatts, with 25 per cent steady and 150 per cent intermittent overload capacity. Tests made on these machines show an average efficiency of 96.5 per cent at one and one-fourth full load, 96 per cent at full load, 95 per cent at three-fourths load, 92.7 per cent at one-half load, and 86 per cent at one-fourth load. These efficiencies are calculated from the measured electrical and magnetic losses, the bearing friction and the windage loss not being included. The short-circuit current of the generator is approximately three and one-fourth times the full load current. The generator has been run under test on open circuit for nearly twelve hours at 12,150 volts with full excitation. Under these conditions the maximum rise observed in temperature in the stationary iron of the machine was only 26.7° C. and the rise in the temperature of the field structure was 16.7° C.

The other leading distinctive type of dynamo-electric machine, driven by steam turbine, is vertical instead of horizontal. The leading example of this may be described as a type which, in addition to having nozzles delivering steam at high velocity to a single wheel, has also stationary vanes that redirect the steam which has been discharged from the first wheel into the second wheel. The design of this entire unit, electrically and mechanically considered, has embodied many radical features as compared with other similar apparatus. The shaft, as noted, is vertical and the whole weight of the revolving part is borne in the smaller or earlier designs by an oil film maintained by a pressure pump at the lower bearing. The delivery of steam to the turbine part is controlled through a system of electrically operated individual valves worked by a small controller, a centrifugal governor moving the controller. The revolving field structure of the dynamo is mounted upon the same shaft as the turbine wheels, and above them in the same common casing. The stationary part of the generator is supported by the stationary portion or casing of the turbines, the whole apparatus being built up, in a machine that is rated at 5,000 kilowatts, into the general form of a vertical cylinder about 25 feet high and 14 feet in diameter. The total weight of such a machine complete, including turbine and generator, is 400,000 pounds, with the capacity as stated of 5,000 kilowatts load, and capable of running at about 75 per cent overload condensing, and at nearly full load noncondensing. The first large machine of this type was built for the Chicago Edison Company, and among the latest are those for the New York Edison Company, in which the size has been carried up to 8,000 kilowatts with 50 per cent overload capacity for two hours. This unit at the base is slightly over 15 feet, while the height over the governor dome is 32 feet. The total weight is approximately 700,000 pounds. In accordance with the latest practice of the manufacturers the water type of step bearing is used instead of the oil film type for supporting the weight of the vertical shaft. These turbines are designed to operate under a steam pressure of 175 pounds with 100 degrees of superheat. Their rating permits them to carry a load of 9,000 kilowatts for twenty-four hours of steady running and their overload capacity of 15 per cent, or not less than 16,000 horsepower is guaranteed for two hours as stated. These generators are of the 4-pole type, and operated at a normal speed of 750 revolutions per minute will deliver 3-phase current at a potential of 6,600 volts with a frequency of 25 cycles per second. As will be seen, the leading feature in this latest development is the increase of speed from the 500 revolutions per minute of the earlier 5,000 kilowatt units. With regard to this vertical type of turbo-generator carried up into such large sizes, it is said that compactness and simplicity are resultants of the design, while lateral strain is removed from the bearings which align the shaft, and all deflection of shaft is avoided. To carry such weights as are necessary in the revolving parts of these large units, many very large bearings would be required if the shaft were in a horizontal position. It would also be difficult to so support the wheels that their clearances would not be affected by the sagging of the shaft nor by looseness in the bearings. It might be equally difficult to place the wheels with such a relation to each other that the clearance would not be affected by any expansion of the shaft. In the vertical design the space between the wheels is feasibly reduced to a minimum. The supporting structure is symmetrical and it can not be distorted or put out of line either by the mechanical or steam pressure strains or by the effects of expansion.

Be this as it may, it is the fact that at the period of dynamo-electric construction closing with this report, the turbo-alternators, whether of the horizontal or the vertical type, had become dominant in the field of the production of electrical energy, whether supplied for street railways, for electric lighting, or for power purposes, and their future preeminence was no longer doubtful except so far as the new and larger types of gas engine may be made an economical and mechanical success in the propulsion of dynamos. For such work, three direct connected dynamos were built during 1905 to be driven by gas engines, each with a capacity of not less than 4,000 kilowatts. These interesting units were built for operation in San Francisco, but their operation and testing has been delayed by the catastrophe which visited that city early in 1906.

Closely associated with dynamos is the group of apparatus comprising double-current generators, dynamotors, motor generators, boosters, and synchronous converters, statistics for which are as follows:

TABLE 4.—*Dynamotors, motor generators, and boosters—number, horsepower, and value: 1905 and 1900.*

STATE.	Number.	Horsepower.	Value.
United States, 1905	2,135	279,552	$1,740,534
1900	649	14,397	[1] 379,747
States, 1905.			
Illinois	668	529	29,828
New Jersey	129	2,867	22,006
Ohio	106	23,948	185,567
All other states [2]	1,232	252,208	1,503,133

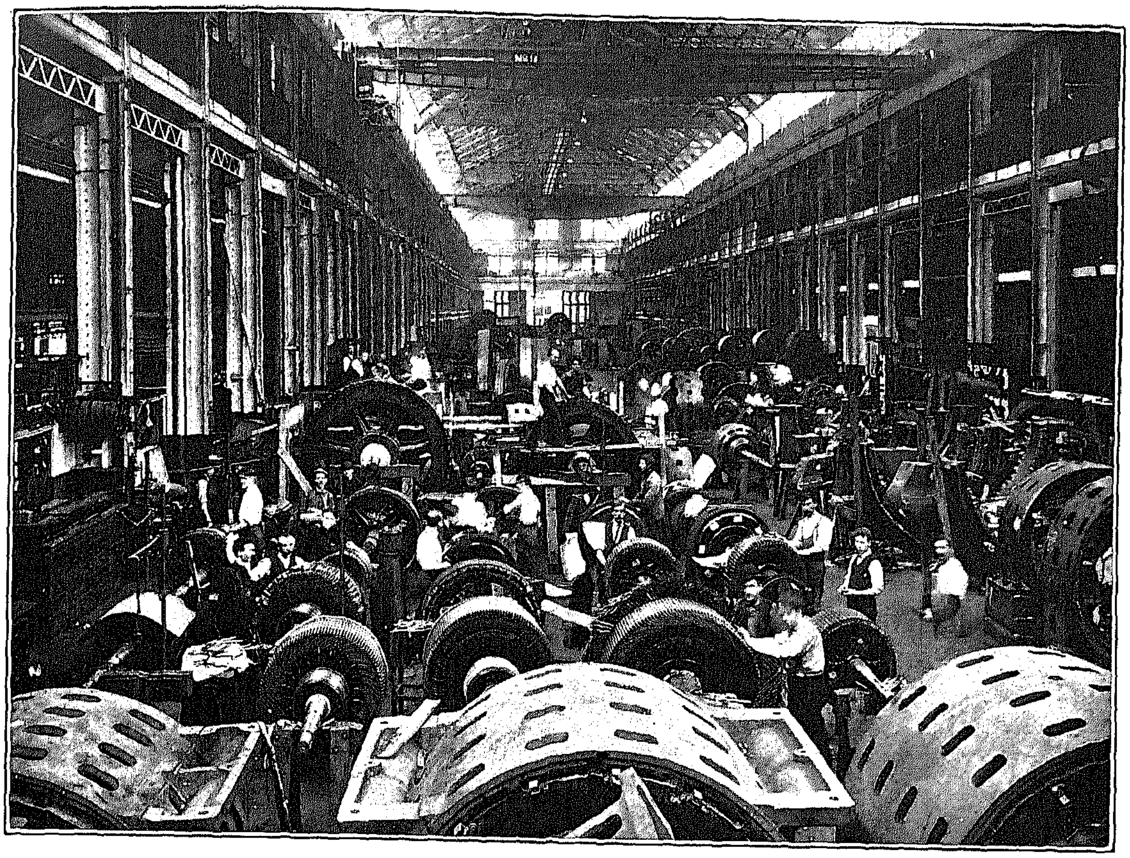
[1] Includes dynamotors, motor generators, and boosters to the value of $25,000 for which number and horsepower were not reported.
[2] Includes states as follows: Indiana, Kentucky, Maine, Massachusetts, Minnesota, Missouri, New York, Pennsylvania, Texas, Virginia, and Wisconsin.

The statistics of Table 4 include 2,135 machines of this type of a total capacity of 279,552 horsepower, valued at $1,740,534, for the census of 1905. All this apparatus embodies the striking characteristics of the generating apparatus by which mechanical energy is converted into electrical energy, but, except in the case of the double current generators, a small and limited group is employed for the manipulation of current so as to render it more readily and economically available in the consumption circuits. As already noted, practically all the 2-phase and 3-phase current generated by the machines enumerated in the preceding paragraphs passes through synchronous converters, by which it is transformed to direct current for charging storage batteries, driving motors, energizing lamps, or setting into operation electro-metallurgical and electro-chemical processes.

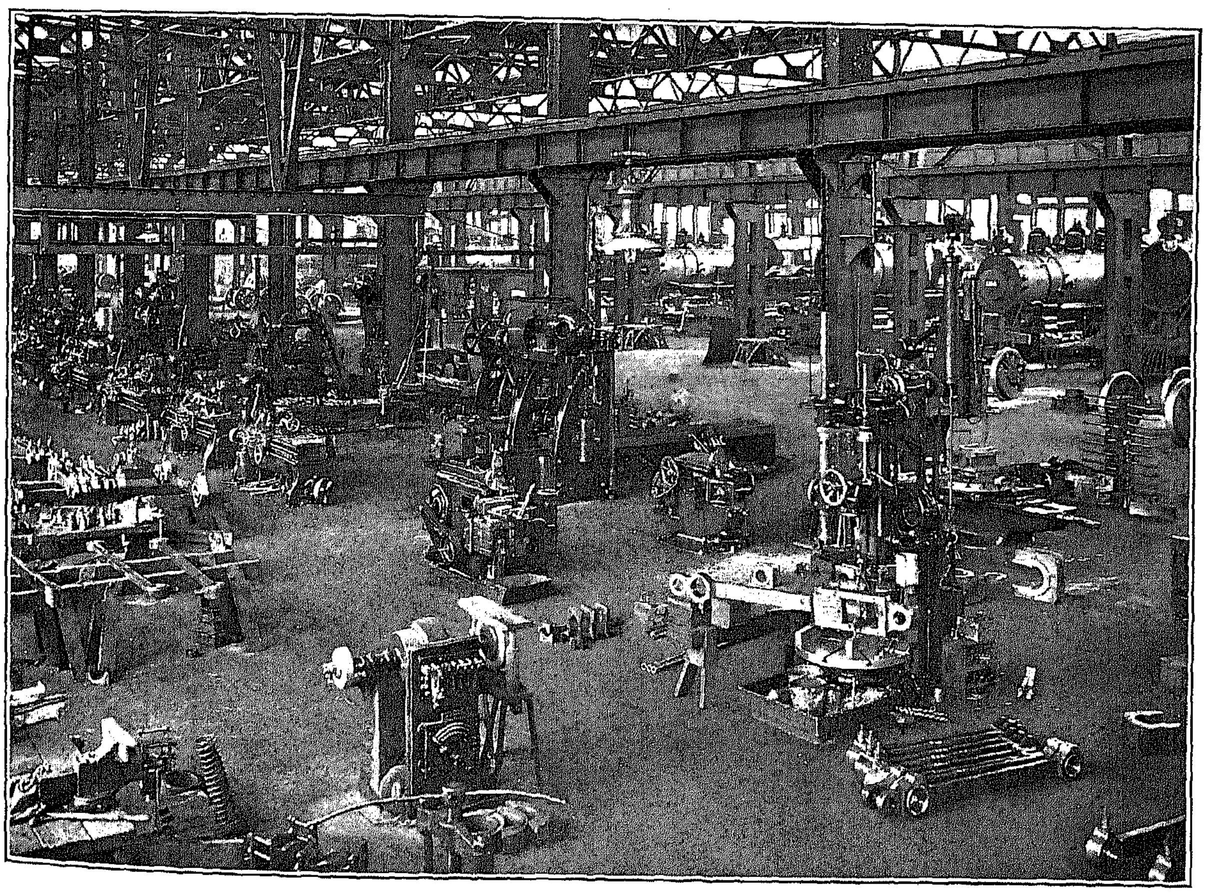
The synchronous converter is a dynamo-electric device receiving the alternating current on one side and delivering direct current on the other side, or vice versa. This type of machine is more particularly favored in America than are the motor generators, where the receiving part of the transformer system is a separate machine mounted on the same shaft as the delivering machine, which is connected to the consumption circuits. In the last year or two motor-generator devices of a large type have come into more general use in America, hence some of them are included in these figures. Of course it will be understood that a synchronous converter can be, so to speak, inverted, and the practice is sometimes found to prevail of driving the machine as a direct current motor, taking electrical energy from direct current supply mains through its commutator and delivering this energy in the form of alternating current from its collector rings. These rotary converters are now often built in units of several hundred horsepower and the substations in which they are located are themselves much larger than were the generating plants of a few years ago. In New York city to-day, while there are barely a half dozen large generating plants located at the water's edge, there are scores of these distributing stations scattered all over the city in which the synchronous converters are located; and the same general disposition is true of the extensive power transmission systems and interurban railroads now to be found in so many of the rural and mining districts of the country.

The dynamotor has been quite extensively manufactured for telegraphic purposes. Its principle is that of receiving the current from a general source of supply and then delivering another current from the same machine at the required voltage for any one of the numerous telegraphic circuits, each to be supplied with a different current. In the dynamotor the two armature windings are usually placed upon the same armature core and are acted upon by the same flux magnet. The object of this construction is to secure compactness and enable the armature reaction of the dynamo to neutralize that of the motor, thus avoiding troubles the chief of which is sparking at the commutator. This method has been found open to the objection, however, that it is somewhat difficult to insulate the two windings from each other and to prevent the high voltage in one from breaking through to the other. A further development of the same idea to secure independence of action between the motor and the dynamo portions of the dynamotor or "rotary transformer"—as it is sometimes called—is to carry the separate armature windings upon separate cores and to allow each to be acted upon by its own field magnets, thus permitting the field of the dynamo to be independently regulated in order to vary the voltage that is generated. In some cases the separate armatures are mounted upon the same shaft with one set of bearings and the two machines are arranged upon the same base or bedplate, sometimes with an intermediate bearing, in which differentiation they approach again the motor generators already described.

As a general thing, while there is some looseness of phraseology about the matter, the term "dynamotor" is applied to the smaller transforming units employed in telegraphic work, etc., and the idea of the synchronous converter is associated with the



WINDING ARMATURES FOR ELECTRIC GENERATORS.



RAILROAD SHOP WITH TOOLS EQUIPPED WITH MOTORS ON MULTIPLE VOLTAGE SYSTEM.

kindred machines doing the heavy work of lighting and power.

Double current generators are machines of the synchronous converter class, for since the synchronous converter is provided with a single armature winding connected to a direct current commutator and the alternating current collector rings, it is evident that if such a machine be driven by outside mechanical energy, it can be made to generate both direct and alternating current; and as a matter of fact in some plants such machines are employed as converters at one period and as generators at another time. One early and typical use of such work was furnished in the installation of the Chicago Edison Company a few years ago, when double-current generator units were installed for the purpose of cross-connecting the generating stations, in order to enable one plant of the system to help out another as desired.

Motors.—Table 5 presents the statistics of the production of electric motors at the censuses of 1900 and 1905.

TABLE 5.—MOTORS—NUMBER, HORSEPOWER, AND VALUE: 1905 AND 1900.

STATE.	Aggregate value.	FOR POWER. Total. Number.	Total. Horsepower.	Total. Value.	Direct. Number.	Direct. Horsepower.	Direct. Value.	Alternating. Number.	Alternating. Horsepower.	Alternating. Value.
United States, 1905	$22,370,626	79,877	678,910	$13,120,948	54,242	382,997	$10,254,854	25,635	295,913	$2,866,094
1900	19,505,504	35,604	515,705	7,551,480	29,615	378,329	5,786,052	5,989	137,376	1,765,428
States, 1905:										
Illinois	446,490	4,321	15,632	384,540	4,321	15,632	384,540	(1)	(1)	(1)
Indiana	229,417	1,509	7,890	229,417	1,509	7,890	229,417			
Massachusetts	1,151,111	19,788	78,161	1,151,111	12,760	68,207	770,761	7,028	9,954	380,350
Missouri	474,016	8,602	8,982	474,016	1,302	1,809	46,631	7,300	7,173	427,385
New Jersey	2,068,889	14,406	76,370	1,692,167	14,406	76,370	1,692,167			
New York	3,213,540	8,440	182,361	2,030,627	2,781	44,899	641,996	5,659	137,462	1,388,631
Ohio	993,457	5,704	33,183	717,780	5,704	33,183	717,780	(1)	(1)	(1)
Pennsylvania	5,171,143	5,886	95,048	5,066,997	5,886	95,048	5,066,997	(1)	(1)	(1)
Wisconsin	1,648,208	4,975	34,164	590,184	4,975	34,164	590,184			
All other states	6,974,355	6,246	147,119	784,109	[2]598	[2]5,795	[2]114,381	[3]5,648	[3]141,324	[3]669,728

STATE.	FOR RAILWAYS. Number.	FOR RAILWAYS. Horsepower.	FOR RAILWAYS. Value.	FOR AUTOMOBILES. Number.	FOR AUTOMOBILES. Horsepower.	FOR AUTOMOBILES. Value.	FOR FANS. Number.	FOR FANS. Horsepower.	FOR FANS. Value.	FOR ELECTRIC ELEVATORS. Number.	FOR ELECTRIC ELEVATORS. Horsepower.	FOR ELECTRIC ELEVATORS. Value.	MISCELLANEOUS. Number.	MISCELLANEOUS. Horsepower.	MISCELLANEOUS. Value.
United States, 1905	12,298	713,181	$4,949,795	1,819	19,907	$152,685	102,535	30,796	$1,168,254	1,333	13,398	$638,473	8,481	36,820	$2,340,471
1900	15,284	666,669	7,568,841	3,017	8,220	192,030	97,577	12,766	1,055,369	385	6,730	[4]2,523,901	7,913	11,392	613,883
States, 1905:															
Illinois	(1)	(1)	(1)	(1)	(1)	(1)	6,203	529	56,800	38	335	5,150	(1)	(1)	(1)
Indiana							(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Massachusetts	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Missouri							(1)	(1)	(1)	(1)	(1)	(1)			
New Jersey	(1)	(1)	(1)				24,513	9,101	319,188	233	2,482	57,534			
New York	(1)	(1)	(1)				3,908	1,292	76,238	(1)	(1)	(1)	3,563	3,565	1,106,675
Ohio	(1)	(1)	(1)	104	382	24,451	15,193	2,538	175,386	138	1,290	30,085	258	2,264	45,755
Pennsylvania	(1)	(1)	(1)	(1)	(1)	(1)	4,375	970	49,647	263	2,425	54,499	(1)	(1)	(1)
Wisconsin										(1)	(1)	(1)	3,300	24,572	1,058,024
All other states	[5]12,298	[5]713,181	[5]4,949,795	[6]1,625	[6]19,525	[6]128,234	[7]48,343	[7]16,366	[7]490,995	[8]661	[8]6,866	[8]491,205	[9]1,360	[9]6,419	[9]130,017

[1] Included in "all other states."
[2] Includes states as follows: Connecticut, Kentucky, Maine, Michigan, Minnesota, New Hampshire, Virginia, and Washington.
[3] Includes states as follows: Illinois, Ohio, Pennsylvania, and Virginia.
[4] Includes motors valued at $2,008,455 for which the number and horsepower were not reported; and 60 motors, valued at $261,722, for which the horsepower was not reported.
[5] Includes states as follows: Illinois, Massachusetts, Michigan, New Jersey, New York, Ohio, and Pennsylvania.
[6] Includes states as follows: Colorado, Illinois, Massachusetts, and Pennsylvania.
[7] Includes states as follows: Colorado, Indiana, Maine, Massachusetts, and Missouri.
[8] Includes states as follows: Indiana, Maine, Massachusetts, Minnesota, Missouri, New York, Virginia, and Wisconsin.
[9] Includes states as follows: California, Colorado, Illinois, Indiana, Kentucky, Maine, Massachusetts, Michigan, and Pennsylvania.

Table 5 shows a substantial advance in number and horsepower over the preceding census year, accompanied by a smaller proportionate increase in the total value. As in the case of dynamos, the larger sizes and the greater number produced may be held to explain directly the smaller cost of apparatus to the purchasing public. The extraordinary fact emerges that the value of the motors built was twice as great as that of the dynamos. During the past five or six years, as evidenced by the statistics of power employed in manufactures, the use of electric motors has become almost universal, so that relatively few new mills or factories of any size are established in which the power is not distributed largely by means of electric motors attached directly to the tools or machines, or by short lines of shafting. This change has been facilitated by the general introduction of electric lighting in industrial establishments, so that the same power plant gives forth its electrical energy for the motor by day and for illumination by night. It is interesting to note that no fewer than 79,877 direct and alternating current motors of a total of 678,910 horsepower were built in 1905 for industrial power and kindred motive purposes, with a value of $13,120,948, giving an average size of 8½ horsepower to the motor and an average value of about $19 per horsepower.

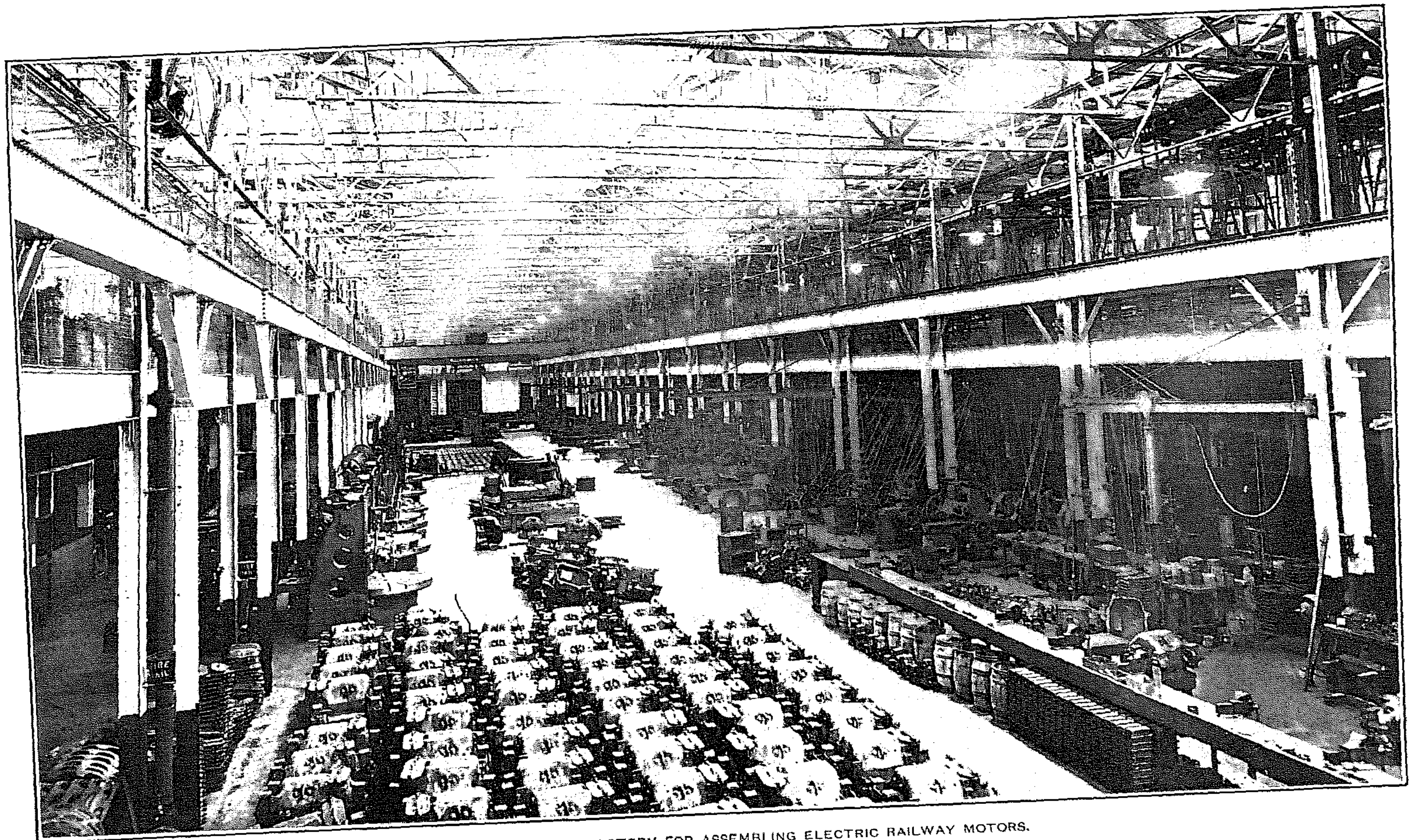
In the street railway field the number of motors required from the manufacturers had actually decreased, being only 12,298, as compared with 15,284 in the year 1900. They had increased, however, in size, but had fallen notably in value, as the capacity was 713,181 horsepower, reported at $4,949,795; whereas in the previous period 666,669 horsepower was returned at a value of $7,568,841—a decline from nearly $11.50 per horsepower to less than $7. This difference was obviously brought about by the gain in size, the railway motors at the census of 1905 having an average size of 58 horsepower as compared with 44 only five years ago. Of course this size is notably exceeded in motors intended for the replacement of steam locomotives, as will be noted below in more detail, but it is also the fact that the larger and longer cars now employed on almost all the electric street railways have necessitated the use of larger motors for their propulsion.

In the automobile field the only serious relative decline is noted with respect to the utilization of electric motors. In 1900 there appeared great likelihood that the electric automobile might advance to perfection as rapidly as other branches of electrical appliances had done, but in general the results have been unsatisfactory, due to the fact that the storage batteries installed have not been able to withstand the excessive jarring and jolting to which they are subjected on uneven roads and poorly paved streets. At the same time even the electric automobile motor has held its own, for while the number is a little more than one-half and the value has decreased considerably, the capacity has increased from 8,220 to 19,907 horsepower. Here again the question of size has had a material influence, and the average capacity of automobile motors has grown from 2½ horsepower to 11 horsepower. This condition is due to the fact that the employment of the electric automobile has very largely shifted from the field of pleasure vehicles to that of industrial types, drays, delivery wagons, etc. Confirmation of this point of view is found in the statement of one manufacturing concern in September, 1905, that in the four years immediately preceding it had built, equipped, and put in operation some 800 electric automobiles for 300 different concerns, nearly all of these machines being intended for industrial purposes.

The electric fan, which has now become a staple electrical product, is shown to have reached over 100,000 a year, valued at more than $1,000,000. As a matter of fact, the type for office use has not varied greatly, being standardized at a fraction of a horsepower. But on the other hand, improved methods of ventilation in theaters, halls, hotels, hospitals, etc., have called for larger sizes, so that while the 97,577 made in the year 1900 had a capacity of only 12,766 horsepower, an average of over one-eighth of 1 horsepower, the 102,535 produced at the census of 1905 had a capacity of 30,796 horsepower, or nearly one-third of 1 horsepower each. Again, it was due to the increase in the size and capacity that the value has been materially reduced. In fact, the electric fan, when regarded upon the horsepower basis, appears to be extravagantly costly as compared with power motors or street railway motors, the average price per horsepower in 1900 having been about $83; but this can readily be accounted for when it is remembered that the average fan motor for desk or countingroom would readily sell at $10 or $12, with a capacity of one-sixth or one-eighth of 1 horsepower. At the census of 1905 the value per horsepower had fallen to much less than half, namely, $38 per horsepower, indicating not only the lower cost of the older, smaller types of fan motor, but the use of a great many ventilating fans of from 2 to 5 horsepower each, so that the prices more closely approximate those for motors of equal rating in other fields of application.

There is no opportunity to compare the relative number and capacity of motors made for electric elevators, as in most cases only the value was given in 1900; but even allowing for an increase in size, it may be questioned whether the decline in value can be accounted for solely upon the supposition of a reduction in price. The electric elevator, which has lately exhibited a spurt of activity, has for some years past had to encounter the opposition of hydraulic and "plunger" types vigorously pushed, and is understood to have barely held its own in the twenty to thirty story buildings now to be found in the larger cities; but there is reason to believe that many of the motors returned under those employed for motive power purposes should have been reported as employed in the elevator and hoisting class, which would have tended to place these figures more upon an equality, with fuller justice to the electric elevator. It is a matter of fact that a large number of new apartment houses in large cities are being equipped with elevators propelled by direct and alternating current motors, and the central station companies report a considerable demand for this class of service.

It should be understood that in both the fan motor and the electric elevator class a large proportion of motors are of the alternating current type, but no differentiation was made in securing the census data. This differentiation would apply equally to the motors enumerated under "miscellaneous." Of these, no fewer than 8,481 were reported for the census of 1905, with a capacity of 36,820 horsepower and a value of $2,340,471. It is to be noted that the motors in this group ranged higher in price per horsepower in 1905 than those in any other category, a fact explained by their small average size and by the variety of their application; spe-



FLOOR OF ELECTRIC FACTORY FOR ASSEMBLING ELECTRIC RAILWAY MOTORS.

cial design and construction being necessary in many instances—as, for example, their use on submarine boats, on board men-of-war for handling ammunition and guns, in exposed places for building operations, in mines for drilling and coal cutting, in post-offices for stamping letters, and in a variety of other uses equally dissimilar and heterogeneous.

The electric motors applied to motive power purposes in industrial establishments are, as the statistics show, of either the alternating or the continuous current type, subdivided again into various groups and classes, determined chiefly by the work to which they are applied. Some motors are designed and supplied to afford constant speed or variable speed and are also compound wound—that is, compounded so as to embody the characteristics of the two other general types. The constant speed motors under normal conditions give practically constant speed for all torques and horsepower capacities within the range of the motors. The synchronous alternating current motors in this group give absolutely constant speed if the cycles or frequencies of current in the circuit upon which they operate remain constant. Continuous current constant speed motors are shunt wound and are usually known by that designation. The alternating current motors in this class, besides being of the synchronous type, are also of the induction type and may be either single phase or polyphase. The induction motor with its absence of commutator has many special advantages and recommendations. The single phase induction motors, included in the figures presented, have generally been built only in the smaller sizes and for operation upon lighting circuits, where the effect of sudden calling for current is not likely to have much if any effect upon the steadiness of the light. When larger induction motors are required, or a large number of small ones, power work is usually done on separate polyphase circuits. One of the difficulties in connection with synchronous motors has been that of making them self-starting, and on account of the low torque developed and the large current taken from the line they have not generally been built of late, although they have been known in the art for several years. The variable speed motor gives automatically great variation in speed for the different torques and horsepower output required of it, and has been found specially suited for work requiring frequent startings and stoppings, such as that in connection with elevators, etc. The compound type of motor is more applicable to work requiring heavy starting torque or frequent startings and reversals, and also for operation at fairly constant speed for great lengths of time. Among the classes of work that may be specified for such motors are the operation of printing presses, machine tools, planers, shapers, etc., where reciprocating motion is desired, the motor being particularly useful in holding back the rush of current from the circuit at the moment of reversal, when the torque required is at a maximum.

During the past few years electric motors of both the alternating and direct or continuous current type have been used to a considerable extent in iron and steel mills and their auxiliary apparatus, and more lately for some of the heaviest operations. Such work includes hoisting, hauling, shears, punches, saws, cross rolls and other rolls, roller beds for slabs, ingots, and blooms, apparatus for pouring steel, horizontal charging machinery for open hearth furnaces, etc. The variable speed motors are used universally for cranes and hauling as well as for the screwing down rolls, charging machinery and the smaller reversible roller beds, while the compound type of motor is also used for the larger roller beds, and for those where the reversals take place less frequently, as well as for the larger saws, cross and straightening rolls, punches, shears, etc. Some idea of the heavy nature of the work now included is afforded by the fact that 1,200 horsepower compound motors were installed recently for the Phoenix Mills to operate the reversing rolls, while two 1,500 horsepower compound wound motors, operating at 100 revolutions per minute and suitable for 25 per cent increase in speed, were ininstalled in the Edgar Thomson Works for rolling rails. A 1,500 horsepower motor was also installed in the Pittsburg Electric Works to drive blooming mills. At one plant in Germany the electrical capacity is of not less than 10,000 horsepower, and the rolls are driven at 120 revolutions per minute, the speed being attained in less than four seconds from the time of starting. The roller train consists of 4 housing frames with rolls of an average diameter of about 29½ inches, turning out blooms, steel rails, and I-beams to a maximum of 17.7 inches in height. These mills have also been turning out blooms from blocks of 2 tons, as well as I-beams 9½ inches high and 164 feet long, and I-beams 13¾ inches high and 82 feet long. In mining operations, partly for deep and speedy hoisting work, motors of equally large capacity have been successfully installed and are now in operation.

Altogether the most remarkable application of electric power in any class of work is that afforded by the new steel works at Gary, Ind., where all the machinery is being installed to be driven electrically, while the gases from the blast furnaces furnish the prime motive power for the operation of the generators. The large rail mill is driven by 3-phase induction motors, ranging in capacity from 2,000 to 6,000 horsepower, attached to the main rolls. These are altogether the largest electric motors in the world. These motors are reversible and are specially controlled, and, being subjected to sudden heavy overloads, each motor is provided with a heavy fly wheel, which, with the system of control, stores up energy when running normally and returns it to the rolls when subjected to heavy overload. Each motor can sustain an overload of 50 per cent for one hour, so that each of three of the motors which has a normal rating of 6,000 horsepower can deliver not less than 9,000 horsepower for one hour if called upon to do so. In controlling these motors for such extremely heavy and trying service a master controller is used, upon which the main line oil switch can be opened or closed, the reversing switch be thrown in either position, or the resistance cut in and out of the rotor circuit in successive steps by means of electrically operated switches or contactors. Special precautions have been taken to insure the automatic protection of the controller system. It is impossible to operate the reversing switch unless the main line switch has been previously opened, and if the main line switch has been opened by the overload trip, it can not be closed without first bringing the controller to the off position. With regard to the special arrangement of the fly wheel in restoring energy to the motor, so-called "slip relays" are provided, in which the actuating coil carries the current to the motor. Whenever the motors are subjected to overloads the slip relays operate, cutting a small portion of the resistance into each phase of the rotor circuit, causing the motor to slow down gradually and the fly wheel to give up a portion of its energy. When the load is taken off the motor, the reverse operation takes place and the motor speeds up, returning the energy to the fly wheel.

Another large field of application of power motors is exemplified by printing offices, where not only the presses but a large number of auxiliary appliances are thus driven. The most conspicuous example of the kind in the United States is afforded by the Government Printing Office in Washington, where about 700 motors, varying in size from one-sixth of 1 to 100 horsepower, have already been utilized for the operation of the two-revolution presses, job presses, stitching machines, shaving and beveling machines, electrotype finishing apparatus, card routing machines, molding presses, and a host of other apparatus required in the processes of the printing art. Mr. W. H. Tapley, the electrician of the establishment, in discussing the equipment, has remarked: "The advantage to be gained from changing over from belted steam driving to individual electric motor for printing-press work is not alone in power saved, but better grade of work, less spoiled sheets, cleaner, healthier rooms for employees, less repairs to machinery, and most of all, an increased product without a corresponding decrease in value of the presses by running at too high speed. There has never been a hitch in the motive power; not a motor has given out. In fact, such a freedom from interruption of power has never been known in the history of the office."

A new type of small motor, which has come into considerable use since the last report for industrial motive-power purposes, is that known generically as the "interpole," which, while essentially a variable-speed motor, can also be used for constant speed work. It is manufactured specially for driving machine tools, pumps, woodworking machinery, laundry machinery, and similar classes of apparatus, whether directly connected or in belted groups. These motors operate on any 2-wire direct current lines at pressures of from 110 to 500 volts. The principle of manufacture in this motor is that of placing auxiliary field pole pieces, small as compared with the main pole pieces, and located between the latter, in the circular ring composing the field. These small pole pieces are provided with coils connected in series with each other and in series with the armature coils, and are so proportioned and arranged as to give the proper field for commutation. This construction enables the brushes to be placed equidistant between the poles; and the motor is capable of reversing its direction of rotation without detriment; and commutation in either direction of rotation takes place without sparking, whether the motor is running with variable load or at variable speed. Since the main current flows through the auxiliary field, weakening of the commutation fringe by an increased load is prevented, and the auxiliary poles produce the compensatory field of commutation independently of the main fields, which with increasing number of revolutions of the armature must be correspondingly weakened. The effect of the auxiliary pole is also independent of the direction of the rotation of the armature, because if the latter is reversed the current in the auxiliary field coils is also reversed. The absence of sparking is a great desideratum, especially where high voltages are employed, and it is this fact which has pointed to the adoption of the motors of the inter-pole type for direct current traction at higher voltages than have been employed hitherto in America. The ordinary direct current railway motor operates on a potential of 500 to 600 volts, whereas the inter-pole types can be employed up to 1,200 or 1,500. In the meantime a large number have already gone into use in mills and factories and machine shops.

The development of the electric railway field has provided, as the statistics show, an extraordinarily large and profitable opportunity to the manufacturers of street railway motors. Strange as it may appear, however, the production of this class of apparatus is confined in reality to three or four factories, and the amount of work done by one of these is relatively insignificant. There is, however, a large class of kindred work devoted to the requirements of mining, for which a considerable number of small electric locomotives are constructed annually. But even this did not materially enlarge the area of manufacture, so that at the most there are not ten factories where street railway motors and electric locomotive motors are built, although the value amounts to almost $5,000,000 a year. Whether the centers of production will remain thus limited in number as the conversion of steam railroads to electrical operation advances, presents an interesting industrial problem, especially as it has been the practice of many steam railway systems to build their own locomotives; and should they continue to do this the creation or enlargement of the shops of electrical manufacturers devoted to this class of work would necessarily be checked. In the modern period embracing especially the electrical régime, namely, from 1890 up to 1902, the number of the street cars had increased in this country, as shown by the census figures, from 32,000 to 66,000. Not only has the number of cars increased, but the carrying capacity has increased, necessitating heavier equipment for the motor cars, and involving in a great many instances the use of four motors instead of the two that were standard in the earlier types of cars. The extreme exemplification of this tendency is found naturally on the interurban roads, and on the elevated and subway systems of the large cities. On large interurban systems it is not unusual to find cars 60 feet in length, weighing from 40 to 60 tons, and four-motor equipments may be said to be universal. To take one district as typical, it may be noted that while 75-horsepower motors are a standard type on the interurban railways of Ohio, the cars of the Lake Shore Electric System have each four 85-horsepower motors, while those of the Scioto Valley have gone so far as to adopt 100-horsepower motors. On the Interborough Subway System in New York, where the express trains have a maximum speed of 45 miles an hour, the motor cars carry two motors of 200 horsepower each, both motors mounted on the same truck—that is, the motor trucks are at one end of the cars, two motors and gear to each axle, while the truck at the other end of the car is a trailer and carries no motive power equipment. These cars, whether built of wood or of steel, are 51 feet long, with seating capacity for 52 passengers.

The latest development in the field of street railway motor construction embraced within the period of this report is the resort to alternating current with the single phase motor, or with motors of this type which can be operated both by the direct current and the alternating current, thus enabling them to fulfill more nicely the best conditions of operation at slow speed and low voltage within city limits, and high speed and high voltage in suburban and rural districts of the same system. The advances in this field have been very rapid, and to such a degree that while a number of street railways have been equipped with this style of apparatus, the New York, New Haven, and Hartford Railroad has gone further and has installed it for use on its first electric zone, having New York as the terminus or center. One of the latest and best exemplifications of single phase motor work is furnished by the Pittsburg and Butler Railway, with a circuit distance of not less than 40 miles, with heavy grades involving an average rise of 8.5 per cent continuously in lengths of 1,100 feet, and with several 7-degree curves, over which grades and curves a schedule speed of 25 miles an hour is maintained. The single phase cars of this road are each provided with four 100-horsepower motors of the compensated type, designed for using both direct and alternating current, so that while using the direct current within the city limits of Pittsburg and Butler, they "let themselves out," so to speak, with the alternating current on the intervening stretch. In these motors the field coils are placed in slots in the cylindrical laminated pole structure, and the compensating coils are distributed over the total pole area. Thus the compensating coils are in a position to neutralize effectively the magneto-motive force of the armature current, while the field coils are in proper mechanical position to allow of the best production of magnetization in the projecting field poles. The field coils of each motor are connected electrically in series, and this connection is not changed at any stage of the operation. The four motors are operated two in parallel, by two in series, for alternating current, while they are connected permanently two in series for direct current operation. Each car is provided with a frame-like skeleton pantagraph type of overhead trolley for picking up the alternating current, and with two ordinary wheel trolleys for direct current work.

In main line operation, such as that involved in the system of the New York, New Haven, and Hartford Railroad for the section between New York and Stamford, Conn., a much heavier type of single phase motor equipment has been required. The total distance is 33 miles, and between the New York suburb of Woodlawn and Stamford the road is equipped with single phase alternating current locomotives taking current from an overhead line. For this electrification 35 locomotives have been ordered. Each locomotive is furnished with 4 motors, each of 250 horsepower nominal capacity. These are of the gearless type and are wound for a normal speed of 225 revolutions per minute. They are connected permanently in pairs and require about 450 volts at the terminals on alternating current and 550 volts on direct current. The frame of each motor is split horizontally, so that it can be removed in halves in order to give access to the interior. In the floor of the cab is an air conduit, from which air is pumped to each motor in such a way as to keep it clean and cool, and this method of cooling enhances the capacity of the motor to such an extent that the rating at continuous operation is almost as good as at the one-hour rating.

On the direct-current part of the line current is taken from a third-rail system with overhead sections at short cross-overs, with the four shoes on each side of the locomotive arranged in pairs of two each. These contact shoes for direct current are ingeniously contrived to work on both forms of third rail, namely, that in which the shoe runs on top of the rail and that in which it makes an underneath or upward contact. The locomotive is also provided with a pantagraph low-tension overhead trolley, and for connecting with the alternating current has two pantagraph type, high tension bow trolleys. Each trolley has a sufficient capacity to carry the total line current under average conditions, but two are provided to insure reserve safety capacity. For alternating current operation 11,000 volts are applied directly to the overhead line, carried by steel bridges over the track, and two step-down transformers on the car lower this pressure to the 450 volts required for the operation of the motors. Each of these locomotives handles a 200-ton train in local service on a schedule of 26 miles, with stops averaging 2 miles apart, and in order to maintain this average speed the maximum speed is about 45 miles. One locomotive is able to handle a 250-ton train on through service—that is, with infrequent stops—while for heavier trains it is the practice to couple two locomotives together and operate them in multiple.

The New York Central and Hudson River Railroad has equipped its New York terminal for operation with electric motors for a distance of not less than 34 miles out on the main line from the Grand Central station to Croton, and for 24 miles out on the Harlem division. At the entrance to this electric zone all steam locomotives are dropped, so far as passenger and mail traffic is concerned, and these trains are handled by electric locomotives of the heavy high speed express type, and in the suburban service by individual motor cars. The first contract was placed for not less than 50 electric locomotives, each of which is capable of making regularly in forty-four minutes without a stop the trip from the Grand Central station to Croton, a distance of 34 miles, with a total train weight of 435 tons. The heaviest of these through trains, weighing 875 tons, is drawn by two of the locomotives at a maximum speed of from 60 to 65 miles an hour, but recently upon test attaining over 80 miles. The locomotive has, broadly, the main lines of the steam locomotive and has four driving axles, on each of which is mounted the armature of a direct current electric motor of 550 horsepower, so that the total rated capacity of the locomotive as a unit is 2,200 horsepower, although for short periods considerably greater power may be developed, making it far more powerful than the largest steam locomotives now in existence. The weight of the locomotive is 97 tons. It has eight driving wheels and four truck wheels, a driving-wheel base of 13 feet, and a total wheel base of 27 feet, the driving wheels being 44 inches and the wheels of the engine truck 36 inches. The maximum tractive drawbar pull is 34,000 pounds, and the tractive pull per ton of engine weight is 330 pounds. The length over the buffer platform is 37 feet, the extreme width 10 feet, the height to the top of the cab 14 feet 4 inches, and the diameter of the driving axles 8½ inches. The voltage of current supplied is 600 volts and the normal full-load current is 3,050 amperes.

These motors mark a distinct advance in electric locomotive construction and have the armature built directly upon the axles. The advantage of direct application of power to the driving axles is thus secured, avoiding the losses in gear and pinion which are encountered in ordinary railway motors employed in street railway work, which have a single reduction between the armature and the car axle. There are only two pole pieces, which are thus practically part of the truck frame, and have flat vertical faces. There is no necessity, therefore, for maintaining a rigid alignment between the field and the armature, and the armature can have a large free vertical movement without danger of striking the pole pieces. The larger part of the weight of the motor, consisting of its field structure and frame, is carried upon the journal box springs outside of the driving wheels. The dead weight on each driving axle is practically the same as on an ordinary steam locomotive, and is said to be about 10 per cent less than that on the heaviest types, while in addition there is no unbalanced weight to produce vibration, which is injurious to track and roadbed construction. The main frame of the locomotive is of cast steel and the field poles and windings are arranged in tandem, the end pole pieces being cast as part of the end frames and the double pole pieces between the armatures being carried by heavy steel transoms bolted to the side frame, and forming part of the magnetic circuit as well as cross braces for the truck. The field coils are wound upon metal spools which are bolted upon the pole pieces. The superstructure to the motors and their truck frame consists of a central cab for the operator or motorman, containing the multiple unit control system, engineer's valves for the air brake system, and the switches and valves for sanding the track, whistling, bell ringing, etc. In this cab is also placed an electric motor driven air compressor, which is automatically cut in and out of circuit when the air pressure falls below 125 pounds or exceeds 135 pounds.

Current is carried from a third rail placed alongside the track by means of multiple-contact, spring-actuated, third-rail shoes, the support of these shoes being carried on channel irons attached to the journal box. Four of these shoes are placed on each side of the locomotive. In the yards at the terminal the large number of switches and crossings necessitates an overhead construction in places, and additional contacts, somewhat after the trolley system, are therefore mounted on the top of the locomotive for collecting current when the locomotive is passing these points. Another type of third-rail shoe, so hooded and protected as not to be dangerous to life nor exposed to accidental contact with falling metal of any kind, has been devised by engineers of the system.

For the enormous suburban traffic handled over the New York Central lines the company has built an initial equipment of 125 steel motor cars, the suburban traffic being brought into the Grand Central station at one level and the heavy traffic with the electric locomotives at another level. These cars are made up into trains of the motor cars and trail cars, as are those on the New York Subway and on the modern electric elevated roads of New York, Chicago, Boston, etc. During the period of initial operation under the electrical régime these cars are coupled up for part of their run for haulage behind steam locomotives. The motor equipment of these 125 motor cars comprises two motors for each car. These machines are rated at 200 horsepower each and both motors are mounted on the same truck. They are operated at a potential of 650 volts, although this can be carried up to 750 volts. The motor trucks are all steel, with 36-inch wheels on the motor trucks and 33-inch wheels on the trailer trucks. The total weight of the motor car loaded is 111,560 pounds, and the weight of the motor per truck is 12,400 pounds. It may be of interest to note that a steam train of the average suburban type with locomotive and six loaded cars weighs 700,160 pounds, while the electric train of equal seating capacity with four motor cars and two trailers weighs 621,360 pounds, or a difference of 39.4 tons in favor of the electric train.

Transformers.—Table 6 shows the production of transformers reported in 1900 and 1905.

TABLE 6.—TRANSFORMERS—NUMBER, HORSEPOWER, AND VALUE: 1905 AND 1900.

STATE.	TOTAL.			50 KILOWATT AND OVER.			UNDER 50 KILOWATT.		
	Number.	Horsepower.	Value.	Number.	Horsepower.	Value.	Number.	Horsepower.	Value.
United States, 1905	66,698	970,908	$4,468,567	3,387	504,009	$1,176,360	63,311	466,899	$3,292,207
1900	36,513	407,451	[1] 2,962,871	(2)	(2)	(2)	(2)	(2)	(2)
States, 1905:									
Illinois	4,628	10,221	31,694	(3)	(3)	(3)	4,628	10,221	31,694
Indiana	4,318	21,190	172,460	25	1,556	9,580	4,293	19,634	162,880
Ohio	1,767	1,082	36,759	(3)	(3)	(3)	1,767	1,082	36,759
All other states	55,985	938,415	4,227,654	[4] 3,362	[4] 502,453	[4] 1,166,780	[5] 52,623	[5] 435,962	[5] 3,060,874

[1] Includes transformers to the value of $2,700, for which number and horsepower were not reported.
[2] Not reported separately.
[3] Included in "all other states."
[4] Includes states as follows: Illinois, Massachusetts, Missouri, New Jersey, New York, Ohio, Pennsylvania, and Wisconsin.
[5] Includes states as follows: Massachusetts, Missouri, New Hampshire, New Jersey, and Pennsylvania.

The production of transformers has nearly doubled from one census to the other, the value having risen from $2,962,871 to $4,468,567, while the total capacity has increased from 407,451 to 970,908 horsepower, and the number from 36,513 to 66,698. These statistics are eloquent testimony to the growing use of alternating current for lighting and power purposes, particularly for lighting in large suburban and semirural districts and for substation purposes in the large railway systems and in most of the large cities. So far as lighting is concerned, the cities of the first class which began originally with lighting systems based on direct current supplied to their customers are still dependent on that type of current, but the operating companies have adopted generation by means of alternating current dynamos, sending out their current at high voltage to substations where it is lowered in pressure by transformers and converted for delivery to the consumption mains. It will be seen from the statistics that more than half the capacity of the transformers manufactured in the census year, namely, 504,009 horsepower, was comprised in transformers of 50 kilowatt capacity and upward, giving an average of nearly 150 horsepower. The effect of size on price is seen in the fact that these larger transformers were returned as valued at $1,176,360, or slightly over $2 per horsepower, a low figure as compared with the price of those under 50 kilowatt capacity. In this latter class, of which there were 63,311, the total capacity was reported as 466,899 horsepower, valued at $3,292,207, or about $7 per horsepower. It is also to be noticed that the average size of these smaller transformers was under 10 horsepower. Taking the figures as a total, it seems that the average value of all transformers in 1905 was about $4.50 per horsepower; whereas in the previous census year, 1900, the average value returned for the total output was slightly over $7.25 per horsepower. This fact emphasizes the effect of the larger size in reducing the cost to the purchaser, but the general reduction is not so clearly determined, for the reason that in the earlier census a differentiation into the two classes was not made between large and small transformers.

As already remarked, these statistics indicate a large production and the important place filled by the transformer in the arts of furnishing light, power, and traction. There are no figures available for the production in the intervening years between 1900 and 1905, and no attempt is made in the present report to distinguish between transformers employed for lighting stations and for power for electric railways, as many of them serve both purposes at the same time. But it is significant that the capacity of the output reported in 1905, namely, 970,908 horsepower, was much larger than the total capacity of the transformers manufactured in 1900. If those of larger capacity than 50 kilowatts be excluded in 1905—as that class would embrace all of those devoted to traction purposes, while probably none in the smaller class was so employed—it is to be noted that in 1905 the capacity was not less than 466,889 horsepower, while, expressed in the same unit of power, the total capacity of all transformers five years before was only 407,451 horsepower. A little further light on this relation as to the use between the larger and the smaller transformers is also given by the Census report of 1902 on lighting plants, where it is shown that the transformers in substations as a part of the central station distributing system had a total capacity of 419,367 horsepower, or nearly one-half as much capacity as all those manufactured in 1905. All the evidence, therefore, that can be brought to bear upon the subject shows that the electric lighting art claims a very large proportion of the transformers manufactured, both as to capacity and number.

The smaller transformers are mainly of the same type as those which were included in the report of 1900 with improvements rendering them more strictly weatherproof; while in the larger sizes it has become the practice to keep them cool by means of immersing the working parts in oil, so that the transformer is virtually an oil tank, containing the primary and secondary coils. In some instances the cooling is also effected by means of air, for which purpose forced draft is occasionally resorted to. The oil is found a better heat conducting medium than air, and a transformer will show a much lower temperature with oil cooling than without. Hence its use is very general through a large range of sizes.

Owing to the development of alternating current power transmission, which has rendered desirable and necessary a corresponding increase in both the kilowatt capacity and the voltage pressure of the transformer units, some of the latest transformers are of sizes that a few years ago would have been considered gigantic. These transformers are used both for stepping-up the electromotive force to a value suitable for transmission economically, and for stepping it down again to safe pressures at the receiving consumption ends. There are several types of these larger transformers. One type, which may be presented as typical, has the oil within it set into continuous circulation by the cooling effect of water coils placed in the top of the transformer tank, to which the oil transfers the heat generated in the transformer. The oil rises through ducts provided in the iron and copper structure of the transformer, giving up its heat to the water coils and descending between the transformer and the wall of the tank. The entire circulation of oil thus effected secures a high cooling efficiency of the oil in the transformer. The largest units of this type built up to the date of the figures of this report were 2,670 kilowatt capacity each, transforming 25-cycle single phase current from 10,000 or 12,000 volts up to 50,000 or 60,000 volts in connection with the utilization of Niagara Falls. A much larger type of transformer, however, is that in which the use of a pump and reservoir in the oil circulation system gives a better control of oil circulation in the transformer so that the heat, which can be easily held down to safe and economical limits of temperature, rises for continuous full load operation; while with sufficient capacity in the oil and water pumps such transformers can carry extreme overloads in the hour of emergency. The oil is circulated by pressure and the water by suction, so that any leak developed in the circulation system does not result in the admixture of the water and the oil. The largest transformers of this type have been those built for the Great Northern Power Company in connection with the development of the St. Louis river in the vicinity of Duluth and have a capacity of not less than 7,500 kilowatts on 25-cycle 3-phase current, and can actually carry 10,000 kilowatts. In these huge transformers the low tension windings are adapted for 6,600 or 13,200 volts, while the high tension windings will withstand 30,000 or 60,000 volts. These transformers have the exterior dimensions as follows: 14 feet 10 inches high, 14 feet long, and 5 feet 10 inches wide.

Switchboards.—Table 7 presents the statistics of switchboards as reported in 1900 and 1905.

TABLE 7.—*Switchboards for light and power—value: 1905 and 1900.*

STATE.	Value.
United States, 1905	$3,766,044
1900	1,846,624
States, 1905:	
California	27,749
Colorado	15,510
Illinois	244,590
Indiana	12,700
Massachusetts	468,689
Minnesota	46,250
Missouri	127,500
New York	1,373,366
Ohio	54,056
Pennsylvania	1,157,027
Wisconsin	11,075
All other states [1]	227,532

[1] Includes states as follows: Connecticut, Delaware, District of Columbia, Georgia, Louisiana, Maine, Maryland, Michigan, Nebraska, New Jersey, North Carolina, Oregon, Rhode Island, Texas, Washington, and West Virginia.

This section of the report is devoted specifically to switchboards intended for electric light and power and electric railway work. It will be understood that there is no system of centralized electrical supply to-day that does not depend upon a switchboard for the manipulation of the circuits—that is, for the connection of the sources of supply with the customer; but this grouping does not include telegraphic or telephonic switchboards, which are included in their respective categories and which are employed for the work of placing the operators or the persons communicating in immediate and direct relationship with each other. With switchboards for light and power the ultimate consumer is not a factor of the problem, whereas in telegraph and telephone boards every circuit of the individual operator or of the individual telephone subscriber must be led to the board in order to permit of the instantaneous and direct interconnection, and this may be said to constitute the great line of differentiation.

As will be seen from the statistics, the value of the lighting and power switchboards has risen from $1,846,624 in 1900 to $3,766,044 in 1905. In other words, the product has almost doubled in the period. This fact, however, does not emphasize fully the importance that the switchboard has assumed in modern installations, for the reason that the board has ceased to be a unit and has in a general way become subdivided, so that in large plants it often extends over several floors, its various parts and mechanisms being placed one above the other. This kind of construction has been called for by the prevailing method of generating electrical energy in the form of 2-phase and 3-phase alternating current for transmission at high voltages to substations, where it is converted into direct current, and there, through the intermediary of the subswitchboards, passes out to the consumption circuits. In the Government Printing Office at Washington is an excellent type of the old style of direct current switchboard, built of Tennessee marble and having a total length of over 83 feet. The new section of this board, with a length of 34 feet, consists of two generator panels and seven feeder panels, carrying not less than 25,000 pounds of copper on its circuits to receive and distribute the current from the generators. This board, which represents an expenditure of several thousand dollars, is bound by handsome, heavy copper molding, with iron framework and angle iron braces, cable carriers, etc., and is heavily coated with asphalt paint for insulation. It will be noted that marble is used, and this, with slate, is the prevalent material. Wood, which was at one time universally used even on boards for currents of high voltage, is now severely discriminated against in the rules of the National Electrical Code.

A recent type of the "straightaway" switchboard for alternating current purposes is furnished in the equipment of the Holyoke (Mass.) Water Power Company, where the long board, all on one floor, is made up of 12 panels, of which 6 are generators, 2 are exciters, 3 are feeders, and 1 is a regulator, while 3 are left blank for extension. The 6 panels equipped with the apparatus for controlling the generators are furnished with push-button switches for the control of the water-wheel governors, the plant being driven by water turbines as well as by steam turbines. By means of this push-button system of control the switchboard attendant is enabled to raise or lower the speed of the water wheel, and hence that of the alternating generator, which is to be thrown into the supply system in parallel, by merely placing his finger on one or both of the push buttons and without removing his eyes from the synchronizing lamp that indicates the proper moment for completing the operation. A more brilliant and striking exemplification of the push-button control in switchboard practice is afforded by the "dummy" type of board which has been installed in several plants and is to be found in some of the largest stations, such as those of the Manhattan and Interborough Railway systems in New York city. The switchboard proper is associated with a control board with which every alternating generator switch, selector switch, group switch, and feeder switch upon the main floor is represented by a small switch connected into a control circuit receiving its supply of electrical energy at 110 volts from a small motor generator set and storage battery. The motors which actuate the large oil switches upon the main floor of the power house are driven by this 110-volt control current, and thus in the hands of the operator the control switches make or break the relatively feeble control currents, these in turn, after the manner of relays, closing or opening the switches in the main power circuits. The control switches are grouped upon the control bench board in conjunction with dummy bus bars and other connections, so that the whole constitutes at all times a correct diagram of existing connections of the main power switches. Thus every time the operator changes a connection by opening or closing one of the main switches, he changes necessarily the diagram before him on the dummy board so that it represents the new conditions that have been established in connection with each control switch. Small bull's-eye lamps are used like signals—one colored red to indicate that the corresponding main switch is closed, and the other green to indicate that it is open. These little lamps are lighted when the moving part of the main switch reaches approximately the end of its travel. If for any reason the movement of the control switch should fail to actuate the main switch, the indicating lamps would not be lighted. The control board is divided into two parts; one for the connection of the alternators to the bus bars, and the other for the connection of the feeders to the bus bars. Such arrangements have simplified and assisted greatly the work of the switchboard attendant, but can not be said to have lessened in any degree the length, or size, or complications of the main switchboard system.

A good idea of what may be called the distributed switchboard may be gained from the electrical control equipment installed in the Waterside stations of the New York Edison Company, where, on the first floor level, adjacent to the steam turbine room in Plant No. 2 are located the exciter units and associated controlling apparatus, a booster, a compensator, and two end-cell switches for the storage batteries. On the first mezzanine floor are the main and auxiliary bus bars, encased in compartments of brick wall and concrete cement, the bus having wired glass doors in front and at the back, where the cables are attached through disconnecting switches. The second mezzanine gallery contains the selector oil switches by which the feeder or generator cables are connected to the copper bus bars or "busses." On the third mezzanine gallery are the potential transformers, whose connections are brought down from the gallery above through disconnecting switches. On the fourth mezzanine floor are the oil switches, from which are led out through series transformers the high tension feeders to the underground mains. On the fifth mezzanine gallery are placed racks to carry the control wires to the operating boards. Hence it will be seen that the switchboard or switching mechanism continues through several floors or tiers of the building and presents a front to the dynamo room far exceeding in height that of an ordinary dwelling house. The view of such a lofty switchboard as seen in the Waterside Plant No. 1 is indeed most impressive, and gives a vivid idea of the enormous equipment and expense necessary for merely handling the currents generated in such enormous volume by the large power houses.

At one time the switchboard industry was carried on by a large number of manufacturers and required little else than skillful working in hard wood. At the present time switchboards, such as those described, with their huge slabs of slate or marble, and their framework of copper, iron, and steel, involve many problems of intercommunication and of apparatus adjustment. The result is that the larger electrical manufacturing companies have virtually taken over the construction of the switchboards for the plants which they equip, and have made a business also of supplying many of the indicating and recording instruments placed upon the front of the boards.

Batteries.—Table 8 presents statistics of storage and primary batteries, parts, and supplies for 1900 and 1905.

TABLE 8.—BATTERIES, STORAGE AND PRIMARY—VALUE: 1905 AND 1900.

STATE.	Aggregate value.	STORAGE.				PRIMARY.					
		Total value.	Weight of plates (pounds).	Value.	Parts and supplies (value).	Total value.	Liquid.[1] Number.	Liquid.[1] Value.	Dry. Number.	Dry. Value.	Parts and supplies (*value*).
United States, 1905	$4,243,893	$2,645,749	16,113,072	$1,569,371	$1,076,378	$1,598,144	1,734,801	$515,530	4,888,361	$513,026	$569,588
1900	3,679,045	2,559,601	(2)	2,559,601	(3)	1,119,444	708,077	[4] 571,370	1,946,688	316,013	232,061
States, 1905:											
Illinois	257,897	257,897	446,181	137,643	120,254	(5)	....	....	(5)	(5)	(5)
New Jersey	259,240	(5)	(5)	(5)	(5)	259,240	356,840	259,240	(5)	(5)	(5)
New York	646,703	304,947	691,375	304,947	(5)	341,756	121,166	69,531	1,582,142	178,611	93,614
Ohio	26,982	26,982	141,429	18,675	8,307	(5)	(5)	(5)	(5)	(5)	....
All other states	3,053,071	2,055,923	[6] 14,834,087	[6] 1,108,106	[7] 947,817	997,148	[8] 1,256,795	[8] 186,759	[9] 3,306,219	[9] 234,415	[10] 475,974

[1] Includes 128 testing batteries with a value of $12,715 in 1905; and 1,200 with a value of $1,350 in 1900.
[2] Not reported.
[3] Not reported separately.
[4] Includes batteries to the value of $1,500 for which number was not reported.
[5] Included in "all other states."
[6] Includes states as follows: California, Maryland, New Jersey, Pennsylvania, and Wisconsin.
[7] Includes states as follows: Missouri, New Jersey, New York, and Pennsylvania.
[8] Includes states as follows: California, Connecticut, Maryland, Massachusetts, Michigan, Ohio, Oregon, Pennsylvania, and Rhode Island.
[9] Includes states as follows: California, Connecticut, Illinois, New Jersey, Ohio, Pennsylvania, Rhode Island, and Texas.
[10] Includes states as follows: Connecticut, Illinois, Massachusetts, New Jersey, and Pennsylvania.

The returns from manufacturers as to the production of primary and storage batteries, parts, and supplies give a total of $4,243,893, as compared with $3,679,045 at the previous census. Of this total in 1905, storage batteries contributed $2,645,749 and primary batteries $1,598,144. As a matter of fact, the total that should be credited to this field would be larger if it were possible to include within it several items which are necessarily thrown into "all other products." Both storage and primary batteries consist of various elements, which are not always distinguishable or sold together as a unit by the same manufacturer, and yet it is not until these are brought together that a complete cell is constituted. In fact, many of the parts and supplies lie outside the electrical field. For example, a storage battery complete consists of lead plates, the separators used between them, the sulphuric acid solution into which the plates are immersed, and the containing jar of glass, porcelain, rubber, etc. The primary battery in like manner consists of various elements, such as the jars, zinc, copper, carbon, sulphuric acid, caustic soda, bichromate of potassium, according to the nature of the cell, and on the constant renewals of these the efficiency and life of the cell depends. There has undoubtedly been a very large increase in the production and use of storage batteries since the census of 1900, but it is not revealed to any extent by the relative figures here presented. It is true that in the year 1900 there was great activity in the department of storage battery automobiles, giving a stimulus to the production of batteries for that purpose; but while the demand in that field has not fulfilled expectations it has grown enormously in other branches of the electrical arts, and to meet it there have been extensions of the factories devoted to this line of manufacture.

The most extensive use of storage batteries, as already indicated, is in connection with central station lighting plants and electric railways. In such a system, for example, as that of the New York Edison Company storage batteries are to be found not only at the substations but also at the generating plant. In the new Waterside Station No. 2 of that company there are two large batteries installed in the basement, one of 140 cells and the other of 150 cells. One of these is kept on the exciting system for the excitation of the alternating current generators and the other is at all times available for the local distributing system. In like manner, for the work of the New York Central Railroad, the electric storage battery equipment is the largest of its kind in the world. It not only takes care of the fluctuations in the load, but is sufficiently large to operate the entire system under normal conditions for a period of one hour, in case of failure of the generating apparatus. Five of the batteries have an output of from 2,000 to 2,500 amperes for one hour, and the three others have outputs of 3,000, 3,750, and 4,020 amperes, respectively. The batteries are located in buildings adjoining the substations, and are operated in connection with the booster and switching apparatus which occupies the substations. The discharge from the battery is governed by a carbon regulator working in connection with the exciters and boosters, the aim and object of which is to make the battery discharge when there is a heavy demand for current from the line and to charge when the demand is so light that the generating plant can economically put its surplus into this reserve.

The use of large storage batteries, employed to improve the reliability of the railway systems as well as to reduce the operating costs, is well illustrated by the interurban roads of Indiana and Ohio. They have usually been installed with enough lead plates to meet the demands of the load at the time of initial equipment. The large tanks which contain the electrolyte in which the plates are immersed, the boosters, and the other accessories are, however, often considerably larger, so that as the load grows, plates can be added to the battery, and the additional work can be adequately taken care of. In Ohio there are 25 such installations and at least 16 in Indiana, making a total of over 40 large storage battery equipments in these two states in interurban railway work alone. They aggregate 9,376 kilowatts at a one-hour rate of discharge, and when increased to their ultimate energy capacity will have an aggregate of 11,710 kilowatt hours. The function of the battery in such work is indicated by the example of the Northern Ohio Traction and Light Company, which has a battery of 195 kilowatts initial capacity and 288 kilowatts ultimate capacity. Before the installation of this equipment it was necessary at all times to operate two 250 kilowatt generators to carry the load and operate the cars. After the battery was installed it was found feasible to operate the load a large part of the time with only one generator, resulting in a large saving of coal. In like manner another battery of 140 kilowatts has been operated on the Ravenna division to assist in maintaining a steady electrical pressure on the line, so that whereas the electromotive force formerly fluctuated between 100 and 500 volts, it is now maintained at a minimum of 400 volts with much greater efficiency in the operation of the cars. The Dayton and Northern Traction Company was a pioneer in Ohio in the use of the storage battery for interurban work and at two substations has batteries, each of which consists of 260 kilowatts capacity. This road was especially laid out with a view to the use of the battery as an auxiliary, and was therefore enabled to install smaller generators and rotary converters than would have been possible had the battery been omitted.

The storage batteries mentioned above are almost wholly of the lead-lead type or those using lead or lead compound as the active material on the plates and diluted sulphuric acid as the electrolyte in which the plates are dipped or submerged. These lead batteries are made in various ways, but are of two generic types, the Faure and the Plante, the former type predominating as that in which the slower forming process of the Plante method is obviated.

A second class of storage battery little known or used is the copper-zinc or lead-zinc type, but a third class of which considerable numbers were made in the census year is that due to Edison in this country and Jungner in Sweden, in which the soluble zinc negative of the lead-zinc battery is replaced by a grid containing an insoluble metallic sponge. Caustic potash solution is employed as the electrolyte. Upon discharge the metallic sponge becomes oxidized, while the metallic oxide on the positive plate becomes reduced; on discharging the original condition is reproduced.

With his aim directed at very exacting requirements, Mr. Edison has made a large number of iron-nickel cells. The structural material of the cell is steel. The grids and cups that support the active material, the connecting and binding posts, the spacing washers, nuts, jars, and cover are all made of thin steel. In fact, the entire cell is constructed of steel, with the exception of the small amount of hard rubber used for insulating purposes. Each piece employed in the construction of the cell is plated before using with a heavy coat of nickel, which is fused to the steel by a special process, adding to the durability and finish of the cell. The active materials, consisting of specially prepared oxides of nickel and iron, are packed into very finely perforated cups or pockets in the plates, each cup or pocket being made in two sections engaging one within the other. To preserve contact between the particles of active material at all times so as to secure the maximum electro-chemical effect, the nickel mass has been admixed with a considerable amount of graphite in the form of excessively thin flakes and the iron mass has been admixed with a small portion of mercury. These added materials act simply as insoluble conductors between the active particles. When filled with the active material these light cups are placed in suitable rectangular openings in the thin steel grid, and the whole being subjected to a very high pressure, the two sections of each cup are firmly locked together and are at the same time fastened securely into the grid, then resembling somewhat the panes of glass in a small window or the slats in a shutter. The result of this method of manufacture is a plate extremely strong mechanically yet one of unusual lightness. To the eye there is no difference between one of the plates packed with nickel oxide and one built up with the iron oxide cups. In the ordinary type of cell there are 24 of the cups in each plate, and the cell consists of 28 such plates, 14 of nickel, connected with the positive pole of the cell, and 14 of iron oxide, connected with the negative pole, each set being strung on a connecting rod, and all of them being interlocked in such a manner that each iron plate has a nickel plate on either side of it, and each nickel plate has two iron plates as neighbors, except in case of the end plates, one of which is of nickel and the other of iron. The outer surfaces of these plates are in juxtaposition, with two sheets of hard rubber serving to insulate the metal plates from contact with the sides of the containing steel jar. The iron and nickel plates are also prevented, by separators, from coming in contact, for which purpose hard rubber rods have been used. It will be understood that cells can be made with a lesser or larger area, this being simply a detail of manufacture to meet the requirements. The outer jar is made of corrugated sheet steel, having pieces of hard rubber at the bottom and ends to protect it from contact with the plates. The cover is welded to the jar, and on it are mounted two stuffing boxes through which the binding posts, fastened to the positive and negative elements of the cell, extend. There are two other small mountings on the cover. One is the separator which separates the spray from the gases when the battery is charged, thus preventing loss of potash and causing the gas to be inodorous. The other is the filler, through which the electrolyte—a 20 per cent solution of potash—can be supplied to the cell and through which distilled water may be added from time to time to maintain the level of the electrolyte, offsetting the loss by evaporation and overcharging. This filler has a water-tight cover held in place by a strong catch. Fastened to this cover is a small spring which causes it to fly open when the catch is released, but it can not be closed again without some small pressure being exerted, nor will it stay closed unless the catch is securely fastened. When the cover is in place, it is always water-tight, and the chances are minimized of leaving it open accidentally and of possible spilling of solution should the cells be severely agitated. These cells are convenient and simply assembled into trays so as to constitute a battery, wooden trays being built to hold four, five, and six cells. The connections between the cells are made by means of heavy copper wire, well nickel plated. This type of battery to the number of several thousand cells was in use at the time of the collection of these figures, but has been subjected to various improvements. One of the great difficulties encountered by Mr. Edison in the development of this battery was to preserve the contact between the nickel particles which alternately expanded and contracted during the charging and discharging operations, resulting in the gradual deterioration in the capacity of the nickel elements. Furthermore, it was found that contrary to the general expectation graphite was not absolutely insoluble to the potash solution when subjected to the effect of electrolysis. To overcome these defects, it is proposed to make the pockets of the nickel mass in the form of small perforated steel tubes in which the material will be packed under a pressure of several thousand pounds per square inch, and to substitute for the graphite, flakes of cobalt or nickel. In this way expansion of the mass is actually resisted by the tubular pocket and consequently the initial contact is indefinitely preserved. The advantages claimed for this general type of "oxygen lift" battery are its greater capacity per unit weight and its longer life, but, on the other hand, objection is made to its low electromotive force of only 1 to 1.25 volts, as compared with the 2 volts and upward of the lead-lead type.

Of late years there has been little change in the primary battery manufacturing field, the reason being that such batteries were not found suited for relatively heavy work, and that in many instances, as in telegraph offices and telephone exchanges, they have been replaced by small dynamo-electric outfits, and by storage batteries. One branch, however, in which there has been marked activity during the past five years has been that of dry batteries. These are in universal use in connection with gasoline or hydrocarbon automobiles, and almost every automobile of that type carries with it an equipment of several dry batteries. These, being under constant use and subject to accidents of various kinds, are frequently renewed, with the result that the production has been very sharply stimulated by the development of the automobile. A primary type of battery that answers many of the purposes of light power, as, for example, driving a fan motor, supplying current to an X-ray outfit, or operating railway signals, is the Edison copper oxide, which, according to Professor Carhart, has a capacity of work per unit weight greater than that of any other battery, either primary or secondary, hitherto known. In other words, 2.2 pounds of its own weight is able to furnish an amount of electrical energy which, if converted into mechanical energy in a perfect electric motor, would be capable of lifting a pound weight 188,000 feet. In this battery the copper oxide employed is furnished in the form of a compressed slab, which with the connecting copper support serves also as the negative plate. In more recent cells of this type the device has been resorted to of reducing a superficial film of copper on the oxide slab before it is sent from the factory. This film of copper also serves to reduce the internal resistance. The other element in the battery is zinc, the solution being caustic soda.

Prof. F. B. Crocker, in a paper read in 1888 before the American Institute of Electrical Engineers on the "Possibilities and limitations of chemical generators of electricity," discussed and compared the various types of primary cells then on the market, and said that little or no progress had been made for almost a half century, but that the apparatus was at fault rather than the chemical action. He has recently directed attention, as a marked advance in the art, to the battery of Mr. F. A. Decker, of Philadelphia, which has been developed during the past two or three years, and regards it as removing the reproach against inventive ability in this field. This cell is of the two-fluid type, with zinc plates immersed in dilute sulphuric acid and graphite plates in a solution of sodium bichromate and sulphuric acid commingled. The size and number of plates employed in each cell depend upon the current required, but ordinarily there are only two or three flat zinc plates about 5½ inches wide by 9½ inches high, each weighing about 1 pound. Each zinc plate and the dilute sulphuric acid surrounding it are contained in a flat, rectangular, porous cup, made by two unglazed earthenware plates with thickened edges and diagonally strengthened ribs shaped separately in steel molds. These plates are made extra thick to prevent warping in burning, and to produce true flat surfaces and straight edges. When united the cup is ground down on each surface to such an extent that the finished walls are thin and translucent. At the same time the cup is quite strong, no breakages occurring even in automobile service. The exceeding thinness of the walls tends to reduce the internal resistance to a minimum, and the fact that these walls are true permits the graphite and the zinc plate to be placed close together with obvious effect in reduction of resistance, which by test is only 0.013 ohm for a cell with two zinc and three graphite plates and all the connections, the resistance of the plates themselves being included. The negative plates are of graphite, corrugated so as to afford large surface for the action of the depolarizing liquid, with stiffening in the thick edges and diagonal ribs. The case around the porous cups and the graphite plates is filled with the depolarizer, consisting of a solution of sodium bichromate mixed with sulphuric acid. Passing over minor details of construction and finish, it may be stated that a cell of this type under test by Professor Crocker with two zinc and three graphite plates was discharged for a period of five and a half hours at 24 amperes, the internal potential falling from 1.9 to 1.3 volts. In other words, the cell gave 126 ampere hours at an average voltage of 1.73, or 218 watt hours. The cell was then shaken to stir up the liquid and gave 24 amperes for fifty-three minutes longer. This corresponds to the conditions that would exist in electric vehicles, electric launches, or in train lighting. The total output, therefore, was 147 ampere hours at 1.684 average voltage, or 247.55 watt hours. As the complete cell weighed 16.14 pounds, including all solutions, connections, etc., the output was thus 14.7 watt hours per pound of total weight, or about twice as great as that obtained from standard types of the storage battery. The liquid constituted only about one-half of the total weight of the battery, so that with an automobile an additional quantity of solution equal to the weight of the battery could easily be carried in tanks. In this case three times as much electrical energy could be obtained with only twice the total weight. In other words, the output would be 22.5 watt hours per pound, or about three times that obtainable from a standard storage battery. The question of cost is, however, a serious one, and the weight of the zinc, sulphuric acid, and sodium bichromate required to give 1 horsepower hour in this battery—assuming all materials to be thrown away after using—would cost about 35 cents, which is admittedly high. On the other hand, the depreciation of the automobile storage battery is very high, and a close comparison would not be unfavorable to the primary type. An advantage also of this battery, as compared with those of the Edison-Lalande copper oxide type, is its voltage, namely, 1.9 initial and 1.7 average, as compared with 0.667 to 0.4. It is evident from these statements that hope is by no means abandoned in the primary battery field and that the industry has taken on a new lease of life.

Carbons.—Table 9 presents statistics for carbons for 1900 and 1905.

TABLE 9.—*Carbons—value: 1905 and 1900.*

STATE.	Total value.	Lighting (value).	Furnace (value).	Brushes, battery, and miscellaneous (value).
United States, 1905	$2,710,935	$1,050,971	$172,454	$1,487,510
1900	1,731,248	1,263,732	10,974	456,542
States, 1905:				
Ohio	2,216,639	875,544	(1)	1,341,095
All other states	494,296	[2] 175,427	[3] 172,454	[4] 146,415

[1] Included in "all other states."
[2] Includes states as follows: Illinois, Indiana, New Jersey, Oregon, Pennsylvania, and Texas
[3] Includes states as follows: Ohio and Pennsylvania.
[4] Includes states as follows: Illinois, Massachusetts, Missouri, New Jersey, New York, and Pennsylvania.

The value of all classes of carbons reported in 1905 was $2,710,935, a gain of almost $1,000,000 over the census year 1900. This gain was almost wholly in the class of "brushes, battery, and miscellaneous," there being, as a matter of fact, a falling off of over $200,000 in the department of arc lamp carbons, in which the amount was only $1,050,971 as compared with $1,263,732 at the census of 1900. Although the amount was small, there was also a very marked gain in carbons for electric furnaces, the total being $172,454 as compared with $10,974, an increase of more than fourteen-fold. Probably no other department of electrical work reported quite so high a gain.

The falling off in arc lamp carbons is not at all due to the smaller production of arc lamps, as the number of these has been steadily maintained; but whereas the old type of open arc lamp required to be supplied daily with new carbon points, the modern types of inclosed arc lamp, which have almost entirely replaced the open type, will burn for a couple of weeks without recarboning, the consumption being so much less in the semivacuum provided by the inner globe of the inclosed lamp. On the other hand, the carbons used in inclosed lamps are of special construction and cost more than the grades usually employed for open lamps, so that the decline in quantity has been to some extent made up by the increase in quality and cost.

Moreover, the past few years have seen the introduction of lamps in which a special kind of carbon stick is necessary. In the ordinary arc lamp employing plain carbons the light of the arc is a bluish white which is often condemned as disagreeable, and, with the object of securing a light which would correspond more closely in color with that of the incandescent lamp and of the gas flame, resort has been made to what are known as impregnated carbons, in which the carbon base has been mixed with metallic salts. The result is that a large number of "flaming" or "luminous" arc lamps are now upon the market and can be seen on the streets of many cities, their light being of a bright golden color. It has been claimed that such lamps can furnish at least five times the light per watt of electrical power as the inclosed arc, but one of the objections has been that the carbons have a tendency to smoke or fume. It is said that in practice it has been found impossible to increase the metallic impregnation of carbon for the flaming arcs above 6 per cent, as beyond that limit the light is no longer steady. For the positive carbon, such metals as calcium, magnesium, barium, etc., are found suitable; while for the negative carbon, metals which form acids are required, such as tungsten, chromium, and molybdenum. Suitable additions in the positive carbon also are fluorspar and magnesia, and for the negative carbons, tungstic acid and chromium fluoride. The diameter of such carbons can be increased so as to increase the life, as they are constructed in several zones or layers, with the mineral admixtures in varying proportions.

Yet another variety of lamp now coming in of the luminous arc type is the magnetite, to which reference has elsewhere been made under "arc lamps," but which may be noted here because it dispenses entirely with carbon. The negative electrode is a stick of magnetite, while the positive electrode is a block of copper.

With regard to the furnace carbons it may be said that these are of considerable size, shape, and variety, depending upon the work required of them. Reference to these in detail can be found in the standard works on electro-metallurgy and electro-chemistry, although details are not usually given of the exact method of use or the extent of consumption. Each year sees some new branch of electro-metallurgical work open up in which such carbon electrodes are used, and it has recently been noted, with regard to the production of pig iron from electric furnaces in Canada, that the consumption of carbon electrodes per ton of pig iron runs between 15 and 20 pounds to the ton, representing, it is stated, an average cost or consumption of 30 cents worth of carbon per ton of the pig metal.

The miscellaneous group of carbons, shown in Table 9, necessarily includes a large amount of other carbons of special shape employed for retort purposes, but there are two other large classes, one including the small carbon buttons and granules used for telephonic transmitters, while the other comprises the carbon brushes now used very largely for all classes of dynamos and motors and invariably for the motors used in electric railway work. Carbons are also used to some extent in electrical resistances, and these are likewise included in the miscellaneous group. In other words, the use of the carbon is universal throughout the electrical arts, ranging from tiny grains up to rods 60 inches in length and blocks well-nigh a foot in diameter.

Arc lamps and searchlights.—Table 10 shows the number and value of open and inclosed arc lamps for 1900 and 1905.

TABLE 10.—*Arc lamps—number and value: 1905 and 1900.*

STATE.	TOTAL.		OPEN.		INCLOSED.	
	Number.	Value.	Number.	Value.	Number.	Value.
United States, 1905	195,157	$1,574,422	1,748	$29,989	193,409	$1,544,433
1900	158,187	1,827,771	23,656	276,481	134,531	1,551,290
States, 1905:						
Indiana	6,372	83,068	(1)	(1)	6,372	83,068
Pennsylvania	48,058	82,965	(1)	(1)	48,058	82,965
All other states	140,727	1,408,389	[2]1,748	[2]29,989	[3]138,979	[3]1,378,400

[1] Included in "all other states."
[2] Includes states as follows: California, Illinois, Indiana, Massachusetts, Ohio, and Pennsylvania.
[3] Includes states as follows: Illinois, Massachusetts, New Jersey, New York, Ohio, Rhode Island, West Virginia, and Wisconsin.

The total production of arc lamps reported in 1905 amounted to a value of $1,574,422, or $253,349 less than for 1900. At the same time the number showed a large increase, rising from a total of 158,187 to 195,157. These lamps were divided into two groups, open and inclosed, and since the year 1900 a remarkable change has taken place in the relative importance of these two types. In this short period the production of open lamps fell from 23,656, worth $276,481, to 1,748, valued at $29,989. This number would barely take care of renewals, and hence it may be said that the open arc lamp, with which the great bulk of electric street lighting has been done for so many years, is in process of extinction and may be in a very few years obsolete. This view is corroborated by the fact that the number of inclosed lamps made in one year has risen from 134,531 in 1900 to 193,409 in 1905, and, as will be seen, the larger number has brought with it a reduction in cost. The smaller number in the year 1900 was valued at $1,551,290 as compared with $1,544,433 in 1905. The average cost per lamp is thus reduced from $11.50 each to $8, or nearly one-third. This is very convincing evidence of the popularity of the inclosed arc as compared with its predecessor.

These open and inclosed lamps are of either the direct or the alternating current type. The vogue of the inclosed type dates back to 1894, although experiments upon it began several years previously. The principal element in its perfection consists in the relation of the inner globe to the arc, whereby with a suitably restricted air inlet a long arc may be steadily maintained by a small current. In the ordinary open arc lamp the carbon pencils, or sticks, burn away in ten or twelve hours, but in an inclosed lamp the cored carbons used will last from sixty to a hundred and twenty-five hours. The small inner globe inclosing them is of elongated oval shape and made of refractory glass, so as to resist successfully the intense heat of the arc. The consumption of carbon in the arc in this inner globe fills it with carbon monoxide and carbon dioxide, and as the globe is virtually air tight the prolongation of life in the carbon is due to the fact that little or no fresh air is admitted to help in the consumption of carbons. Moreover, the presence of carbon monoxide and carbon dioxide in the bulb shortens the arc to a length of three-tenths of an inch, and allows a pressure of 80 volts to be used; but although the pressure is thus increased to almost twice that of the earlier type, the consumption of power is not greater, as only half the current strength is required. These lamps have become popular with the public, because of their soft and steady light and brilliant appearance, and with central station managers, for the reason that as the carbons last so much longer the lamps need trimming only once a week and often only once a fortnight, depending upon the hours of nightly burning.

The latest development in arc lighting involves what is practically a reversion to the open arc, and the results are so striking that while the old open arc with its simple carbons may disappear entirely, the supremacy of the inclosed arc is likely to be seriously challenged by the flaming or luminous arc. The efficiency of light production is greater from incandescent gases than from solids, while amorphous carbon such as that used in the old carbon points is inefficient from the standpoint of light radiation. Hence if earth or metal having higher light radiating properties can be combined with carbon so as to become light giving in the arc, a high efficiency would result in the arc lamp using such impregnated carbons. The idea of introducing substances for the arc of higher radiating power than carbon was patented as far back as 1876, while experiments on the subject were made at least thirty years earlier. One of the first practical workers in this field in recent years was Hugo Bremer, of Germany, whose lamps were first brought to this country about four years ago and were employed in New York city. The principal feature of this lamp has been the employment of a compound carbon, the arrangement of carbons at an acute angle to each other, the use of a metal chamber above the arc for reflecting the light downward, and the employment of a magnetic field for the automatic regulation of the arc. In this lamp the carbons are forwarded or focused by gravity. When the arc lengthens to or near the breaking point as the "carbon" burns away, and thus makes it difficult for the arc to sustain itself, an electro-magnetically operated lever, used also to "strike" the arc when the lamp starts into operation, reestablishes the arc, and by its motion enables the electrode to feed until the arc reaches its normal length. Both the electrodes are of small diameter; the positive carbon being about five-sixteenths inch and the negative carbon about one-quarter inch. The negative carbon electrode is an ordinary solid carbon of the kind used in standard arc lamps, but the positive electrode is a cored carbon of special composition—that is, it contains metallic salts in considerable quantities, such as magnesium and boron. These two electrodes are inclined toward each other at an acute angle, and the points are surrounded by a metal chamber open below, like an umbrella. The magnesium in the positive carbon makes a snow-like deposit on the surface of this reflector, this white providing additional highly reflecting surface. The coating obtained in this way adheres to the metallic reflector surface to the thickness of about one-eighth inch. A simple arrangement is employed to obtain the magnetic field for the control of the arc, its strength being dependent upon the current flowing through the lamp, which gives an automatic character to the magnetic regulation. The color of the light is varied at will by the use of proper metallic salts, etc., and is usually of a clear golden hue. The general principle of such lamps is that, on becoming heated by the passage of current, the salts which have been introduced into the carbon are volatilized and rendered incandescent. The hot gases thus generated furnish a path for the passage of the current of less resistance than the air.

The Bremer lamp has also been made with carbons vertical to each other as in the ordinary arc lamp. This is also true of the Blondel arc, in which only one of the carbons is impregnated with salts for increasing the illumination. The upper carbon is surrounded by a reflector, and the positive lower impregnated carbon consists of three parts—a core and two concentric layers around it. The outside layer is pure carbon; the middle and thickest layer is a mixture of carbon and salts, such as those of calcium, magnesium, etc.; while the central core has the same composition but is less compressed. The object of this arrangement is that the arc shall always remain in the center of the carbon and the carbon shall burn off uniformly. The thickness of the carbon varies with the size of the lamps. In the upper carbon, which with direct current is the negative one, the impregnation is very slight, and consists almost entirely of pure carbon. The vapors from the salt in the lower carbon rise into the arc and are heated to white heat and condensed on the reflector at the top of the lamp. The reflector consists of a central circular reflecting disk of insulated material and an external ring of metal. The Blondel lamps were first made for a current of 5 amperes or 3 amperes, but there is a later type which consumes only 1 ampere. These lamps burn normally on 50 volt circuits.

The flaming arc lamps as a class may be said to operate single on 55 to 65 volt circuits, or two in series on 110 to 120 volt circuits, and four in series on 220 to 240 volt circuits, on either direct or alternating current. The "carbons" burn from eight to fifteen hours, and are said to consume 0.163 watts per hemispherical candlepower in lamps of good efficiency. Some lamps have been used in this country which employ 17-hour carbons, but it will be seen that all such lamps, like the old open type of pure carbon arc lamps, are subject to the disadvantage of more frequent trimming than the inclosed arcs, necessitating the constant attendance of linemen and trimmers.

The magnetite arc lamp, like the "flaming" arc, has already gone into considerable use on street circuits. Its negative electrode consists of a stick of magnetite, while its positive electrode is simply a copper block. This lamp burns for one hundred and fifty hours, or as long as an inclosed arc lamp, but without necessitating an inner globe, while the production of light for 300 watts electrical power is rated as equivalent to that of the ordinary arc at 450 watts. The objection raised to this lamp, as to the others of the flaming arc type, has been the smoky deposit. The statement is made that pure magnetite, while fulfilling the requirements of a carrier of the arc flame, consumes rather quickly, and it has therefore had incorporated with it small quantities of substances, such as titanium compounds, for increasing the efficiency and steadiness of the arc and the life of the electrode. In the manufacture of these electrodes a greater density and longer life are secured by partially reducing the material to metal. Another method of improving the electrode is that of adding a "restrainer" or a substance which reduces the rate of consumption. A simple and satisfactory form of electrode is that in which the material is pressed as impalpable powder into a thin iron tube, which is then sealed over by the arc. In the ordinary carbon arc lamp the light comes from the incandescent crater of the positive carbon on direct current and not from the arc flame, whereas in the magnetite arcs, which are also operated on direct current, no light issues from the terminals but comes entirely from the arc flame; and hence an arc length of from ¾ to 1½ inches has been found most efficient. The feeding mechanism differs from the "floating system" of the carbon arc lamp and is much simpler, involving a feeding device to maintain constant arc length. In the magnetite arc lamp, therefore, when the electrical pressure is applied to the lamp, the arc is struck, and the electrodes are separated to a definite distance, say, ⅞ inch. The electrodes are then locked in this position and remain fixed until, by the slow consumption of the negative electrode, the arc length and thereby the arc voltage has increased sufficiently to operate the feeding mechanism, which resets the arc to its original proper length. An instance of work done with the magnetite lamp is afforded by Portland, Oreg., where after trying 800 lamps for several months the installation was increased to 1,200, these lamps, moreover, being operated by direct current obtained through mercury arc rectifiers to which alternating current is delivered at a pressure of 18,000 volts. These rectifiers will be referred to elsewhere. The magnetite arc lamps in use in Portland consume 320 watts in the lamp in place of 500 watts in the carbon arcs employed before, and obtain for 364 watts of transmitted power the same illumination that originally required 806 watts. This involves a saving of not less than 1,768 kilowatt hours per lamp per year. The cost of attendance on these lamps has been a little less than on the old direct current open arcs which they displaced, and the difficulties have gradually disappeared from operation. The outages that were noticed at first were due to the magnetite sticks. A button of hard glazed slag would form on the end of the stick and act as an effective insulator. The magnetite electrodes were made by the process of packing the magnetite powder or compound into an iron sheath or cylinder, as noted above. This was done at first by hand, with the result that it was uneven, and the slag formed when the sticks were packed too firmly. Machine packing has, however, been adopted and this difficulty has practically been eliminated.

One further innovation in arc lamp practice is the introduction of lamps in which smaller carbons are used, the lamps having been tried with success in Chicago. It is claimed that there is a marked increase in the amount of light obtained from a given quantity of power as well as a whiter light. The light is steadier, as the arc can not wander so easily around the crater. The size of the carbon adopted is $\frac{5}{16}$ inch. On a 3.5-ampere lamp the use of $\frac{5}{16}$-inch carbons, as compared with the usual $\frac{1}{2}$-inch carbons, gives a consumption of 2.2 watts per candle, as against 3.4 watts with the $\frac{1}{2}$-inch carbons, or an increase of 50 per cent in light. It is necessary to change the lamps slightly to use the smaller carbons, and this is done in the local company's repair department. The gain in steadiness and efficiency is found to be of much importance, especially in meeting the competition of gas arc lamps. The company is now obtaining a life of about one hundred hours from the $\frac{5}{16}$-inch carbons. The smaller carbons do not blacken the inner globe as much as the larger carbons. With large carbons it was necessary, in order to secure good efficiency, to clean the inner globes every seventy hours, or once between each trimming. It is now unnecessary to clean between trimmings. The increase of efficiency by the use of smaller carbons, as well as the greater steadiness and improved color of the light, due to the fact that there is not such a preponderance of violet rays, are matters upon which laboratory tests are hardly necessary, as they are apparent even to the casual observer. Before $\frac{5}{16}$-inch carbons were made the company's standard, the matter was exhaustively tested. Some alternating current arc lamps have also been equipped and put in service with $\frac{5}{16}$-inch carbons, with great improvement in the illumination. Small arc lamps of this general type have also been tried in Germany, within the past year, with the object of closing the gap between the standard arc and the ordinary incandescent.

In the group of arc lamps must be included searchlights and projectors. Table 11 shows statistics of this type of lighting devices for 1900 and 1905.

TABLE 11.—*Searchlights and projectors—number and value: 1905 and 1900.*

STATE.	Number.	Value.
United States, 1905	1,924	$114,795
1900	8,283	225,635
States, 1905:		
California	490	16,147
New York	1,050	47,267
All other states [1]	384	51,381

[1] Includes states as follows: Colorado, Illinois, Indiana, Michigan, New Jersey, Ohio, Pennsylvania, and Wisconsin.

According to the table the number had decreased 77 per cent, while the value had decreased about one-half. On the face of it there would appear to be a serious decline in this class of production since the year 1900, but there are some reasons which would indicate the existence of conditions of a nature more satisfactory to the manufacturers. As will be seen, the average cost per searchlight had risen in the period from $27 to $60, but this is in reality due to an increase in the size and capacity of the searchlight. It is now some years since searchlights were found a desirable and necessary adjunct on board steamships of all sizes, with the result that practically all vessels of American register have been equipped with them. The field of consumption having been thus filled up, practically the only market that is left is the annual accessions to the merchant marine, and it will be seen that 1,924 searchlights would probably take care of all the additions to the steamship fleets of the United States. The merchant marine and the additions to the Navy are practically the only outlets for the manufacturers of searchlights, and the figures quoted indicate that the market has been well taken care of, the other searchlights not accounted for thus being required chiefly for renewals or for ships not previously equipped. This group would also include probably some larger focusing lamps of the kind used for theatrical purposes; but these again have not been treated separately and are very often merely large arc lamps of the ordinary type.

Incandescent lamps.—Table 12 shows the number and value of incandescent, and decorative and miniature lamps, etc., for 1900 and 1905.

TABLE 12.—INCANDESCENT, AND DECORATIVE AND MINIATURE LAMPS, ETC.—NUMBER AND VALUE: 1905 AND 1900.

STATE.	Aggregate value.	INCANDESCENT LAMPS.							DECORATIVE AND MINIATURE LAMPS, X-RAY BULBS, VACUUM TUBES, ETC.	
		Total value.	16 candlepower.		Below 16 candlepower.		Above 16 candlepower.			
			Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.
United States, 1905	$6,953,205	$6,308,299	83,333,285	$4,608,084	19,779,834	$1,132,011	9,598,439	$568,204	1,584,495	$644,906
1900	3,515,118	3,442,183	21,191,131	2,910,023	2,906,817	308,626	1,222,250	223,534	397,432	72,935
States, 1905:										
Illinois	92,500	(1)	(1)	(1)	(1)	(1)	(1)	(1)	601,010	92,500
Massachusetts	898,000	898,000	7,694,243	834,675	(1)	(1)	384,423	63,325	(1)	(1)
Missouri	346,841	346,841	20,498,570	346,841	(1)	(1)	(1)	(1)	....	....
New Jersey	10,235	(1)	(1)	(1)	(1)	(1)	(1)	(1)	32,461	10,235
New York	239,810	(1)	(1)	(1)	(1)	(1)	(1)	(1)	654,972	239,810
Ohio	1,591,438	1,591,438	33,915,818	1,076,057	7,901,719	303,168	4,436,415	212,213	(1)	(1)
Pennsylvania	29,417	29,417	365,503	27,790	(1)	(1)	17,819	1,627	(1)	(1)
All other states	3,744,964	3,442,603	[2] 20,859,151	[2] 2,322,721	[3] 11,878,115	[3] 828,843	[4] 4,759,782	[4] 291,039	[5] 296,052	[5] 302,361

[1] Included in "all other states."
[2] Includes states as follows: California, Colorado, Connecticut, Illinois, Kentucky, Maine, Michigan, New Jersey, New York, Oregon, and Texas.
[3] Includes states as follows: California, Colorado, Connecticut, Illinois, Kentucky, Massachusetts, Michigan, Missouri, New Jersey, New York, and Pennsylvania.
[4] Includes states as follows: California, Colorado, Connecticut, Illinois, Kentucky, Michigan, Missouri, New Jersey, and New York.
[5] Includes states as follows: Connecticut, Iowa, Massachusetts, Ohio, Oregon, Pennsylvania, and Rhode Island.

One of the largest specialized departments of electrical production is that of incandescent lighting. The gain in this branch since the year 1900 has been quite remarkable, the total value rising from $3,515,118 to $6,953,205, so that the amount has almost doubled in the period. The principal gain as to quantity and value has notably been in 16-candlepower lamps, which remain the standard, although there are indications that it is likely to be raised, owing to the competition of gas of higher candlepower than was common when the incandescent lamp was introduced. The number of incandescent lamps of 16 candlepower has risen from 21,191,131 to 83,333,285, and the value has nearly doubled, but it will be seen from the table that there has been a remarkable reduction in value per lamp, so that these lamps reach the consumer at a retail price proportionately reduced. Lamps below 16 candlepower in illuminating capacity are used to an increasing extent for various purposes, and the number increased from 2,906,817 to 19,779,834, or more than fivefold. The value rose from $308,626 to $1,132,011. In like manner there was a remarkable increase in the number and value of the lamps above 16 candlepower, these being principally 32 and 50 candlepower. The number increased from 1,222,250 to 9,598,439, the gain being almost sevenfold. The increase in decorative and miniature lamps, etc., is not so great as might have been expected from the prevalence of street signs, but the increase was from 397,432 to 1,584,495, with a correspondingly large increase in the value. As a matter of fact, a large proportion of lamps below 16 candlepower are employed for decorative and sign purposes. It is only in the group of decorative and miniature lamps that an increase in price per unit is shown, but this is due to the attempts to place at the disposal of the public very small lamps of ingenious design and construction for special effects. In reality, the product throughout the group as a whole shows a remarkable reduction in cost, the more noteworthy in view of the fact that during the past five years nearly fifty manufacturers have allied themselves under the protection of certain patents, standardizing their methods of production and quality of output. This combination does not constitute a monopoly, as there are also a large number of independent manufacturers.

The importance of the incandescent lamp in the field of electrical industry is evidenced by the fact that, as shown by the statistics of the Bureau of the Census in the Report on Central Electric Light and Power Stations, out of a total of 3,620 private and municipal stations enumerated in 1902 no fewer than 3,484 were engaged in commercial or other private incandescent lighting, while 606 private and municipal plants reported that they were engaged exclusively in the business of incandescent lighting. Further evidence as to the importance of the incandescent lamp was given by the fact that of the total income of all stations of $85,700,605 more than half—$44,657,102—was derived from incandescent service. It is true that during recent years the supply of electrical energy for motive-power purposes from central stations has gained rapidly, but in view of the enormous increase in the production of incandescent lamps it would appear that the proportion of income from light thus exhibited has at least been maintained, and when compared with the income from arc lighting may be said to have increased. In view of these points, it will be readily understood that among manufacturers as well as among central station managers and the owners of isolated plants there has been seen an extraordinary demand for improvements in the manufacture of incandescent lamps, resulting in the last five years in an outburst of research and invention in this field that changed its aspect entirely. The use of the electric street sign has also had a very marked effect on the production of incandescent lamps, and the result of an inquiry made by one of the central station companies during the past year shows from the data furnished by 1,188 central station companies that no fewer than 75,000 electric street signs were in use in the United States, yielding an income of over $4,000,000 a year from power consumption.

Before noticing the more radical innovations in the art of incandescent lamp manufacture it is well to put on record the improvements which have come from the perfection of familiar processes, and have gradually reduced the selling price of the lamp of the carbon filament type to a point where practically ten lamps are sold for a dollar instead of one. The carbon filament lamp, when introduced, contained about thirty times as much platinum in the leading-in wires to which the carbon strip is attached as does the lamp of the present day. The exhausting of air from the lamp by mercury pumps in order to create a high vacuum now requires but a single minute, where half an hour was necessary ten years ago, and from four to five hours at the beginning of the art. As a matter of fact twenty-five years ago the mere cost of exhausting a lamp was greater than the whole cost of the lamp at the present time. All the glass blowing operations on the bulb have been changed from hand work with expensive skilled labor to machine work that a tyro can regulate, and the labor cost of the glass processes is barely 10 per cent of what it was in 1882. All the lamps sent out are tested by photometric process, but to-day that incidental work costs but one-tenth of what it did formerly. The first successful lamps were based upon carbon filaments made from paper and bamboo, but at a very early stage cellulose material was employed, and it has now come into universal use. Such lamps, of a standard 16-candlepower capacity, require but 50 watts of electrical power for their full efficiency, so that the current consumption has also been cut in two. It is estimated that in the first quarter of a century 250,000,000 incandescent lamps of carbon filament type were produced, or at the average rate of 10,000,000 a year; but, as the figures already quoted indicate, the total number is now over 100,000,000 a year.

It is probable that for some time to come lamps of the carbon filament type will continue to be manufactured in large quantities, but even in these important improvements have recently been made, the object being to secure high candlepower with less consumption of current. The principal lamp of this modified character has what is known as the "metallized" carbon filament, which is rated at 2.5 watts per candlepower, as compared with the plain carbon filament type, whose standard consumption has been 3.10 watts per candlepower. The new filament is obtained by applying an additional process to the ordinary carbon filament, the treatment including heating in an electric furnace to a temperature of from 3,000° to 3,700° C., this firing being performed both before and after treatment. The additional processes result in the production of an exceedingly pure form of carbon, having greater density and considerably less specific resistance than the older filament, while the temperature coefficient is changed from negative to positive. For this latter reason the term "metallized" has been employed to describe the new filament, although it contains no metal. These lamps are now generally available in all the standard sizes and have immediately become popular.

A far more important and radical advance is that which has been made in the production of incandescent lamps with metallic filaments in place of carbon. Some of the very earliest work in the subdivision of electrical current for lighting purposes was done with filaments of a metallic character, such as platinum, but these were found at the time insufficient to serve as the basis of a commercial art, although hope in that direction was not entirely abandoned. Experiment has been maintained for many years, and the first success is due, as in so many other fields of chemical and metallurgical research, to the perseverance of German scientists. Several years ago, with the fundamental principle as a starting point, that the visible part of radiation from an incandescent lamp filament increases progressively with the temperature of the filament, elaborate laboratory experiments were begun in Germany to discover a metal that would withstand a much higher temperature than the carbon lamp filament can endure economically. The result of a long series of tests was to determine the selection of tantalum, which in a pure state was found to yield very satisfactory results.

The chemical properties of tantalum are very remarkable. When cold, the material strongly resists chemical agents; it is not attacked by boiling hydrochloric acid, nitric acid, or sulphuric acid, and it is also indifferent to alkaline solutions; it is attacked solely by hydrofluoric acid. Heated in the air, it assumes a yellow tint at about 400° C. like steel, and also like steel the tint changes to dark blue when the tantalum is exposed for some time to 500° C. Thin wires of it when ignited burn with low intensity and without any noticeable flame. It greedily absorbs hydrogen as well as nitrogen, even at a low red heat, forming with them combinations of a metallic appearance, but rather brittle. It combines with carbon very easily, forming several carbides which, as far as they are at present known, are all of metallic appearance, but very hard and brittle. When in the form of powder, still containing, as previously stated, oxide and hydrogen, the specific gravity is about 14; when purified by fusion and drawn into wire, it has a specific gravity of 16.8. It is somewhat darker than platinum and is about as hard as mild steel, but shows greater tensile strength. It is malleable, although the effect of hammering is relatively small, so that the operation must be long and severe to extend the metal into a sheet. It can be rolled as well as drawn into very fine wire. Its tensile strength as a wire is remarkably high and amounts to 133,000 pounds per square inch. The electrical resistance of the material at indoor temperature is 0.165 ohm for a length of 1 meter and a section of 1 square millimeter; the temperature coefficient is positive and has a value of 0.30 between 0° and 100° C. At the temperature assumed by the incandescent filament in the lamp under a load of 1.5 watts per candlepower, the resistance rises to 0.830 ohm for a length of 1 meter and a section of 1 square millimeter. The Siemens-Halske Company in Germany has taken out about 200 patents on the tantalum lamp, comprising about 1,000 claims. Experiments with many hundreds of the tantalum lamps gave a useful life of four hundred to six hundred hours, during which it consumed about 1.5 watts per candlepower. Useful life is defined as the time at the end of which the lamp has lost 20 per cent of its "light power." The candlepower increases during the first one hundred hours, whereby the specific power consumption decreases to about 1.3 watts per candle. The latter then increases, and at the end of the useful life the lamp consumes 1.8 to 2 watts per candle. The lamp, however, continues to burn for one thousand or one thousand five hundred hours. It is found to burn much better on direct than on alternating current, as the latter appears to disintegrate the filament rapidly; and in the United States it is now being used only on direct current circuits. The price to the retail purchaser of a 22-candlepower tantalum lamp, consuming 44 watts of electrical power, is 60 cents; and the New York Edison Company, which supplies new lamps free to its customers, makes a charge of 35 cents for this lamp. This practice may be taken as an index of the general practice of the central station companies in introducing the new illuminant. The makers in Germany have produced and placed on the market a 2.2 watt lamp for pressures of 50, 55, 60, 65, 75, 100, and 110 volts, whose useful life is quoted as being from eight hundred to one thousand hours, with the total life often reaching one thousand five hundred or two thousand hours.

Another lamp of the metallic filament type is the osmium, which has been introduced to some extent in Europe but is not yet widely known in the United States. The crude material is very finely divided osmium—one of the rare metals—which is mixed with binding substances so as to form a thick, tough paste, which is forced under very high pressure through a die. A thread is thus obtained, which is formed into loops. The threads are then dried and heated in a vacuum in order to carbonize the binding material, and they are next subjected to the processes of formation. The threads, which at this stage consist of porous, rough osmium with a high content of carbon, are heated for a long time by means of electric current, being brought gradually through higher and higher temperatures to white heat in an atmosphere containing a great deal of steam and various quantities of reduced gases. In this manner the filament becomes pure porous osmium of a far greater density than the original rough thread. During the use of the lamp the osmium surface becomes gradually smoother and smoother, which accounts for the increase in the light given out by the lamp in the first few hours of use. The filament, which has an approximate length of 15 inches, is divided into three separate loops connected in series by means of two loops of platinum wire, the middle of each of which is fused, by means of a glass bead, to the top of the stem carrying the two leading-in wires. Each filament is anchored in order to prevent the loops from touching the dome of the bulb, and the anchor device consists of a small glass rod to the end of which is attached a turn of small wire or white refractory metal. The filament is anchored not at its extremity but somewhat above the turn of the loop. The lamps can be burned only in a vertical downward position. The consumption is 1.5 watts per candlepower, and the standard type is a 50-volt 25-candlepower lamp, guaranteed at that consumption of electrical power. The useful life of the lamp is given as about two thousand hours, but some have been burned five thousand hours. The osmium lamp is somewhat more fragile than the ordinary carbon filament lamp if exposed to hard knocks, but it seems able to withstand a great deal of vibration, as in train lighting, for which it has proved satisfactory in connection with storage battery equipments. Its low voltage has also made it desirable for mine safety lamp purposes.

Another lamp of this character is one in which the filament is made from a metal alloy of which the rare metal zirconium is a component. Lamps of this kind require only a small pressure, such as 2 or 4 volts, and hence, like the osmium, are available more particularly in connection with storage batteries. Tests on these lamps show that 2-candlepower lamps at 4 volts give a consumption of 0.92 watt per candlepower, whereas the ordinary carbon filament lamp of the same low candlepower consumes 3.8 watts. The lamp is expensive in first cost, but, as will be seen, the cost of operation is low, and a more recent lamp of this type is reported to have a consumption of 1.2 watts per candlepower with a life of five hundred hours, but needs careful handling and is commercial only on low voltages.

The latest development in metallic filaments for incandescent lamps relates to the work on tungsten, conducted principally abroad, although in the last three or four years a large amount of research and investigation has gone on in the United States also. The merit of the tungsten lamp consists in the fact that it consumes only between 1 and 1.25 watts of electrical power per candlepower, as compared with the 3.10 of the ordinary carbon filament type, 2.5 of metallized filament, and the 2 watts of the tantalum lamp. While tungsten is considered one of the rare elements, its compounds are already of considerable use. Sodium tungstate is employed in impregnating fibers to make them fireproof, and as a mordant in dyeing. Tungsten bronzes are employed largely as bronze powders and pigments. The chief employment of tungsten in recent years, however, has been for high-speed tool steels and for ordinary steel in armor plates and large guns. A few years ago very little was produced in this country, but the quantity of tungsten concentrates reported for the year 1905 was 803 tons. The tungsten concentrates valued formerly at $2 or $3 per unit are now worth at least $6 per unit, the unit meaning 1 per cent of a ton. It will be obvious, therefore, that tungsten is a rare element, although not in the same sense as osmium or platinum. Like most metals proposed for incandescent lamp filaments, tungsten has a lower electric resistivity than carbon, and for this reason the manufacture of high voltage tungsten lamps is a more difficult process than is the production of carbon lamps for the same voltages—say, the standard, 110. In the main, however, these difficulties in the manufacture of tungsten lamps have been successfully overcome, as the lamps are now on the market in both Europe and the United States.

The fundamental value of tungsten for lamp filaments lies essentially in its enormously high point of melting or volatilization. In this respect it perhaps resembles carbon and the nonmetallic elements. In the common use of the word "metal," pure tungsten is virtually unknown. It has not yet, for instance, been reduced to ingot form from which anything could be hammered, or cut, or drawn. Hence, so far as is known, a filament of wire such as is used in the tantalum lamp, for example, can not be paralleled or duplicated from tungsten, so that the filaments now in use in tungsten lamps have to be obtained by what may be called roundabout methods, and when completed are like carbon filaments, aggregations of amorphous structures or of infinitesimal crystals. Three different processes are in use for making tungsten filaments.

The first process is based on the effort to coat a carbon filament with tungsten and results in the simultaneous dissolution of the carbon filament, and its replacement by finely divided tungsten, which is strengthened by a process akin to "flashing," or, in other words, the heating up of the filament in the vapor of a tungsten compound. The other two processes start with very finely divided tungsten, worked up into a paste, from which the filaments are formed. Further treatment is then given by firing. The earlier processes dealt with a paste made of what may be called precipitated tungsten. The later process is based on so-called colloidal metal, which presents the advantage of almost infinitely fine subdivisions. The result is of the same nature, whether the filament is prepared by the "substitution" process, the paste process, or the colloidal process—namely, an extremely fine thread 1 or 2 mils in diameter, of compactly aggregated pure or nearly pure tungsten. These filaments are dense and of smooth and uniform appearance, but thus far appear to be quite brittle, as might be anticipated from their structure. The elimination of this tenderness is one of the problems of the future for this new lamp. These lamps have an advantage over the tantalum in the fact that they can be burned equally well on both alternating and direct current; but like the tantalum, the tungsten lamp is best burned in a vertical downward position, although in this respect it more nearly resembles the osmium. The lamps that have been introduced commercially are rated at 25 candlepower, consuming 1 watt per candlepower and are given a life of not less than one thousand five hundred hours. A standard lamp introduced in Europe and already known in the United States consumes 40 watts and has three filament loops with a total length of filament of 17 inches.

The statistics of decorative or miniature lamps, etc., include also vacuum tubes, vacuum and vapor lamps, and X-ray bulbs, which are not enumerated separately. The vacuum tubes and lamps are used for lighting and for photographic purposes. The X-ray is now employed almost exclusively for surgical investigations, chiefly those by which the interior of the human body can be inspected, and broken bones, foreign substances, etc., be located. The vacuum tubes consist principally of those based upon the utilization of the vapor of mercury. This type has been upon the market since 1903 and has come into extensive use. The words "vacuum tube" are employed generically to distinguish the exhausted bulbs or lamps which contain no filaments, but which have in them gases other than air or such metals as mercury, which will when vaporized "carry the arc," so to speak, and will thus maintain illumination. In the leading lamp of this type the light giving element is a gaseous vapor of mercury inclosed in a hermetically sealed glass tube, varying in length from 17 to 45 inches, and about 1 inch in diameter. This tube is suspended from the ceiling and is mounted on a tilting arm, suspended from a pendant canopy which contains the regulating mechanism. When the current is turned on the mercury becomes vaporized, thus maintaining the circuit throughout the length of the tube, which becomes wholly luminous. The complete lamp outfit may be said to comprise the exhausted glass vacuum tube, the holder and reflector, and the auxiliaries.

The tubes intended to operate on direct current have a positive electrode of iron at one end and a negative electrode of metallic mercury in a bulbous cup at the other end. The tubes for alternating current lamps have two positive electrodes of iron at one end and a negative electrode of mercury at the other end. The alternating current enters the vacuum by the positive electrode and leaves the tube by the negative electrode. These alternating current lamps operate in reality as a converter, in application of the principle of negative electrode resistance, which will be referred to later. In all types of the tube the terminal connections to the sources of electrical supply reach the electrode through platinum wires. The lamps are set in operation by tilting them for an instant, either mechanically, by pulling a small chain attached to the upper end, or automatically, by means of a small magnetic attachment. This tipping of the higher end of the tube causes the mercury to flow from one end to the other in a small stream, which bridges the vacuum in the tube momentarily, thus closing the circuit through the tube, and the resulting arc of current vaporizes some of the mercury. The subsequent steady flow of electrical current in the vacuum, after the return of the lamp to the normal position at a slight angle, increases the vapor pressure and excites it to a high degree of luminous incandescence. The holder or fixture bracket for the tube consists of a lamp rod with clamps, from which the tube can be easily removed or inserted, and the suspension bar hung close to a light colored ceiling without reflectors, or else equipped with flat or curved reflectors of different styles. The standard flat reflectors, 6 inches wide, are used generally where the lamps are hung at some distance from the roof or ceiling. The faces are white enameled so as to increase the diffusion of light, while the reflector tops and holders are finished in a lustrous black. The auxiliary consists of two or three coils of resistance wire, an inductance coil, and a ballast bulb intended to correct abnormal voltage variations on the line, all being connected in series with the tube. This auxiliary mechanism is placed within a small canopy, heat insulated from the ceiling by an asbestos shield, and fastened to the ceiling on a plate attachment having a claw foot into which the suspension bar is secured.

The standard type of lamp of 700 candlepower for direct current is 55 inches long, with a length of 45 inches of light-giving tube. It is operated at $3\frac{1}{2}$ amperes and consumes 385 watts when installed single on 110 volt circuits, or 0.55 watt per candlepower.

The direct current lamp is made in two sizes—one 24 inches long, $17\frac{1}{2}$ inches of tube, giving 260 candlepower; and the other $27\frac{1}{2}$ inches over-all length, with $20\frac{3}{4}$ inches of tube, giving 300 candlepower.

The alternating current lamp of 425 candlepower is 34 inches long, with a 28-inch tube, and is designed to operate on all single phase circuits of a frequency of 60 cycles or more. It consumes 275 watts, or 0.64 watt per candlepower. These tubes appear to have a long life, ranging in many cases over ten thousand hours, although they become somewhat blackened with long service.

The absence of red rays in the mercury vapor lamp renders it undesirable or inapplicable for every purpose, but it is found particularly useful in industrial and other plants, and it may be noted that all the United States Government currency and internal revenue stamps are printed under its light in the Bureau of Engraving and Printing at Washington, where the nature of the presswork requires a high quality of widely diffused light. Another typical instance of its use is in the New York Times building, where no fewer than 42 of these tubes are employed, of which 26 are in the press and stereotyping rooms, lighting an area of 1,700 square feet. Mr. Peter Cooper-Hewitt, who is to be credited with the development of this lamp, has improved the color of the light by the addition of the vapors of lithium, potassium, and rubidium, which will, however, attack the tube if made of quartz. Other attempts in the direction of changing the color of the light involve the introduction of inert gases, such as neon, nitrogen, or argon. Means adopted, external to the lamp itself, to supply the deficiency of red rays have met with no marked success. In the meantime the lamp, during the past two or three years, has become so widely used as no longer to excite comment, and the prejudice or objection to the color has died out so far as any industrial work is concerned.

There are one or two other systems of mercury vapor lamps, including those in which incandescent lamps have been associated with the tube, so as to secure an agreeable blend of the two lights. A more distinctive variation, however, is found in the Moore system, which is based upon considerable lengths of tube, ranging as high as 200 feet all in one stretch, giving an unbroken band or cornice of light around the room or space thus illuminated. These long tubes are made on the premises of the customer by sealing hermetically together tubes that come in lengths of 8 feet 6 inches, a new portable gas fire having been worked out for this purpose. The lamp is of the alternating current type, the electrodes reversing their sign at each alternation, necessitating high voltage to be applied at the terminals in order that the intervals between the successive impulses will not be apparent to the eye, which would otherwise be disagreeably affected by the unsteadiness or fluctuations of the light. All the distinctly electrical apparatus is placed in a single steel case or box, from which the tubes extend for illuminating purposes. A low-potential alternating current circuit supplies the apparatus with electrical energy at 60 cycles, and the tube contains a nonmetallic gas or vapor under very small pressure. The terminal of the tube within the box contains at each end carbon internal electrodes. Within the box also is the step-up transformer, to the low-potential coil of which current is supplied, the high-potential terminals being attached directly to the tube electrodes. Hence the only wires extending from or into the box are the ordinary low-potential service wires. Some of these tubes are 150 to 200 feet in length with a diameter of $1\frac{3}{4}$ inches, operating at a brilliance of 4.2 candlepower per foot of tube. The efficiency varies with the length of the tube, and an actual total candlepower for one instance is claimed of 2,200 with a total consumption of 3,300 watts. The tube, in addition to being operated in continuous lengths—as, for example, around the four sides of a room or of a long passageway—can be bent back and forth into frames for photographic purposes or can be made to follow the irregular outline of a building or portico, and can even be twisted so as to form letters and spell words. In this last form it lends itself admirably to advertising purposes. The color of the light is excellent, and for the illumination of large areas such tubes appear to have a promising future, although apparently they can not be used economically in small units or short lengths. An effective illustration of their employment is furnished in one of the largest department stores in New York city, where two tubes of 154 feet each, attached to the ceiling of a basement floor, have displaced nine arc lamps and give effective and agreeable illumination over goods of a very varied nature.

In passing, a most ingenious and important utilization of the mercury bulb or vacuum tube must be noticed in respect to its use as a converter, transforming alternating to direct current in places where only the former is available and only the latter is desired. The possibility of conversion of alternating current into direct current in this manner depends upon the laws which underlie the familiar starting characteristics of the mercury vapor lamps. In the lamp the reluctance to start was in some respects an obstacle, while in the converter the whole function depends upon this resistance; and the invention was an extremely ingenious means of rendering useful what was otherwise a troublesome characteristic. Various types of this apparatus are now largely used, principally for the charging of storage batteries from an alternating current circuit, and but for the existence of this device the batteries which can be charged only with direct current would require step-down transformers and rotary converters. In other words, they would need costly miniature reproductions of the substations familiar in electric railway and central station lighting.

The whole transformation of current for a set of automobile storage batteries takes place in a vacuum glass bulb resembling a very large pear, in the standard outfit about 9 inches in diameter. This glass globe has two or more positive electrodes of iron at the top, by which the alternating current enters the vacuum. At the bottom of the globe is a small pool of mercury constituting the negative electrode through which the current takes a continuous or direct outward flow to the batteries or other devices. Through the action of the negative electrode resistance, the positive electrodes pass current only into the bulb, and oppose any flow of the current from it. The current can therefore flow in one direction only—through the pool of mercury at the base of it—so that the impulses, waves, or fluctuations of alternating current are diverted from the alternating circuit and leave the vacuum in the form of the desired positive or direct current. The starting resistance of the negative mercury electrode is overcome by tilting the converter bulb until the mercury connects with the mercury of a small supplementary electrode, and current passes between the two. This tilting is accomplished automatically when the alternating current and direct current switch and the converter switches on the panel board in front of the globe are thrown in, and is repeated automatically upon the resumption of the flow of line current after interruption from any cause, so that an excellent protection is afforded against reversal of current. The efficiency of such apparatus is said to be not less than 80 per cent in supplying current at 115 volts to a set of from 20 to 44 cells of storage battery, and the whole converter equipment occupies a space of but 15 by 22 by 26 inches. Such an equipment has a minimum operating current of about 6 amperes and a maximum capacity of 30 amperes in continuous running, giving direct current voltage of from 50 to 115 volts. It may be noted that a certain amount of voltage is absorbed in the converter bulb itself, namely, 15 volts, which is practically independent of the volume of current flowing and which appears as heat and a slight quantity of light within the bulb and which is dissipated into the air through the glass.

A type of lamp that belongs in neither the arc nor the incandescent field, but which is also included in the statistical group of decorative and miniature lamps, etc., in Table 12, is the Nernst, which has come into widespread use since the date of the last report, and is now in operation in connection with hundreds of central stations and isolated plants in the United States. This lamp, which owes its origin to a German scientist, has as its light-giving member a glower, which although not brought to incandescence in a vacuum, as is the filament in the ordinary incandescent lamp, at the same time does not burn away as does the carbon in the various forms of arc lamp. The glower is made by passing through a die a dough composed of the oxides of rare earths, mixed together with a suitable binding material. A porcelain-like thread or string is thus obtained which is cut, after drying, into short, convenient lengths and is then baked. Platinum terminals are attached to these glowers, which are then ready for insertion in the lamp. The terminal connections between the glowers and the leading-in wires, as made by Doctor Nernst, consist of a few turns of platinum wire around the end of each glower, the convolutions being finally pasted with cement. A later form of successful terminal is that in which little beads of platinum are embedded in the glower ends, to which the leading-in wires are subsequently attached in such a manner that any shrinkage of the glower material results in a firmer contact with the platinum. The peculiar feature of glowers is that when cold they are insulators, but they become conductors when hot, so that they must be heated before they will pass electrical energy sufficiently well to maintain themselves at a light-emitting temperature. Moreover, as the glower is an oxide, incapable of further oxidization, it is operative in the open air or within loosely closed globes, and being, moreover, capable of withstanding a much higher temperature than is the filament of the ordinary incandescent lamp it admits of great economy in operation, while furnishing a light of remarkably superior white quality and color. The glower in a standard 220-volt Nernst lamp is 1 inch long by $\frac{1}{32}$ inch in diameter. Hence it is in sharp contrast to the ordinary carbon filament as to length and thickness. It is obvious that as the glower is a nonconductor when cold it requires some form of heater to bring it up to a conducting temperature, so that current can flow through it and cause incandescence. The glower becomes a good conductor at about 600° to 700° C. Various forms of heaters have been made to work automatically, as the earlier forms of lamps in which the heating was done by hand were far too slow and cumbrous for commercial practice. The heaters in common use consist of thin porcelain supports mounted with fine platinum wire, which in turn is held in place and protected from the intense heat of the glower by a refractory paste.

Associated with the heater is a cut-out, which disconnects the heater from the circuits as soon as the glower lights up, which takes several seconds. The cut-out comprises a small coil, an armature, and contact, the coil being heat proof and embedded in cement, while the contact is nonoxidizable, being of silver. The heater circuit is normally kept closed by the force of gravity, as the lamps are operated in the downward position, although a successful form of universal cut-out is available which will operate with the lamp in any position. The mode of operation of the lamp is therefore the admission of current to the heater, making it white hot, whereupon its proximity to the glower causes the latter to become a conductor through which the current then passes. When the current through the glower has reached the predetermined proper amount, the cut-out coil becomes energized by the glower current passing through it, and the arm of the cut-out which had hitherto closed the heater circuit is attracted and opens the heater circuit, so that only the glower is left in operation.

Another part of the lamp is its ballast, or steadying resistance, of fine iron wire. The conductivity of the glower increases with the temperature, so that if used directly on a constant potential circuit this temperature would continue to rise, and very soon the increasing amount of current flowing would destroy the glower. Hence the steadying of the current is accomplished by this ballast of iron wire, which possesses the property of increasing its resistance with great rapidity on reaching the critical temperature, and operates to prevent short circuiting, or "flashing out." Thus with a 10 per cent rise in current, the increase of resistance in the ballast is 150 per cent, so that the glower is thus protected through a wide range of supply voltages. This iron wire is guarded from the air to prevent its oxidation and the rapid change of temperature, and is therefore mounted in a little glass bulb filled with hydrogen, which is an inert gas and conducts the heat from the ballast to the walls of the bulb better than other gases. These diminutive working parts are all mounted in the lamp body in a suitable manner. The glower and its heater of course project into the surrounding glass globe, while the other parts are inclosed in a canopy from which the globe depends. The main features are alike in all the lamps, and various sizes, or degrees of illumination, are obtained by assembling one or more standard glowers with their auxiliaries within the canopy and globe. Hence the smaller lamps are burned with but a single glower, while in the larger type as many as six glowers are employed. The perishable parts, such as glowers, heaters, and ballasts, are easily renewed, being mounted in removable pieces called the "holder," which may be pushed into place or taken out like an incandescent lamp with regard to its socket. The lamps are burned usually on alternating current at a frequency of 60 cycles and preferably at 220 volts, those in use in this country having a range of use on any frequency of from 25 to 133 cycles. The lamps are made for both 110 and 220 volts, and one glower lamp at 110 volts has a consumption of 44 watts of electrical power. The 6-glower lamp at 110 volts has a consumption of 556 watts and at 200 volts a consumption of 528 watts.

A development of interest during the past year in connection with the Nernst lamp has been the making of a series lamp of moderate candlepower for street illumination, thus allowing the lamp to be used in places where a fairly large number of small units is required. The outfit consists of a single glower lamp connected with a series transformer, the primary coil of which is adapted for a circuit carrying 6.6 or 7.5 amperes of constant alternating current. Hence the lamp may be used on any of the constant current series systems, and the ordinary 50-light "tub" transformer will energize about 200 lamps of this new type. The glower and heater in this particular form of lamp are mounted in a vertical position on a porcelain base, and the heater is made in the form of a helix around the glower. Another exemplification of the use of the lamp is afforded by the huge new terminal of the Pennsylvania Railroad in New York city, for which this type of lamp has been adopted, and for which no fewer than 20,000 glower units will be required.

Lighting fixtures.—Table 13 presents statistics of electric light fixtures for 1900 and 1905.

TABLE 13.—*Electric light fixtures—value: 1905 and 1900.*

STATE.	Total value.	Fixtures (value).	Lamp sockets, receptacles, *bases, etc.* (value).
United States, 1905	$5,305,466	$3,294,606	$2,010,860
1900	4,344,599	3,750,670	593,929
States, 1905:			
California	447,109	447,109	....
Connecticut	1,694,785	397,498	1,297,287
Illinois	639,405	639,405	(1)
Minnesota	7,000	7,000	....
New York	1,063,945	1,063,945	(1)
Ohio	150,500	150,500	(1)
Pennsylvania	406,610	406,610	(1)
All other states	896,112	[2] 182,539	[3] 713,573

[1] Included in "all other states."
[2] Includes states as follows: Colorado, Delaware, Massachusetts, Missouri, New Jersey, Oregon, Rhode Island, and Texas.
[3] Includes states as follows: Illinois, Massachusetts, New York, Ohio, Pennsylvania, Rhode Island, and Texas.

A considerable increase is shown in the value of electric light fixtures of all kinds reported in 1905, the amount being $5,305,466, as compared with $4,344,599 in the year 1900. The increase is accounted for to a great extent by the larger manufacture of sockets and bases incidental to incandescent lamps, for which an increase of 238.6 per cent was shown for the period, but the bulk of the amount is, as before, represented by the fixtures themselves. It will have been gathered from the preceding data as to the development of electric lamps of new forms and characteristics, that there has been a considerable development also in the fixtures to hold these lamps, none of these newer fixtures being known or included in the statistics at the time of the previous census. The Moore vacuum tube, the Hewitt and Steinmetz mercury vapor lamps, and the Nernst lamps all require special fixtures of their own for their most efficient use, and even some of the new forms of incandescent lamps have had special fixtures carefully designed for them, in order to secure the best results in diffusion and distribution of light. For example, the new metallic filament lamps are associated with fixtures and special types of holophane reflectors, which are harmonized in their relationship to the lamp and to each other, with a great gain in efficiency of illumination and of general artistic effect. As a matter of fact, the whole art of fixture designing and construction has undergone a very marked change and improvement during the last few years, on account of the coming into existence of the distinctively new branch of illuminating engineering, which is already so well recognized that it is represented by a national society with upward of 500 members. It has been estimated that the yearly expenditure for lighting in the United States is well above $200,000,000, of which at least $20,000,000 is wasted on account of the use of improper fixtures, shades, reflectors, etc., and the aim of these specialists in illumination is to work in close relationship with the architect, the decorator, and the designer of gas and electric fixtures.

The modern art of illumination may be said to have broken away entirely from the standard and stereotyped bracket and chandelier associated with the use of gas. The adoption of electricity, with its greater flexibility of application, has permitted the use of many methods quite impossible with other illuminants. It is obvious, even to the casual observer, that a great deal of modern lighting within doors is done without fixtures and is in the nature of overhead or cove lighting, where the lamps are concealed within a hollow cornice; or else the lamps shed their light through a transparent ceiling so that there is a general diffusion without any small individual illuminant being presented to distract or annoy the eye and with a general absence of glare. This method of diffusing light has become very popular for large spaces. At the same time the electrical fixtures must always have a conspicuous place in the art of illumination, and these are made in greater quantity than ever, while increasing attention is paid to their finish and artistic design.

It is said that the first incandescent electric light fixture was made as early as 1842 by Mr. William Pearce, of Boston, Mass., for Mr. George Peabody, the banker and philanthropist, who was assisting in his electrical experiments an unfortunate young inventor named Starr, who anticipated much of the practical development of electrical illumination that did not come until nearly forty years later. It is said that this pioneer fixture had no fewer than 26 little lamps set in sockets, fashioned like ears of corn, symbolizing the then 26 states of the Union. The bulbs were of molded glass to imitate kernels, and the socket had leaves of sheet brass hammered into the likeness of cornshucks. Thus early it will be seen that the artistic value and adaptability of incandescent lamps was appreciated. The range of electric light fixtures is to-day so infinite that it is impossible to enumerate them all or to do more than characterize them. A good example is afforded by any new edifice, and for such purpose the new Federal building in Chicago will serve, the equipment there being of unusual size, providing for some 15,000 lamps. The first installation contained over 10,000 lamps of 16 candlepower, while the later development of studies with regard to the fixtures and the use of cove and concealed lighting has rendered possible the employment of lamps of 4, 8, and 10 candlepower, so that the present installation is the equivalent of 15,000 lamps of 8 candlepower. In order to permit the use of these lamps no fewer than 2,970 outlets in the building were furnished with electrical fixtures, which have been installed at an expense of about $50,000. In the main rotunda 900 lamps of various powers are employed, many of them in fixtures carrying a holophane globe, placed around galleries and corridors, and with 16-globe electroliers, which are hung at the first floor level, and at the face of the rotunda floor level 100 feet higher. The brackets or electrical fixtures for this purpose cost $400 each, and are constructed of cast brass, weighing 750 pounds each. The globes, 30 inches in diameter, are of leaded white ground glass illuminated with 12 ruby-colored 8-candlepower lamps inside and with a row of eighteen 8-candlepower white frosted lamps around the equator. The main vestibules, which are finished in granite, have 12 large fixtures of architectural design and generous proportions of the bracket type, each carrying a sandblasted globe which contains six 16-candlepower lamps. The stairways are further illuminated with massive newel post stands, while in the corridors and rooms are stalactite fixtures and a variety of other wall brackets and ceiling clusters harmonizing with the general treatment of the building.

Special treatment of this character will, in fact, be found in every large new building now erected, and in some instances the purpose of the building calls for novel fixtures, as, for example, those installed in the main dining room of a large new hotel in New York, where the fountains that play during mealtime are in the nature of electric fixtures with the lamps shining up from the base through the water.

Telephone apparatus.—Table 14 shows the number and value of telephones and telephone apparatus and supplies for 1905.

TABLE 14.—TELEPHONES AND TELEPHONE APPARATUS—NUMBER AND VALUE: 1905.

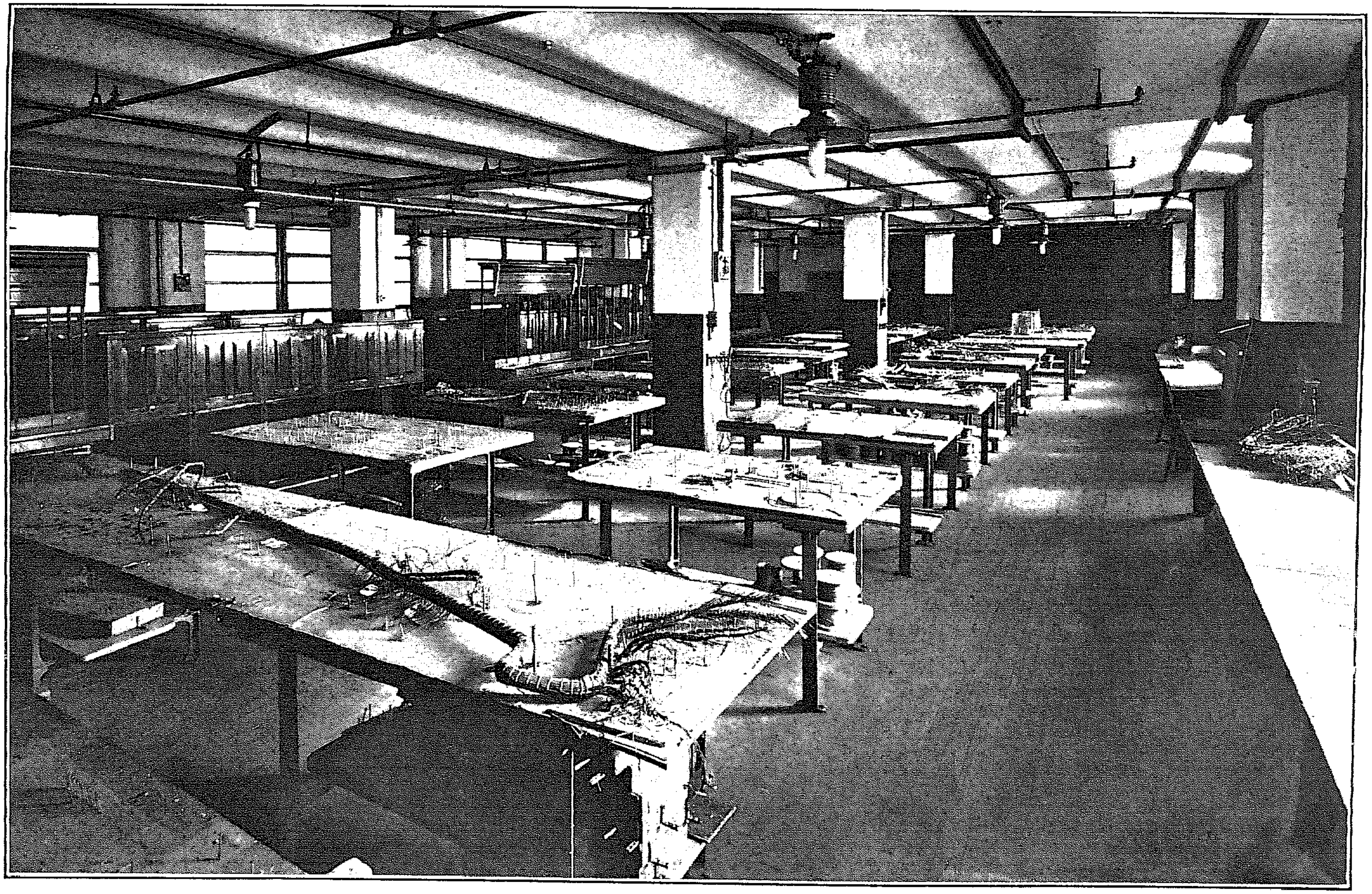
STATE.	Total value.	TELEPHONES.						INTERIOR SYSTEMS COMPLETE WITHOUT INSTRUMENTS.		CENTRAL SWITCHBOARDS.		PRIVATE EXCHANGE BOARDS.		Telephone parts and supplies (value).
		Transmitters.		Receivers.		Complete sets of instruments, not included in transmitters and receivers.								
		Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.	
United States	$15,863,698	850,815	$824,204	831,195	$696,113	887,447	$6,483,418	4,560	$68,826	4,283	$5,154,447	3,917	$564,795	$2,071,895
Connecticut	129,215	(1)	(1)	(1)	(1)	(1)	(1)	....	....	(1)	(1)	(1)	(1)	129,215
Illinois	8,357,521	87,688	140,099	141,935	127,037	588,750	3,942,343	3,410	31,390	2,199	3,144,595	1,153	179,031	793,026
Indiana	490,157	(1)	(1)	(1)	(1)	34,370	334,170	....	....	328	105,387	(1)	(1)	50,600
Maryland	50,900	(1)	(1)	(1)	(1)	2,400	33,600	(1)	(1)	(1)	(1)	....	....	17,300
Massachusetts	264,487	(1)	(1)	(1)	(1)	5,860	53,520	(1)	(1)	(1)	(1)	....	....	210,967
Missouri	148,258	(1)	(1)	....	....	15,532	148,258	(1)	(1)	(1)	(1)	(1)	(1)	(1)
New Jersey	56,873	(1)	(1)	(1)	(1)	(1)	(1)	....	....	....	....	(1)	(1)	56,873
New York	4,165,653	649,627	572,365	554,935	457,970	104,180	982,834	209	5,305	776	1,695,709	2,194	331,042	120,428
Ohio	736,463	29,000	32,550	23,200	23,850	39,362	382,275	85	6,500	203	122,500	(1)	(1)	168,788
Pennsylvania	221,203	2,930	2,930	(1)	(1)	18,210	172,295	(1)	(1)	(1)	(1)	(1)	(1)	45,978
Wisconsin	130,515	(1)	(1)	(1)	(1)	10,218	130,515	....	....	(1)	(1)	(1)	(1)	(1)
All other states	1,112,453	[2]81,570	[2]76,260	[3]111,125	[3]87,256	[4]68,565	[4]303,608	[5]856	[5]25,631	[6]777	[6]86,256	[7]570	[7]54,722	[8]478,720

[1] Included in "all other states."
[2] Includes states as follows: Connecticut, Georgia, Indiana, Maryland, Massachusetts, Michigan, Missouri, New Jersey, and Wisconsin.
[3] Includes states as follows: Connecticut, Georgia, Indiana, Maryland, Massachusetts, Michigan, New Jersey, Pennsylvania, and Wisconsin.
[4] Includes states as follows: California, Connecticut, Georgia, Michigan, New Jersey, and South Carolina.
[5] Includes states as follows: Georgia, Maryland, Massachusetts, Missouri, and Pennsylvania.
[6] Includes states as follows: California, Connecticut, Georgia, Maryland, Massachusetts, Missouri, Pennsylvania, Rhode Island, South Carolina, and Wisconsin.
[7] Includes states as follows: California, Connecticut, Georgia, Indiana, Missouri, New Jersey, Ohio, Pennsylvania, South Carolina, and Wisconsin.
[8] Includes states as follows: Alabama, California, Colorado, Georgia, Iowa, Michigan, Missouri, Nebraska, Oregon, Rhode Island, South Carolina, and Wisconsin.

The total value of telephonic apparatus manufactured, as reported at the census of 1905, had a value of $15,863,698, as compared with $10,512,412 for the census of 1900. These figures do not reveal all the facts, for during the period covered no greater activity was shown in any department of electrical application than in telephony. A very large proportion of other electrical apparatus, including dynamos, motors, motor-generator sets, insulated wires and cables, conduits, etc., were required for the equipment of telephone exchanges and in connecting the stations of individual telephone subscribers, and only an analysis of the product for these other fields, and an apportionment to the various branches of electricity, would bring out the high relative importance of telephonic development. As in the earlier figures of telephone manufacture, the value of products roughly divided itself in halves between the receiving and transmitting instruments, and the switchboards.

The value returned for the 4,283 central switchboards was $5,154,447, to which should be added the 3,917 private exchange boards of a value of $564,795, making a total of $5,719,242. To this should be added a large proportion of the value of $2,071,895 reported for telephonic parts and supplies. The subscribers' apparatus used in connection with these exchange boards and smaller equipments was reported as having a value of $8,003,735, of which $6,483,418 was represented by complete sets of transmitters and receivers. It will be noticed that individual transmitters and receivers, manufactured but not assembled into complete sets, very nearly balanced each other, as might have been expected, there being few uses for a telephone receiver when not associated with a transmitter, and vice versa. It will be observed also that the equipment within the central station exchange was broadly equivalent in value to that employed in the exterior equipment at the subscribers' stations, which according to this table would show a gross increase of about 1,700,000 subscribers during the year 1905. This sweeping assumption would not, however, be justified, for the reason that a great deal of apparatus is destroyed each year or becomes obsolete, so that the new simply replaces the old in a great many instances. No large fire occurred in any community—as at Baltimore or San Francisco—in which telephonic apparatus was destroyed in considerable quantities at the subscribers' stations; but even this diminution of apparatus already in use is perhaps not equal to that which is caused by the abolition of the older magneto-calling method and its substitution by the central energy system; it being necessary in the former case to signal the exchange by the manipulation of a little crank on the telephone set, while in the central energy or common battery system all that is necessary is to remove the receiver from the hook on the transmitter stand.

All the telephone exchange service of the country is furnished by the Bell system and by that which bears the general name of "Independent." The exchanges connected with the network of the American Telephone and Telegraph Company during 1905 reported an increase in the period of 441,734 stations. If it is to be allowed that the new connections to the independent systems proportionately equal this, it will follow that new equipment was called for by these subscribers to the amount of about 800,000 sets, which would indicate that about half the new apparatus manufactured goes to replace that which has been worn out, destroyed, or become obsolete. A certain amount, however, of



KEYBOARD CABLES FOR TELEPHONE EXCHANGE (SKELETON OF SWITCHBOARD SECTION IN THE REAR).

the telephonic apparatus made in the United States is exported; but the statistics of the manufactured exports do not give these figures in detail. A certain number of stations also are fitted up in connection with interior systems, but these in the aggregate are insignificant as compared with the central exchanges, for, while no fewer than 4,560 interior systems were returned, their value was only $68,826, from which it is evident that the number of stations connected—as, for example, on the different floors of a factory—would number but a few thousand at the most. It has been claimed that in recent years the number of independent telephone stations has increased more rapidly than the number of the Bell stations; but there are no exact data on the subject and the last figures available, namely, those of the Census report for 1902, gave a total of 1,317,178 Bell stations and 998,119 independent stations. There has been an enormous development of telephony in the great cities during the past five years, but at the same time one of the great features of telephonic increase has been the utilization of the telephone in rural districts, so that to-day no agricultural section of the country is without its village exchange and its farmers' lines.

The vital importance of the telephone system to the business and social life of the twentieth century may be shown by the fact that in 1905 the Bell system alone reported 4,532 exchanges in operation, 6,043,518 miles of wire in exchange and toll service, and 74,718 employees, with total exchange connections for the year of 4,360,996,000, or an average of nearly 14,000,000 per day. Even if the number of connections through the independent exchanges and networks should not equal this, it will be readily seen that an enormous amount of traffic in the nature of business, social, and family intercourse was transacted with the aid of the telephone, and indeed it would be impossible to imagine the conduct of American life upon its present basis without the telephone.

Illinois is the great center of the telephonic manufacturing industry in the United States, both as to number of factories and as to output. As shown in Table 14, this state accounts for more than half of the total value of product. It reports, for example, 588,750 complete sets of instruments, at a value of $3,942,343; 2,199 central switchboards, valued at $3,144,595; 1,153 private exchange boards, at a value of $179,031; and telephone parts and supplies, to the value of $793,026. The product in New York state was also quite large, although far below the aggregate in Illinois; the value reported for 104,180 complete sets of instruments being $982,834, and $1,695,709 for 776 central switchboards. It also had the largest proportion of the private exchange boards, numbering 2,194 and valued at $331,042. Both in Indiana and Ohio there was a fairly large production of apparatus, Indiana reporting 34,370 complete sets of instruments, valued at $334,170, and 328 central switchboards, valued at $105,387. The product in Ohio was about the same in quantity and amount, namely, 39,362 complete sets of instruments, valued at $382,275, and 203 central switchboards, valued at $122,500. Michigan and Massachusetts came next to Illinois in the manufacture of miscellaneous telephone parts and supplies, the output in Massachusetts being $210,967, while that of Michigan can not be shown separately. The product in the factories devoted to telephone parts and supplies is somewhat analogous to that in the bicycle and automobile field, these smaller factories chiefly making pieces which afterwards would be assembled into completed apparatus in the larger factories.

The telephone switchboards enumerated in this report are of two main classes—manual and automatic—which subdivide themselves into a great many varieties. The manual switchboard is that in which the connections between the subscribers are made at the central exchange by operators, who connect the lines of the different subscribers at the board by means of plugs joined by flexible conductors, all such connections being made in accordance with requests received over the line from the calling subscribers. These manual boards constitute a very large proportion of the boards included in the present statistics. There were in 1902 no fewer than 10,842 manual boards in use, and while no detailed figures are given, it is the fact that nearly all of the central switchboards and the private exchange boards made in the census year were also of the manual variety. This condition is likely from all appearances to continue for many years, although the automatic method has of late exhibited a rapid increase. During the past year fewer of the manual boards constructed were of the magneto type—in which each subscriber's substation has a small battery to energize its transmitter, and a tiny magneto-generator in the bell box, by revolving the handle of which the subscriber signals the central exchange. For all large boards of the manual type, as well as for a growing number of the smaller ones, the common battery system is in increasing favor, and in 1905 no new large exchange equipment in the United States can be named which was not of the latter type. In the common battery system, aside from the concentration of the source of all the electrical energy for the system at the central office there is another general feature which distinguishes it sharply from the older magneto-system. The signals on magneto-switchboards are of the electro-magnetic drop character, which operates in such a manner that when the current comes in from the subscriber's line, the drop or shutter corresponding to his line and carrying a number is dropped or otherwise moved, thus exposing the figures of the drop to the operator, who thereupon ascertains the wishes of the subscriber and connects him with the required circuit. The visual drop has long been considered inadequate to the needs of modern telephony, because the operator often fails to notice the falling shutter, and also because the shutter mechanism requires relatively so much space. In all the new large boards associated with the common battery practice the lamp signals are used, consisting of a very small incandescent lamp which flashes into visibility the moment the subscriber removes his receiver from the instrument at his office. When several thousand subscribers have to be represented and interconnected in the limited space of a multiple switchboard, the advantages of such signals are apparent, as they are extremely compact and hence economize space; having no working parts, they can be placed in any position vertically, horizontally, or at any angle; moreover, they are automatic in action, so that the signal disappears immediately when the energizing current is cut off. They also give a much more positive and attention compelling signal than any other form of indicator that has yet been tried in telephone practice. To quote the language of Mr. Herbert Laws Webb:

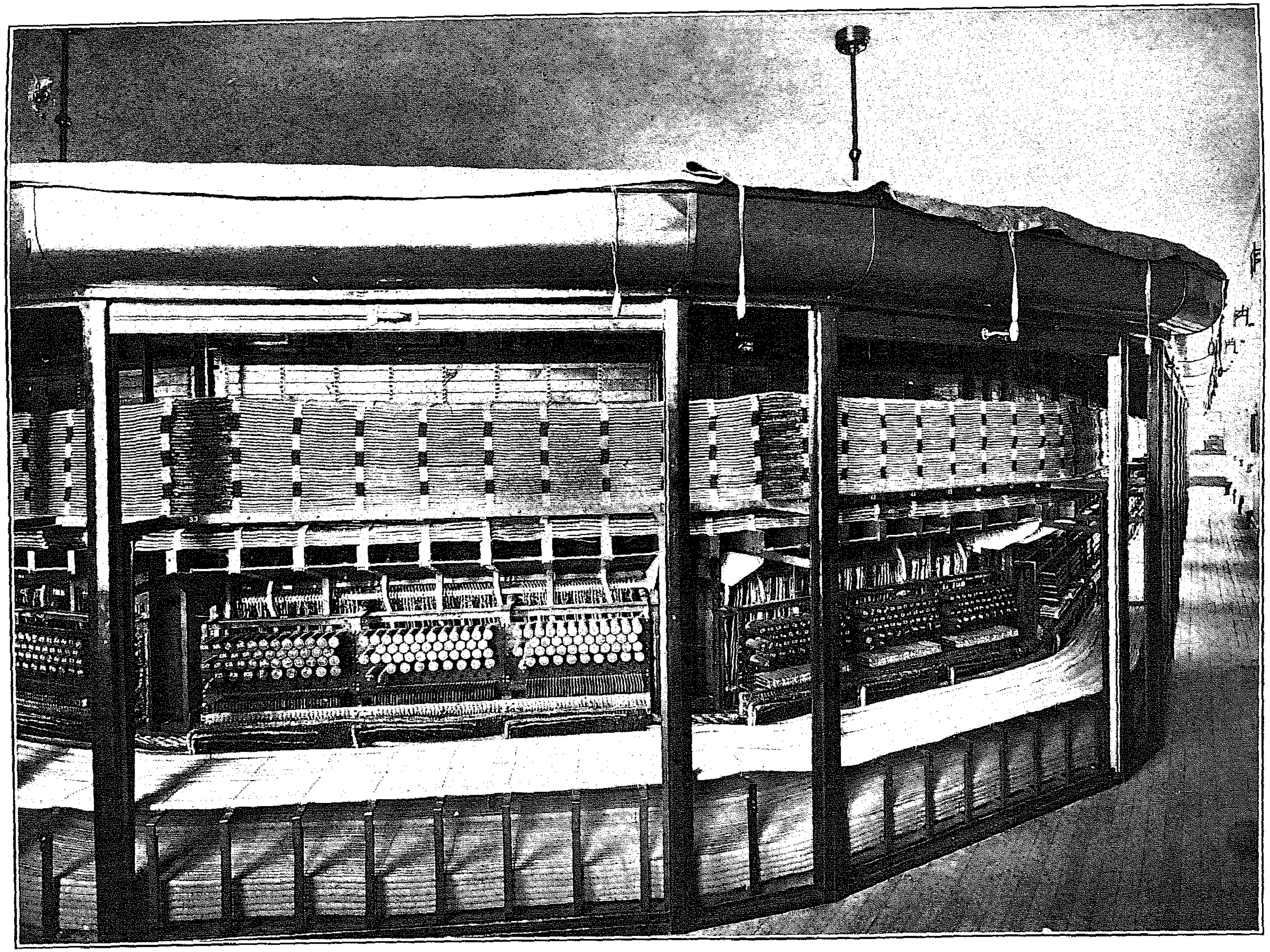
> These various qualities enable several radical improvements to be made. The signals are placed immediately adjacent to the jacks or cords they control, which, in large switchboards, is impossible with electro-magnetic indicators; the line lamp is immediately above or below its corresponding answering jack and the supervisory lamps are in line with the connecting cords and close to them. With this arrangement the operator loses no time and has to exert no brain power in tracing the relation between the signal and its corresponding jack or cord. The difference in effect between the modern arrangement of directly associating the signals with their corresponding jacks and cords and the old arrangement of placing the signals in a separate part of the board from that occupied by the jacks and cords is something akin to the difference between a telegram in plain language and one in code. In the one case the meaning of the signal flashes instantly to the brain of the operator, and in the other case a certain effort, and a certain interval of time, are required for translating the meaning of the signal. The automatic working of lamp signals is of much wider range than that of electro-magnetic signals. We had self-effacing, or automatically restored indicators before lamp signals were introduced. But the self-restoring indicator had but two positions—only two words in its vocabulary, so to speak. The lamp signal has several; it may be alight or out, corresponding to the down and up positions of the indicator, but it may also flash, and it may be made to flash at different rates of speed, easily recognizable. Therefore, apart altogether from the fact that it is much more easy to apply to lamps distinctive marks indicating different classes of service than it is to apply such marks to indicators, the lamp signal is able to convey a greater number of meanings as a working signal than an indicator. Finally, the more assertive and positive signal given by a lamp as compared with an indicator is due to a simple physical fact—the great sensitiveness of the eye to light. The glowing of a lamp signal instantly attracts attention, no matter at what angle the lamp may be relative to the eye, and in many cases the lamp is seen instantaneously where a fallen drop would be unnoticed for several seconds. The lamp is seen out of the corner of the eye, so to speak, whereas an indicator must be more directly in the range of vision.

Mention has also been made of the fact that in the telephone switchboard of the modern common battery type the distributed battery, so to speak, that was formerly located in individual cells at every subscriber's station is now all centralized at headquarters, where it is far more available for inspection, renewal, maintenance, and continuous operation. The primary batteries that were formerly in use, scattered widely over a large territory, were subject to all kinds of accidents and interruptions from freezing, spilling of acids, corrosion, breakage of jars, etc.; whereas to-day the idle capital represented alike by the local battery and the magneto-generator with its incidental expenses, is done away with, and a large source of electrical energy is substituted, which stands ready at the central office to be drawn upon freely at any instant by any subscriber.

The work of the common battery office is performed with the aid of the storage battery, and the majority of such installations are operated at a potential of 24 volts, requiring a minimum battery of 12 cells. In most instances a duplicate of adequate capacity is installed and is associated with more than one method of generating, so that the services may be rendered free from all danger or possibility of interruption. It is stated that owing to the lessening of labor the operator, by these modern methods of signaling in common battery systems, can handle with success an average of about twice as many subscribers as with the old system. Another feature of this work has been the division of an exchange into virtually two sections to facilitate the transfer of communication at junctions from one circuit to another, the existence of supervisory lamps on the board enabling the incoming checking operators to signal back automatically to the answering operators whether the lines wanted are engaged or disengaged or out of order—the aim of this being to lessen the amount of trouble due to "line busy" or "engaged" difficulties that were the bugbear of all exchanges and the annoyance of all subscribers.

There is necessarily a great deal of complexity still about the modern common battery switchboard, but some of the gains resulting from its use are indicated in the striking statement that in a large exchange a room which formerly contained a magneto-switchboard equipment for 5,200 subscribers' lines, now contains a switchboard equipment of modern apparatus with lamp signals, which has a capacity of 9,600 lines. Moreover, the gain in time, due to the shortening up of the period necessary for connecting and disconnecting subscribers, adds greatly to the traffic-carrying capacity of equal plants under the two systems.

The other general class of switchboards included in this report is the automatic, in which all manual operations, whether of the magneto-exchange or the common battery system, are dispensed with, and all the operations of connecting and disconnecting are performed by automatic mechanisms at the central station set into motion by the subscriber himself. The subscriber's station consists of the usual telephone transmitter, receiver, battery, bells, induction coil, etc., with the addition of a call dial placed just below the



TELEPHONE SWITCHBOARD, SHOWING REAR VIEW OF SUBSCRIBERS' SECTIONS, WITH MULTIPLE CABLES, ANSWERING JACK CABLES, CORD CIRCUIT CABLES, AND RELAYS.

transmitter, on the periphery of which are ten numbered finger holes, carrying the numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0. When the subscriber wishes to call a number, he takes the receiver down and moves the dial around successively step by step to the separate numerals constituting the number, when having completed the number he presses a button beneath the dial and rings at once the bell of the other subscriber called. If the line required is free, the connection is completed. If the line required happens to be busy, a buzzing sound in the receiver of the calling subscriber informs him that such is the case, whereupon he waits until the other line is clear. This step-by-step mechanism is simple and ingenious and works satisfactorily. For exchange purposes of the automatic system two classes of switches are employed. One set is known as the "selectors," of which there is one for each telephone connected with the central exchange; and the other is spoken of as "connectors," of which there are ten for every one hundred selectors, and which are in groups, each capable of connecting a hundred telephones. The selector connects its calling telephone with the connector in the proper group, which in turn connects with the required telephone in the group to which the connector belongs. This is employed in the case of exchanges of 1,000-line capacity or less. In larger exchanges a second auxiliary selector is employed, in the nature of an intermediate switch, which divides the work of selection with the first selector and therefore facilitates the work. These automatic switches at the exchange are mounted on steel shelves, 25 to the shelf, each board carrying four shelves of the first selectors and one shelf of the connector switches. This typical arrangement for central exchanges of 1,000 lines is modified in larger exchanges up to say 10,000 lines, where the board is made up of six shelves, four carrying the first selectors, one carrying second selectors, and one carrying the connector switches. The floor space occupied by such a condensed switchboard is 11 feet 6 inches by 12 inches in depth, and these boards or exchanges can be readily increased by simply adding new sections with the desired number of switches mounted thereon, without the disturbance of the board or the exchange already at work.

The system of trunking cables is similar to that in manual practice, and the selection of the trunk is automatically accomplished by means of the "wiping fingers" on the shaft of the selector switches, which pass over all the busy contacts and stop at the first idle point. The electrical equipment in the operation of the system follows generally the lines of the standard manual exchange, and consists of a 52-volt storage battery for furnishing current; and there are, as usual, cross-connecting boards or distributing racks, equipped with heat coils and carbon lightning arresters; a ringing machine, with "busy back" and "howler" attachments; a "telltale" board for the location of trouble; and the usual accessories of a small power plant.

The telephone switchboard is an exception to many other forms of construction, in that the cost per unit increases at a greater ratio than that of the mere physical enlargement of the board and of the system. The cost of a switchboard, in fact, ranges from $500 to $1,000 per square foot, varying according to the number of wires accommodated, while the life of the board is comparatively short. The system in New York city, for example, has practically been rebuilt three times in sixteen years, owing to the radical improvements made in switchboard systems and in the trunking cables, each time involving the abandonment of the then existing plant. Some of these exchanges have, in fact, been rebuilt three times in a little over ten years, showing an actual depreciation of 25 per cent per annum, although the old plant was not physically unserviceable. In a small switchboard with sections or places for two operators, there would be two sets of circuit branches and sockets for each telephone line, so arranged that the operator can make connection by plugging into them. In a large switchboard, however, with places for 50 operators there must be 50 sets of such connections for each telephone line—the number of this class of connections multiplying twenty-five times for each telephone, in order to enable each operator to reach all the subscribers who are connected into that central switchboard. The difference in cost of manufacture is immediately brought out by noting the material thus entering into the composition of a small switchboard of 600 telephones and one for 10,000 telephones, the individual items and details in each being alike and of the same cost. In the smaller switchboard there are only 43,000 soldered connections for the circuits, or about 72 to each telephone. In the larger switchboards, however, there are no fewer than 2,500,000 soldered connections, or 250 to each telephone. In the smaller board there is the quantity of 220 miles of wire circuit, or about one-third of a mile to each telephone. This in itself is very often as much wire inside the exchange for the subscriber as there is outside connecting his station with the exchange. In the larger switchboard, however, there are no less than 10,000 miles of wire, or at least 1 mile to each telephone. The other details follow in similar proportion, so that the whole expense per telephone is vastly greater in the larger boards, no matter what refinements or economies are introduced in the process of manufacture. Hence, as an actual fact, the cost of the largest boards will sometimes reach as much as $1,200 per foot of length, while one-third of the gross revenue of a telephone company is necessary to maintain such a board and the plant in good order without any reference to the cost of operation or of extensions.

As the statistics show, no fewer than 3,917 private exchange boards were built during 1905. No such boards were enumerated separately at the census of 1900, although a number of them were in use, and it is probable that boards of this type were included in the class of "interior systems" at that census, as the distinction between these two classes of boards had not been clearly defined at that time. On June 1, 1905, there were as many as 6,637 private branch exchanges in Manhattan and the Bronx boroughs of New York city, with 17,704 central office lines furnishing service for 67,176 stations. The installations of this character vary from those with one or two lines or stations up to such large systems as that in a leading hotel with 1,200 telephones, or in a large dry goods store with 2,000. These private exchange boards are manufactured for many special uses and the advantages of their employment have been so great that the number of operators employed on the private exchange boards in New York city alone is more than twice the number of the operators in the central exchanges there. This concentration of lines from the individual telephones in business establishments to a single desk, where the desired interior and exterior connections can be made, has in reality done much to limit the size of the central switchboards themselves, as it is obvious that if every circuit were brought out to a central exchange, the boards would be of even more unwieldy proportions than they are now, while the outlook for the future would involve problems in switchboard construction with which no known resources of the art could grapple.

Including the separate transmitters and receivers, it would appear that a total of about 1,700,000 complete sets of telephonic substation instruments—that is, each set comprising a receiver and a transmitter—were manufactured in 1905, giving an average value of about $4.75 for each set, the total value being in excess of $8,000,000. The transmitters and receivers are of a great many different styles of construction, but all of them are essentially of the same nature in the two classes of apparatus, the differences being mainly such as might be expected where a number of manufacturers are endeavoring to give individuality to their products. All the transmitters now manufactured in the United States are of the microphone type, including the single contact, the multiple contact electrode, and the granular carbon varieties.

The prevailing theory as to the action in the transmitter is that as the pressure between the carbon electrodes or particles increases, the area of the contact increases so that it becomes denser, and is a better conductor. In the single-contact transmitters the resistance of the circuit is varied between two points forming a single contact. In the multiple electrode transmitter a number of pieces of carbon points, blocks, or balls are brought into contact. Several such transmitters were at one time in use, particularly for the purpose of long-distance work where a heavier volume of current was deemed necessary. However, few, if any, of these are now made, the prevalent and predominant type being that of the granular carbon. In this class of apparatus carbon particles are used, as practically all forms of this are variations of the original White "solid back." The carbon particles now most favored are made from anthracite coal, the minute pieces of which are highly polished and are selected according to their degree of hardness. These particles are sifted through sieves having about 50 to 55 meshes per inch, and the average size of these particles is from 0.020 to 0.022 inch along the direction of the greatest dimension, although some particles in use are considerably larger. Great pains are taken to secure particles of a uniform grade, as in this way the effect of "packing" is greatly reduced. Unless these particles are of uniform size they naturally have a tendency to pack or to settle down into a compact mass, and the more solidified the carbon becomes the less readily can the current flowing in the transmitter circuit be made to fluctuate, according to the variations of the diaphragm caused by the sound waves directed against it by the voice. These granules of carbon are inclosed in a shell or casing between a front and back electrode of carbon. The vibration of the diaphragm, being communicated directly to the front electrode, varies the pressure and distance between it and the back electrode. The movement of the diaphragm is in some of these instruments dampened by springs which prevent too great amplitude of its vibration. The carbon working parts are inclosed in cups of brass, aluminum, etc. This again is usually inclosed in an outer receptacle or two-piece cup of metal, the two parts being permanently riveted or secured together so that the working parts can not be tampered with. A hard rubber flaring mouthpiece is placed in front of the speaking orifice of the transmitter, and the back is mounted upon a stand with swivel to permit its being raised or lowered in adjustment to the mouth of the speaker. The transmitter and the receiver are mounted together, either as desk sets or as wall sets. In the wall set the induction coil which is employed in the transmitter circuit is often placed in the base of the arm carrying the transmitter itself. It is also sometimes mounted upon the backboard of the telephone box. The base and arm are made of cast iron joined in such a manner as to permit of considerable vertical movement of the transmitter, so as to accommodate it to the height of the different speakers.

The induction coils are constructed and mounted in various manners by different manufacturers. In one approved type the core consists of a small bundle of fine Swedish iron wire. The primary is mounted over this, consisting of three layers of cotton covered wire. The secondary coil is mounted in two sections, bare wire being employed and the adjacent convolutions being kept apart by means of a fine thread of silk wound alongside and parallel with the wire. Between each layer of wire a layer of paper is inserted in the process of manufacturing, so as to make the insulation complete. The machinery for the manufacture of coils in this manner is so ingenious that several coils can be wound simultaneously, the layers of paper being introduced automatically between each layer of the winding without any stoppage of the machinery, which is operated at very high speed. The use of the bare wire tends to cheapen the process of manufacture, as compared with the use of insulated wire. After the secondary windings have been finished the outside of the whole coil is usually covered with black cloth or other waterproof material, or else shellacked or varnished. The terminals of the coils are brought out to clips on the base, so as to serve as binding posts for connecting into the circuit, and they are numbered or lettered for purposes of identification in subsequent use. To give an idea of the amount of wire employed in each little coil, it may be mentioned that the winding of such coils for local battery use consists generally of about 150 turns of No. 22 wire for the primary and 6 layers of 6,000 turns of No. 36 wire for the secondary. It is by means of these induction coils that the feeble currents set up by the voice are so intensified that they are enabled to traverse long distances and overcome the resistance of many miles of transmission line without such loss as would impair them or render the undulatory current incapable of repeating successfully the operation in the receiver at the distant end.

Telephonic receivers as a general thing have varied little in outward appearance in several years, and some forms go back with little change to the original "butter stamp" adopted in the earliest years of the art. The receivers as now made consist essentially of an inclosed shell of hard rubber within which is a magnet, at the diaphragm end of which is a coil of fine wire, this solenoid consisting of very fine silk insulated copper wire wound on a spool. At one time most of the receivers employed in the United States were of the single pole magnet type, but the great majority are now of what is known as the bipolar type, the diaphragm end of the magnet carrying two solenoids instead of one, with the object of securing greater sensitiveness. In all the earlier instruments, and in many of those still in use, the binding posts of the receiver were exposed and exterior to the hard rubber shell, but in a great many of the instruments now the posts and connecting cords are carried within the shell, so that they are not so liable to work loose, and thus avoid the liability of dangerous contact on the part of the user should the incoming line be suddenly charged with "sneak" currents from railway or lighting circuits or from lightning. The troubles in the earlier type of receivers from the unequal expansion between the metal and the rubber parts are now hardly ever encountered, owing to the improvements in manufacture. The diaphragm of the receivers consists usually of very thin sheet metal vibrating in front of the magnets, and the diaphragms are either tinned or lacquered on the sides exposed to the breath to prevent corrosion from the moisture condensing on them.

For the use of all who must listen to the receiver continuously, as do the operators in the central exchanges, special receivers are made up in what is known as "watch case" or "head" form to be held to the ear by a flexible headband. Here the permanent magnets in front of which the diaphragm vibrates are of the ring type, being closed magnets, so as to produce poles on the opposite sides of their circumference. Fastened to the compound ring magnet are circular pole pieces which carry the electro-magnetic coils. The face of these pole pieces is closely adjacent to the diaphragm, as in the ordinary butter stamp receiver. The working parts are mounted in a hard rubber cap or shell and the diaphragm is clamped between the front face of the cup and the flattened ear piece, while the binding posts to which the terminals of the cord are attached are usually carried within the shell. Some forms of the watch case receiver are made up also for various uses where the employment of the longer receiver would be inconvenient.

It has already been noted that a considerable proportion of the manufactures in the telephone class were of parts and supplies, the total amounting to $2,071,895. This classification embraces a wide variety of parts, the chief items being the signaling apparatus in magneto-telephone sets and the line protectors, fuses, etc. Each magneto substation carries a pair of small gongs, between which swings a striker, forming part of an electro-magnetic system, so that the movements of the striker cause the bell to ring. The magneto generator included in the set is in reality a tiny alternating current dynamo which is operated by hand, so that when the crank is turned its armature is revolved rapidly and an alternating current is sent out over the line circuit to the central office to throw the subscriber's numbered drop on the switchboard. The substation is safeguarded against abnormal current by means of a protector placed on the backboard of the telephone set, a common form being a spark gap which consists of a pair of carbon plates, one of which is grounded, while the other is connected to the line, the plates being separated by a thin perforated mica washer. This is usually associated with a fuse or heat coil of fine fusible wire, which sometimes takes the shape of a tubular fuse, the wire being inclosed in a hermetically sealed small tube, which protects the fuse from the air and enables it to operate more uniformly. The tubular fuses are, however, used more particularly in connection with the protection of switchboards, being mounted in sets or gangs ready for insertion on the distributing board at the central exchange. In the present report fuses and lightning arresters are as a class brought to account under a separate heading, and it is likely that many intended for telephonic use are there enumerated rather than as telephonic parts and supplies.

It will be readily understood that quite outside of the main switchboards and the apparatus in use at the subscribers' stations there is a large amount of miscellaneous apparatus which is included in "telephonic parts and supplies," and some of which even falls into other classes of manufacture. Each exchange, for example, in addition to its local and toll-line boards, is equipped with intermediate distributing frames or boards equipped with connectors to which the outside circuits are brought, so that they may be readily connected to or disconnected from the circuits within the exchange. In the case of the common battery systems there are also relay frames equipped with mounting strips for insulating individually each set of line relays, these being encased in dust proof caps or jackets. A central exchange is also provided with desks for the chief operator and the monitors and wire chiefs, each of these desks being thoroughly equipped for the supervision of the work within the exchange by the superintending force or for testing apparatus or lines immediately when any trouble arises on the circuits. The details that must be supplied in connection with ordinary interior telephone systems, intercommunicating systems, or those for simple intercommunication, are numerous also.

For many years past it has been the custom to employ the telephone for the transmission of music, sermons, speeches, etc., sensitive transmitters for this purpose being placed in the vicinity of the stage, the pulpit, or the musical performers. Separate companies have been organized for business of this character, while in Budapest, Hungary, a news system has been associated with such work. A more radical innovation or employment of the telephone owes its origin to Dr. Thaddeus Cahill, of Holyoke, Mass., who has developed within the last few years a most original and ingenious system of music production, and its distribution, by means of electrical currents over the telephone circuits. The principle of the invention is that each current of electricity from an alternating current dynamo has its own specific predetermined rate of vibration or frequency in the circuit, and that this current when brought to a telephone is there heard as a musical note. Middle C string on the piano, for example, has 256 vibrations per second, and in like manner the vibrations of current produced by the dynamo designed for that purpose number 256, and are heard as the same note in the telephone. The inventor has designed, therefore, and placed together on a common shaft 145 small alternating current dynamos, each with its characteristic current vibration, and these currents led to a keyboard can be manipulated there by the performer who, with the aid of the various transformers, or "tone mixers," is enabled to give a musical performance based wholly upon the current of these dynamos instead of upon the vibrations due to the use of reeds, strings, or pipes. The keyboard is operated by the performers just as is that of the piano or organ, or can be associated with a mechanical attachment, as in the pianola. The performers, having control of the dynamos, give not only the fundamental notes, but also the overtones or harmonics by compounding the various vibrations in such a manner as to play any chosen piece of music, and can also stamp on the sounds the quality of those from various musical instruments, such as the organ, violin, flute, etc. The plant where these electrical vibrations are generated can be connected with a large number of telephone receivers in different parts of a city, and hence the same music can be heard, simultaneously, at points miles apart. The electrical vibrations, with negligible loss in transmission, become music as soon as heard in the receiving telephone, to which is attached a megaphone horn in order to intensify the sound and enable it to be heard by several persons at once. It will be understood that these currents usually produce music only in the telephone receiver, but they can also be made audible as music in the "flame" of an electric arc lamp.

The telephone receivers and the horns attached can be exposed in full view of the audience, but are preferably inclosed or concealed in baskets of flowers, divans, ornamental urns, newel posts, etc., according to the nature of the room in which the music is to be rendered. Each receiving telephone requires a surprisingly small quantity of current for the delivery of music and a score of them will take no more than an ordinary incandescent lamp. The first commercial plant installed in New York city driven by a motor of 200 horsepower has an estimated capacity of from 15,000 to 20,000 subscribers, each furnished with a telephone that can be heard by a large audience. The music has been transmitted from the original plant at Holyoke, Mass., as far as Springfield, Mass., and New Haven, Conn., with success, but it is intended that each "central" shall be restricted to local delivery of its music. In addition to the large sets of apparatus for central station music purposes, the owners of the patents are manufacturing smaller isolated plants intended for separate use, and giving music, as desired by the individual performer, in exactly the same manner as an isolated light and power plant.

An ingenious piece of apparatus which has been introduced within the past year or two for use in connection with the telephone is the Poulsen telegraphone, the object of which is to furnish a record of the speech received over the telephone. Dispute often arises as to the exact nature of telephone conversations, and litigations have arisen on account of the discrepancy between the alleged statements of the interlocutors.

In the telegraphone the principle employed is that of recording upon a narrow traveling steel strip, or fine wire, the message or speech as received. As now manufactured and actually in use, the telegraphone embodies two large spools mounted on top of a small box which is equipped with an ordinary telephone transmitter and a pair of telephone receivers. From one spool to the other, standing 6 inches apart, runs a steel wire $\frac{1}{100}$ inch in diameter. Standing between the spools, on a vertical support or arm, are two small electro-magnets facing each other, about $\frac{1}{16}$ inch apart. When the conversation is going on, the magnets are switched into circuit, the wire is set in motion between the two spools, running from one to the other, and the vibrations of the voice as received from the distant transmitter are communicated electrically to the magnet coils. As the wire travels between the magnets it becomes magnetized with an intensity and a polarity corresponding to the strength of the particular sound vibrations, which correspond to the waves of electric current at that instant. When the conversation is finished, and the record is therefore complete, the spools are reversed and the wire reeled back. When it is required to listen to the conversation or to the message which has been taken by the telegraphone during a man's absence from his office, the receiver is put into circuit with the magnets and the wire is once more reeled off from one spool to the other. The magnets and the magnetic wire now act in such a manner that the coils are electrified, strongly or weakly, just as they were under the influence of the original undulatory waves of current created by the voice vibrations. In this manner the varying vibrations stamped magnetically on the traveling wire are communicated by it to the receiver and the conversation or message is reproduced by the receiver. The wire travels at the rate of about 10 feet per second. In addition to serving as a record for telephonic messages, the telegraphone is made to do also the work of a phonograph for receiving dictation; the wire with the dictation being run through again afterwards by the typewriter, who places the receiver to her ear for the purpose. In this manner a large amount of dictation or correspondence is provided for, as there are about 2 miles of wire on each spool. Another feature of the apparatus is that the reversal of the apparatus so as to secure the record cleans the steel wire of the record it has received. The passing of the wire before the electro-magnets "wipes off," so to speak, the magnetic impression which the wire had received originally. The whole apparatus has been developed into simple, compact form, and while not yet in extensive use, must be regarded as a part of the resources of the telephonic art available at the time of the present report.

During the past year or two submarine signaling based upon the use of the telephone has been introduced and a number of light-houses and steamships have been equipped with the system, which is of American origin, owing its perfection to Prof. Elisha Gray and Mr. Arthur Mundy, of Boston. The principle embodied is found in the fact that sound vibrations travel very easily in straight lines in the water—at about four times the speed that they do in air—and can be heard at a considerable distance if there is apparatus upon which the vibrations can impinge.

In the submarine telephone signaling apparatus now manufactured, a small tank is attached to the inner side of the skin of the vessel. This tank is filled with a chemical solution, denser than water, and contains a microphone. A sound reaching the ship's side through the water, passes into the solution in the iron tank and the vibrations impinge upon the sensitive microphone, acting as do the corresponding vibrations of the voice in the transmitter system of a talking circuit; from there the currents are carried to the receiving station in the pilot house, or other appropriate place, such as the ship's bridge, and are there heard by the telephone receiver. The receiving box is equipped with two telephone receivers instead of one. By holding first one receiver and then the other to his ear, the pilot, or navigating officer, can tell on which side of his vessel the submarine bell is located that is giving notice of danger, for the reason that the sound vibration travels in straight lines and therefore the direction can be very accurately determined. The same method applies to the indication of the location of two steamships during a fog, as both can tell the direction of travel and thus modify their course to prevent accident. In a report to the United States Navy Department, Lieutenant-Commander Walling has stated that the direction of a submarine bell can thus be determined by the telephone within one-eighth of a point on the mariner's compass. More definite data as to the commercial use of the invention are afforded by the fact that the signals of Nantucket, Fire Island, and Sandy Hook lights and light-ships have been picked up by approaching steamers from Europe at distances of 4 miles, the bell code numbers being known to the officers of the vessels. A great deal of work was done with the system during the year 1904–5, and at the time of the preparation of this report 19 light-ships on the Atlantic coast, about 125 steamships, and 2 American battle ships had submarine signal equipments. This American invention has also been introduced abroad and placed upon English, French, German, and Dutch light-ships.

A composite form of apparatus has recently been introduced, called the "telegraphone." It will be noticed that this name is somewhat confusing, as it has already been adopted for the Poulsen recording telephone apparatus previously described. This instrument is in all outward appearance similar to the ordinary telephone, but it is not intended for telephonic use in the ordinary sense of the word. Through an adjustment of the railway telegraph circuits the apparatus can be attached to regular telegraph wires in such a manner that conversation, as well as the transmission of signals, can be carried on without interference by the calling devices with the Morse relays. The railroad telegraph apparatus can thus render double service; as the composite set avoids the cost of stringing an overhead circuit which is necessary when separate telephones are used by the railroads. It is stated that several hundred complete sets of this apparatus were manufactured during 1904. It should also be pointed out that simultaneous telegraphy and telephony over the same circuit has long been practiced in this country and in Europe, with methods and apparatus that are described in all the standard books dealing with the transmission of intelligence. The use of the telephone principle in railway telegraph signaling was also adopted by Mr. Edison several years ago in his well known "phonoplex."

Telegraph apparatus.—Table 15 shows the production of telegraph instruments, switchboards, and parts and supplies, reported in 1900 and 1905.

TABLE 15.—*Telegraph apparatus—number and value: 1905 and 1900.*

STATE.	Total value.	INTELLIGENCE (KEY, SOUNDER, ETC.).		Police, fire, district, and miscellaneous (value).	Wireless telegraph apparatus (value).	Switchboards, and parts and supplies (value).
		Number.	Value.			
United States, 1905..	$1,111,194	76,826	$187,744	$592,070	$114,050	$217,330
1900..	1,642,266	199,410	[1]354,212	1,231,167	....	56,887
States, 1905:						
New York..............	412,106	24,756	96,339	145,438	8,500	161,829
All other states........	699,088	[2]52,070	[2]91,405	[3]446,632	[4]105,550	[5]55,501

[1] Includes instruments to the value of $5,300, for which number was not reported.
[2] Includes states as follows: Illinois, Maryland, New Jersey, and Oregon.
[3] Includes states as follows: Illinois, Maryland, Massachusetts, Ohio, and Wisconsin.
[4] Includes states as follows: California, Colorado, District of Columbia, and Massachusetts.
[5] Includes states as follows: Maryland, Massachusetts, Missouri, Nebraska, New Jersey, and Wisconsin.

It will be noticed that there is an apparent falling off of at least half a million dollars in the value of telegraphic apparatus for 1905 as compared with 1900; the value in the earlier year being $1,642,266, whereas the last census year it was reported as only $1,111,194. This decline was perhaps more apparent than real, as in recent years the larger telegraph systems have shown an increasing disposition to make and repair their own apparatus rather than to purchase it from manufacturers in the open market. It is obvious that throughout the country the mere wear and tear on apparatus sending and receiving a hundred million messages a year, would require considerable outlay for renewals, even if no new offices were equipped. As a matter of fact, a large number of new telegraph offices of an extensive character have been equipped in recent years, calling for apparatus in quantities at least equal to those required at earlier periods in the art. To take a typical case, the Western Union telegraph system reported for the year 1904 the equipment of 338 new offices and no fewer than 356 in the year 1905, while during the two years referred to large offices were remodeled or reequipped at such important centers as Boston, Philadelphia, Cincinnati, Cleveland, and St. Louis. Moreover, in the year 1904 dynamo current was substituted for chemical cell main batteries in fifteen important centers of the same corporation, involving in the change extensive renewal, adjustment, and rearrangement of apparatus.

The newer apparatus in the telegraphic field includes that employed for what may be called high-speed printing purposes, intended to supplement or supersede the work of the manual operators who still transmit with the lever key the great bulk of American messages. The quantity of apparatus of this "machine" character manufactured is still quite small, but it would seem that the inventions in this field must result in making machine telegraphs play a conspicuous part in the telegraphic art. It has been said by one of the most prominent managers in the telegraphic field that the advances in the direction of developing and perfecting printing telegraph systems, adapted to all the requirements of modern service, leave no doubt as to the employment of such systems in the domain of commercial telegraphy. The most conspicuous systems of this character utilized to any degree in the United States are those of Buckingham, Rowland, Murray, and Delany.

In the Rowland system the basic principle is the employment of alternating current, which, dominant in the domain of light and power, is ideal also for the long distance transmission of intelligence. In order to transmit the signal, however, the alternating current is modified. For each signal the base, so to speak, is a block of alternating current, consisting of 11 half waves which are modified by the reversal of any two. In other words, the sending of signals is actually accomplished, not by supplying the line with current at the moment the signal is being transmitted, as in ordinary telegraphic methods, but by cutting out certain of the alternating current waves. Hence one or more of the signals can be made to consist of a combination of suppressed half waves, the signals so produced being then translated automatically into printed characters. In this manner, and by grouping the waves so as to permit of entirely different and independent signals being sent from four typewriter keyboards, each of the four transmitting operators employed can cut out four different wave combinations and thus send as many different signals over the line in a single second. Forty words per minute is given as a fair rate of speed for a practiced operator with this system, and as the system can be duplexed, eight times that number, or 320 words in all, can be sent over a telegraph wire and printed in one minute. The late Prof. H. A. Rowland developed his system so that the letters of the alphabet, figures, and some extra signs are printed automatically in such a manner that each operator, by writing on the ordinary typewriter keyboard, prints on a page 8 inches wide at the other end of the line over which he is sending. These pages of printed matter have the general appearance of an ordinary sheet of typewritten matter, with the letters and figures appearing in clean cut block type.

In the Murray printing telegraph system the typewriter is again employed—the messages being mechanically both transmitted and recorded with it. Perforated paper tape is first prepared by means of a keyboard mechanism, the punches corresponding with letters and figures, and the tape is then passed through a Wheatstone transmitter, which, at a high rate of speed and operating automatically, sends out the signaling currents to the distant receiving station. These currents are utilized not to actuate the printing mechanism directly, as in the case of the other printing telegraph systems, but to produce a second perforating tape at the receiving end—this tape controlling mechanically a typewriter in the same manner as the perforated rolls of music operate mechanical pianos or organs. The Murray system affords a high rate of transmission on the wire and a high rate per operator, but is subject to the criticism that both the sending and the receiving stations employ a perforated tape, which in actual practice involves delay, especially in the case of errors or damaged tape. A maximum theoretical speed for the Murray apparatus working simplex is given of 96 words per minute and a practical speed of 120 messages of 30 words each per hour. Working duplex this system is credited with a theoretical speed of 192 words per minute and 240 messages per hour.

The Buckingham system is the first really rapid long distance page printing telegraph that has ever been introduced successfully, and it has been in use for a considerable period of time on some of the longest circuits in the United States. The distinguishing features of the invention consist again of a typewriter perforating apparatus for preparing the paper tape for transmission purposes, and the printing mechanism at the receiving end of the line. The perforated paper tape is run through the Wheatstone transmitter, which forwards the signals automatically to the distant receiving station; there they are received upon a Wheatstone relay and thence repeated into the local circuit mechanisms; these are of a novel and ingenious character, and so operate that the current distributing apparatus and the type wheels print messages upon regular telegraph blanks. These blanks encircle a tube, and when the printing of a message begins, one of them is slid edgewise upon a brass tube which serves as a support. When the blank has been printed, it is slipped off quickly to one side and a fresh blank takes its place. The message when thus printed is spread out by cutting it open, when it can be forwarded immediately to the addressee. The four-type wheels in the Buckingham system carry 32 characters, inclusive of the letters of the alphabet and punctuation marks, this special alphabet having been devised by Mr. Buckingham as adapted to the system. It is subject to the general objection of requiring a preliminary perforated tape, but on the other hand the messages received are printed ready for delivery, a notable point in total speed of transmission. In messages over Western Union circuits between New York, Chicago, or Buffalo, during six or seven years of operation, a working capacity of 200 messages per hour operating duplex has been noted. A modification of this system has been introduced in the Barclay method, which embodies a form of electrical typewriter of great sensibility and rapidity in action, and a comparatively simple printing mechanism so devised as to meet more fully the service requirements, and aiming at the same time to improve the legibility and general appearance of the printed message as sent out to the public. It is said that with the Barclay system a speed of at least 100 words per minute has been secured.

The Delany rapid telegraph system includes a perforator machine which may be operated by the ordinary Morse key at the highest speed of expert operators. With two such machines an automatic transmitter may be fed with perforated tape, and messages sent over the line at a rate up to the highest ability of the typewriter operator receiving at the distant end. Thus, with two perforating operators working at 20 words per minute, the automatic transmitter will deliver 40 words per minute in improved Morse to the receiving operator, so that the capacity of the circuit may be doubled, and a duplex become equal to quadruplex in output with six operators as against eight. The quadruplex wire may also be made to carry double the number of messages with twelve men doing the work of sixteen. The speed is limited only by the impulse-conveying efficiency of wires, or the delivery of impulses of sufficient power to make a mark with iron recording wire on the chemical tape by electrochemical action, permitting of ready transcription by the receiving operator, who has to translate the marks on the tape. The perforated message is made up entirely of dots, all impulses having the same time value, and each succeeding one being of opposite polarity to the one before it. The time between the positive marking impulses and the negative, cutting off, or spacing impulses determines whether the character is a dot or a dash in the Morse alphabet. As a matter of fact the perforator can be worked by an ordinary keyboard transmitter, so that any typewriter can perforate the sending tape without even knowing the Morse alphabet. The receiving machinery is under the control of the transmitting operator, so that it may be stopped at any instant. The chemical receiving tape is only slightly damp and is wound up on wheels as it passes through the machine. It is not handled by anybody, being drawn in short lengths in front of the typewriter as the transcription is effected by means of a mechanical contrivance which is under the control of the typewriter's foot. It is stated that the transmitting apparatus is capable of running up to a speed of 10,000 words per minute, and that 8,000 words, or 2,500 impulses, a second have been recorded over an artificial circuit.

A great deal of time and attention has been devoted by inventors to the development of writing telegraph systems, and considerable ingenuity has been displayed in their manufacture. One system is in use in the United States at the time of this report and is being continuously developed. It depends, broadly, upon the principles of the parallelogram of forces, so that by compounding the movements of a point in two directions, one at an angle to the other, the actual path described by the point is the result of the two separate movements. In the telautograph, as thus worked out, the receiving pen operates under the variations of the magnetism of two electro-magnetic systems at right angles to each other, and reproduces with very close approximation the handwriting of the operator at the transmitting end in accordance with the motion of his pen or stylus. At the transmitting end a pencil is attached by rods to two lever arms which carry contact rollers at their ends, these rollers bearing against the surface of current carrying resistances connected with the sources of direct current supply. Hence the writing currents pass through the resistances to the rollers and thence to the line wires, so that as the stylus is moving in the act of writing the relation or position of the rollers in respect to the rheostats is constantly changing, and hence currents of varying strength are let through. Satisfactory operation is obtained with currents of a pressure from 80 to 250 volts, and the ordinary 115-volt current from incandescent lighting circuits is quite suitable. A master switch at the transmitter makes the necessary changes in the circuits and cuts out the mechanism when it is not in use. There is also a device for shifting the transmitter paper a distance of one line of ordinary writing, just as the paper is carried forward on a typewriter frame. The writing space is about 2 inches long and 5 inches wide, and allows for four or five lines of writing. When the sheet has been filled up, fresh paper is readily brought into position at the transmitter and with equal ease at the receiver. At the receiving end the apparatus for automatic writing is highly ingenious, particularly with regard to the supplying of ink and securing an easy, smooth movement of the transcribing pen. This apparatus has been introduced in the United States coast defence service for sending ballistic data from position-finding stations to the gunners. A special type of the telautograph has been manufactured for and adopted by the United States Signal Corps for fire-control communication. Commercial service is represented more specifically by its employment in hotels and clubs, communicating between restaurant and kitchen, for example.

Wireless telegraphy, since the last report on electrical manufacturing was made, has entered into such a sphere of importance and usefulness, both in peace and war, that its treatment has already become the subject of national and international control. Inventors in this field have been numerous, not only on both sides of the Atlantic but in South America and Japan, and the amount of wireless telegraph business now transacted is quite large, thousands of messages being daily transmitted through the ether, chiefly between ships and shore, but also between stations upon land. All of these wireless telegraph stations depend upon wire towers or antennae, carried high in the air in order to give off to, and to receive from, the ether the electrical impulses impressed upon it by the transmitting system. The wireless telegraph stations along seacoasts or on shipboard already number several hundred, and every navy and important line of commercial steamships has its complete system of wireless telegraph apparatus. The introduction of the system has already been carried so far that it has been put on board some of the larger boats of the American fishing fleets. The whole coast line of Europe is dotted with wireless telegraph stations, and a chain of stations also extends along considerable portions of the American coast as well as up the St. Lawrence river. The equipment of these systems with towers and high tension generating apparatus has developed a new field of manufacture, but only the figures of specific telegraph apparatus are embraced in the values given in this report under "telegraphy," including the special transmitters, receivers, coherers, keys, and other features. The generating plants for stations of high power with a "striking" radius of hundreds of miles are now equipped with alternating current generators and transformers of considerable horsepower. The distance of the message bears a fair ratio to the amount of electrical energy employed in sending out the high frequency impulses to the atmosphere.

The leading systems of the apparatus in use in the United States are the Marconi, the Slaby-Arco, the Braun, and one or two others of European origin; but there are several highly ingenious and successful American systems, notably those of Fessenden, De Forest, Massie, and Stone, all of which have been put into commercial operation. A principal element in the wireless telegraph systems is the device for intercepting the etheric impulses so as to convert them into signals. A leading type of coherer apparatus consists of a small pencil-like glass tube filled with metallic filings, which are caused to cohere by the incoming impulses and which are usually made to decohere by means of a tapper in the local circuit. This little tube receives the successive impulses and records them with auxiliary appliances, or renders them audible in a telephone receiver. The coherer by its variations operates a very sensitive relay, with an ink-recording device, by means of which the message is registered in the Morse alphabet. Some of the coherer systems are automatic in their operation. The rate of signaling with the filings coherer is comparatively slow, being limited to about ten or fifteen words per minute, on account of the sluggishness and mechanical inertia of the various parts. The distance of operation with this coherer also seems to be somewhat limited. A typical autocoherer system is that which has a telephone receiver in circuit, the variations of the current producing sound in the telephone receiver of long or short variation, corresponding to dots and dashes of the telegraphic alphabet.

Another form of autocoherer, or detector, is that devised by Marconi, based upon the principle that electrical oscillations affect the magnetic changes in iron, enabling them to occur more rapidly. An endless belt of thin wire about 12 inches long revolves on a pulley operated by clockwork, and passes through a spool on which are wound two coils of fine wire. The outer wrapping or coil is part of a circuit in which is included a telephone receiver, while the inner coil of wire is connected in series with the vertical wire tower or antennae. Two horseshoe magnets having their like poles adjacent to each other are placed in proximity to these coils, and while normally the changes of the magnetism in the traveling wire in proximity to the magnets are not sufficiently rapid to set up currents in the coil, the conditions are different when rapid electrical oscillations occur in the inner coil, these being accompanied by correspondingly rapid momentary changes in the magnets of the traveling core or wrapping of thin wire. The consequently rapid variation of the magnetic lines, or field of force, in the traveling wire set up momentary currents that are detected or heard as sound in the telephone receiver. It appears that a speed of 25 or 30 words a minute can be obtained in practice with the detector, thus doubling the rapidity obtainable with the filings coherer.

Another form of receiving apparatus is the Fessenden detector, which consists of a small insulating vessel, wherein is placed a weak solution of nitric acid. Down into this solution penetrates for a short distance a very fine platinum wire, and another platinum wire enters the acid from the bottom of the vessel. This device, or detector, which is called a liquid barretter, is connected for receiving between the vertical wires, or antennae, and the ground. The principle embodied is that all the resistance in the conducting medium is concentrated within a short distance of the point where the fine platinum wire enters the acid. Hence all the temperature effects are local or take place inside a hemisphere of comparatively small radius. The heating effect of the small battery in the shunt circuit normally increases the resistance of that circuit, but the resistance is broken down by the incoming electrical oscillations, and the variations of the current strength due thereto are recognized, in the telephone receiver employed, as dots and dashes. According to Mr. Fessenden, the action of this detector is not electrolytic, but thermic. Apparatus of a similar character for wave detection has been employed in the De Forest system, the detector being a very fine wire extending into the liquid contained in a small cup, with another wire running through the base of the cup. The liquid in the cup is a slightly acidulated solution. The principle, according to Doctor De Forest, being that the action is electrolytic, the current from the small battery sets up a further electromotive force of polarization which the arriving oscillations disturb, thus securing the desired audible result in the telephone receiver.

A more recent and highly ingenious form of apparatus of De Forest invention is that known as the "audion." This receiver for wireless telegraphy consists of a low voltage incandescent lamp with carbon filament, connected to a source of current consisting of a battery of dry cells and a rheostat for varying the current at will. Within the bulb of the lamp are placed two platinum wings, one on each side of the filament. A second set of dry cells is connected between the positive end of the filament and the platinum, the latter being connected to the positive pole of the battery. When electrification is produced in the neighborhood of the incandescent filament, a positive leakage discharge current will pass from the platinum wings through the attenuated gas in the bulb to the filament, and the conductivity of the gas between the wings and the filament increases rapidly with the increase of the heating current through the filament. When the audion is connected, either inductively or conductively, in an oscillation circuit of a wireless telegraph receiver, it forms an extremely sensitive detector of ether or Hertzian waves, giving responses or indications in the telephone receiver several times louder than any other known form of wireless receiver subject to the same impulses. It is stated that the device is extremely selective in its behavior with reference to waves of different lengths, and can be closely tuned with the syntonizer. By regulating the heating current—the potential between the wings and the filament, or the distance between these—the audion is made to a great extent selective for itself to the received impulses. It gives no evidence of fatigue under any conditions of use, requiring no adjustment in the receiver, and needing no protection from the violent impulses of the transmitter at its own station, as compared with the sensitiveness of the receivers of the electrolytic type, which are said to be completely upset by one such violent impulse unless protected by a shunting switch.

As will be noticed from Table 15, a large proportion of telegraphic apparatus in 1905—in fact, one-half, $592,070—is comprised under the head of "police, fire district, and miscellaneous." The miscellaneous telegraphs in this group are not numerous, but the other three classes are important and are in constant demand. During recent years there has not been much change in any of them, except in the association with the older forms of telephony, which is under trial in various cities for fire and police purposes. The district messenger box is still to be found in most large modern buildings, but no essential change has been made in its mechanism or in the variety of the calls that may be effected through it. Here again the telephone has had some influence, and in more than one modern form of district messenger box an attempt has been made to add the telephone to the apparatus as a means of increasing its efficiency. The general subject of municipal telegraphs, including fire and police systems, will be found treated in great detail in the special report issued by the Bureau of the Census, entitled "Telephones and Telegraphs: 1902."

Insulated wires and cables.—Table 16 gives the value of insulated wires and cables manufactured as reported in 1900 and 1905.

TABLE 16.—*Insulated wires and cables—value: 1905 and 1900.*

STATE.	Value.
United States, 1905	$34,519,699
1900	21,292,001
States, 1905:	
Connecticut	2,156,369
Illinois	3,666,313
Massachusetts	1,001,522
New Jersey	8,234,885
New York	10,911,897
Pennsylvania	2,885,052
Rhode Island	5,122,464
All other states [1]	541,197

[1] Includes states as follows: California, Indiana, New Hampshire, Ohio, Oregon, and Wisconsin.

A total value of $34,519,699 was returned for the production of insulated wires and cables by 61 factories during the census year 1905. The industry was well distributed throughout the country, being carried on in 13 different states. The chief center of the industry is New York, which, with 12 factories, reported an output valued at $10,911,897; New Jersey follows, with 7 factories and an output valued at $8,234,885; and Rhode Island is third with an output valued at $5,122,464. As will be noted these 3 Eastern states accounted for considerably more than half of the total output, and if the product of Connecticut, $2,156,369, be added, it will be seen that these 4 Eastern states accounted for more than five-sevenths of the whole output of the country. The two other states conspicuous in this line of work were Illinois and Pennsylvania, the former with an output of $3,666,313, and the latter with an output of $2,885,052. The entire production of the country is reported by value only, the sizes of wire being so numerous and the complexities of their manufacture into cables being so intricate that no definite figures could possibly be secured as to the length in feet or the quantity in pounds. Every branch of electrical industry requires large amounts of insulated wires and cables. Every telegraph office and telephone exchange employs large quantities of such wires and cables. Every house or factory or office building wired for electric lighting and power receives and distributes its current through insulated conductors. Every motor car is heavily cabled, while every dynamo and motor is built up with insulated wires and cables. Some idea of the consumption of this class of material in one field alone may be formed from the fact that at the close of the year 1905 the companies constituting the Bell telephone system had in use not less than 320,000,000 pounds of copper wire, which would represent a value of copper alone of about $60,000,000. This copper is largely made up into cables of a permanent type, carried upon no fewer than 8,000,000 poles, and through 95,000,000 duct feet of underground conduit. An equally impressive idea of the consumption of cable is afforded by the fact that the electric zone of the New York Central and Hudson River Railroad has in its transmission circuits 1,500,000 pounds of copper in cables, and for the transmission and subsequent distribution from the substations a total weight of 3,000,000 pounds of cable, a large proportion of which is heavily insulated. In this electric zone there are 16 miles of cable conduit, 97 miles of cable in the conduits, 344 miles of cable upon poles, 3 cable towers, and 383 splicing chambers, where the short lengths of cable are united and made continuous throughout the system. Another striking fact is that a single telephone switchboard of the large modern type contains as much as 10,000 miles of insulated wire.

Underground cables in the field of electric lighting and power work are manufactured in three main classes: High tension, multiple, or single conductor cables of relatively small current carrying capacity, for operation under working pressures of from 2,500 to 25,000 volts; low tension single conductor cables of large current carrying capacity, operating under electric motive force of about 650 volts or less; and return cables of large current carrying capacity, but operating only under a pressure corresponding to the voltage "drop" in the return feeders. The third class has hitherto received little attention, and, in fact, bare copper cable has generally been installed, but the desirability of the use of insulated cables of this class has been approved and recognized in the last few years. High tension cables of the first class have developed from the stage where merely rubber was used for insulation up to the time of the present report, when rubber, varnished cambric, saturated tape, and paper insulation have all been brought to a high state of perfection for this work. Rubber is used only where local conditions seem to demand an insulation that is impervious to moisture, so that in case the outer protected lead sheath should be punctured the cable itself need not necessarily fail. The superintendent of motive power of the Interborough Rapid Transit Company, of New York city, points out that where cables have to be installed in conduits that are under water part of the time or on the beds of rivers, etc., the extra investment for the more costly rubber insulation is justified, since in case of a leak in a submarine or submerged cable lead sheath it usually becomes a total loss if insulated with paper or nonmoisture proof material, whereas good rubber lasts indefinitely under water. For pressures above 22,000 volts some form of varnished cambric or impregnated cloth is preferred in place of paper, owing to its higher resistance to puncture for a given thickness. Conservative practice in cable manufacture with paper insulation for standard working pressure of 3,000 volts requires on a cable ranging from No. 000 to 300,000 circular mils a paper insulation thickness of $\frac{9}{32}$ inch, with $\frac{7}{64}$ inch thickness of lead in a single conductor cable up to $\frac{9}{64}$ inch in a three-conductor cable. In heavier cables with paper insulation, as, for example, 1,250,000 to 2,000,000 circular mils, with the same working pressure of 3,000 volts, good practice requires an insulation of paper of $\frac{8}{32}$ inch, with $\frac{9}{64}$ inch thickness of lead in the outer sheath.

As already noted, a very large amount of insulated cable manufactured is employed in telephonic work. The conductors in most telephone cables are Nos. 19, 20, or 22 B. & S. gauge copper wire. The single wires are first insulated with paper wrapped spirally on the wire, providing in good insulations four thicknesses of paper between the wire and the outside of the insulation. It is so arranged that in doing this work one of each pair of wires receives two wrappings of gray paper, or two wrappings of red paper, or some other contrasting color, so that when the wires are twisted together into pairs each has its distinctive color. It can be readily understood that this means of identification facilitates the work when the cable is put into use. After the wires have been twisted in pairs they are laid up in a coring machine consisting of a series of drums and spindles, revolved in such a manner that at the end of the operation a cable core has been built up which has its alternate layers of wire put together in the same direction and the intermediate layers put on in the opposite direction, the object being to secure a noninductive core. After this core has been made, it is given a wrapping of heavy manila paper and is then dried very carefully in ovens, in order to secure high insulation and low electrostatic capacity in the finished cables. The next process is that of encasing the core in a lead sheath. Melted lead is put into lead presses, allowed to cool, and subjected to enormous pressure. It assumes a plastic state and is squeezed out around the cable core, where it assumes a solid state and forms a continuous unbroken sheath upon the cable. The lengths of cable are then tested and are ready for shipment on drums to the point of use. The great advantage of paper insulated cable is that its low electrostatic capacity makes it much less expensive than other types. The rubber cable requires three times as much copper conductor as the paper cable, hence as the capacity increases with larger conductors the rubber insulation becomes more expensive than paper, on the basis that rubber cable has about three times the electrostatic capacity of paper cable. The object of making the telephone cables in twisted pairs is to avoid cross-talk induction, and the length of the twist varies from 3 to 6 inches.

Several years ago a type of telephone cable embodying most of the essential requirements mentioned above was developed for the American Bell Telephone system. This "conference specification" was as follows:

Sizes.—Number of pairs, 25, 30, 50, 60, 100, 120.

Conductors.—Copper 19 B. & S. gauge, conductivity 98 per cent of pure copper.

Insulation.—Dry paper.

Conductor arrangement.—Twisted pairs, length of twist not over 3 inches.

Core.—Laid up in successive reversed layers, with a lay of at least one turn in 2 feet.

Seal.—The end of each length sealed with insulating material for at least 2 feet.

Sheath.—The cores to be inclosed in a lead pipe $\frac{1}{8}$ inch thick, having at least 2.9 per cent of tin.

Electrostatic capacity.—Shall not average more than 0.080 microfarads per mil.

Insulation.—One hundred megohms per mil.

Guarantee.—Capacity shall not increase, nor insulation decrease, for five years.

There have been some modifications suggested by experience during the past few years; but the chief one, perhaps, is that which has carried the sizes of cable from 120 pairs up to 200 and even 400 pairs, the economy of the larger cable being considerable. A further modification in telephone cable is due to Dr. M. I. Pupin, who has introduced a method of locating inductance coils in telephone cables in such a manner as to assist the voice currents and prevent the deformation of the waves upon which accurate transmission depends. If the electrical waves have a length of 15 miles, and these balancing inductance coils are placed at such a distance, the current will be assisted by them in its travel and the waves will retain their proper shape, enabling the receiver to give forth the transmitted speech or sound with a minimum loss of volume or quality. Pupin cables have already come into extensive use and, it is understood, have been installed for service between such points as New York and Philadelphia, enabling the circuits to be placed underground the entire distance.

While reference has been made above to india rubber as a substance that may be said to come in physical competition with paper in the manufacture of insulated wires and cables, it should be added that gutta-percha also is in use to a considerable extent as a gum of the highest insulating quality and as one which is suitable for such work virtually without any preparation beyond that which is necessary in purifying it from foreign materials. Gutta-percha has long been regarded as the standard insulation for submarine cables, but, as until recent years very little submarine cable was manufactured in this country, gutta-percha cable was not regarded as a typical American electrical product. Within the last decade, and particularly within the last five years, these conditions have changed. As late as the time of the Spanish-American War a deep-sea cable had never been manufactured in the United States, prominent as was the association of this country with the very first cable enterprises to span the Atlantic ocean. Through the insistence of Gen. A. W. Greely, Chief Signal Officer, U. S. A., and his faith in the ability of American manufacturers, the first cable was made and laid for war purposes by Col. James Allen of the United States Signal Corps, at Guantanamo, Cuba. Over this cable all the war news was flashed directly to Washington from the seat of operations, and the final victory at Santiago was reported to the White House within an hour of its occurrence.

Another important enterprise and development in this direction occurred a few years later, when in 1902–3 an American company manufactured and laid for the Mexican Government 500 miles of rubber submarine cable in the Gulf of Mexico. This cable is 500 miles long, weighing 1,300 tons, with a deep-sea diameter of 1 inch and a shore-end diameter of twice that size. This cable after manufacture was loaded in four tanks in the cable ship and was laid successfully, since which time it has been in continuous service.

The most extensive and interesting achievement of American manufacturers in this field associated with the United States Signal Corps has been the creation of a new system of over 2,000 miles of American-made cable for the Philippine Islands. This system places Manila in immediate communication with the most distant islands of the archipelago and renders feasible the swift administration of civil and military affairs from the seat of government. A corresponding system of equal magnitude laid with seamless rubber cable of American manufacture is that which has been created by the United States Signal Corps in Alaska, where the network in 1904 included 2,079 miles of cable.

Conduits.—Table 17 shows the value of electric conduits reported in 1900 and 1905.

TABLE 17.—*Electric conduits—value: 1905 and 1900.*

	Total (value).	Interior (value).	Underground (value).
United States, 1905	$2,416,245	[1] $2,153,069	[2] $263,176
1900	1,066,163	(3)	(3)

[1] Includes states as follows: Connecticut, Massachusetts, New Hampshire, New Jersey, New York, and Pennsylvania.
[2] Includes states as follows: California, Connecticut, Indiana, and New York.
[3] Not reported separately.

Unless wires are carried overhead upon poles in the form of single conductors or cables, they are now almost invariably installed in conduits underground, or in interior conduits if used within the buildings. The present report gives a total of $2,416,245 for both classes of electrical conduit, divided into two quite unequal portions, namely, $2,153,069 for the interior class of work and $263,176 for underground conduits. No division was made of this product into the two classes in the census of 1900, when the total reported was $1,066,163. On the other hand, no attempt has been made this time to secure any record as to the mileage of duct feet or of the straight conduit. In the census of 1900 only about half the amount reported was accompanied by statistics from establishments able to report quantities, and the data proved so inconclusive as to render it inadvisable to make a further attempt to determine quantities; although this data would be relatively easy to obtain in connection with interior conduits, as compared with those for underground work, the latter being often of a multiple character. Hence a linear foot of conduit may comprise anywhere from 2 or 4 to 12 or 20, or even more, feet of duct.

In 1905 the production of interior conduit was reported from 10 establishments and of underground from 5, located in 8 states. The statistics in detail by states can not be shown separately without disclosing individual operations. The chief centers of conduit production were, in the order named, Pennsylvania, New Jersey, New York, and Massachusetts, these 4 states producing $2,298,090 of the $2,416,245 for the entire country. The product elsewhere throughout the country was negligible. So far as underground conduit is concerned, it is not to be understood that this embraces all the conduit employed during the year in this class of electrical construction, as material is often used or is made up on the spot which does not come into any regular manufacturing category.

Reference has been made to the statistics of terra cotta and fire clay conduits and electric porcelain supplies, included as part of the industries of that character and reported separately. These are not included in the figures of Table 17 in any manner. As already intimated, however, the total for interior conduits may be taken as representing the full factory value of the product, as "interior" conduit, so called, is made specifically for such use. At the same time it is not unusual to employ an unlined or uninsulated bare iron pipe of merchant size for some classes of interior work, and this pipe, not being made exclusively for interior electrical purposes, is of course not regarded as coming within that branch of manufacture. The rules of the national electrical code provide that such unlined pipe can be used for wires and cables having a heavy braid on the outer covering. Pipe of this character, as will be readily understood, can also be safely employed for runs of telegraph and telephone or annunciator circuit not exposed to any danger of cross connection or short circuit with other wires carrying heavier currents for light and power.

The interior conduit included in the present statistics consists generally of two classes—insulated metal, such as iron and steel pipe, which has a coat of some enameling and insulating substance, and conduits woven of textile fabrics and impregnated with insulating compounds. In insulated metal conduits the enamel or protective lining is firmly attached to the pipe so as to form an integral part of the surface, and does not break or crack when a length, at a temperature of 212° F., is uniformly bent to an angle of 90° with a curve radius of 15 inches in pipe of 1 inch or less and a radius of fifteen times the diameter of the pipe for larger sizes. This insulated lining is at least $\frac{1}{32}$ inch in thickness, does not soften so as to flow at temperatures below 212°, and is sufficiently resisting to other tests to make it thoroughly satisfactory for protective insulation in the walls of buildings or for placing in elevator shafts and other exposed places. A great deal of ingenuity has also been devoted to the subject of conduits of textile fabrics, and these without protection, or with a metallic sheath, constitute a very large proportion of the interior work now done in the United States. It is now the practice to install the entire conduit system of a new building in advance of wiring, as the building itself progresses, and it is virtually completed before a single wire or cable is drawn in, the ends of the conduit runs being brought out at each floor or room so as to connect with the junction boxes, panel switchboards, and the service wires to the consumption devices, such as lamps, motors, heaters, etc. Some of the wiring is still done in wooden or metal moldings, but this of course is no part of the conduit system, which is now regarded as essentially an integral part of a new building, as the water or gas pipes.

Annunciators and clocks.—Table 18 gives the number and value of annunciators for 1900 and 1905.

TABLE 18.—*Annunciators—number and value: 1905 and 1900.*

STATE.	Number.	Value.
United States, 1905	93,140	$185,870
1900	57,022	[1] 224,885
States, 1905:		
New York	22,019	61,959
Pennsylvania	22,220	40,824
All other states [2]	48,901	83,087

[1] Includes annunciators to the value of $25,320, for which number was not reported.

[2] Includes states as follows: California, Connecticut, Georgia, Illinois, Massachusetts, Michigan, Nebraska, New Jersey, Ohio, Oregon, and Texas.

The value of electric annunciators reported during the census year 1905 was $185,870, as compared with $224,885 five years earlier. As in so many other departments of electrical manufacture, the decrease of value is due rather to simplification and cheapening of the processes of manufacture than to a falling off in the demand. During the year no fewer than 93,140 annunciators were made. A very large number of the small annunciators were made for installation in modern dwellings, few houses of any pretensions being considered complete without an annunciator system connecting the sleeping apartments, servants' quarters, sitting rooms, dining room, etc. The bulk of the apparatus was produced in 5 states, in the order named—New York, Pennsylvania, Michigan, Illinois, and Massachusetts. The value in these 5 states aggregated $173,085, or 93.1 per cent of the total for the United States.

The principal development in this department has been in the substitution of lamp signal annunciators for the earlier needle type. In the new lamp annunciator, instead of needles or drops operated by magnets, the indications are furnished by small telephone switchboard incandescent lamps, which are connected to the various push buttons located at the point of call. In series with these lamps and buttons are lamp relays that are energized when the push button is pressed, and that keep the lamp illuminated until the call has been answered and the lamp has been cut off by means of a short-circuiting button or a number of buttons on the annunciator. Some of these new annunciators have a button to short-circuit the relays in this manner at the bottom of every column of lamps, and the arrangement gives satisfactory results. In connection with this system there is furnished on each annunciator either a single stroke bell or a buzzer, so that when the bell is used and the push button is actuated by the person making the call, one stroke is given on the bell, while when the buzzer is used the indication is given for just the length of time that the push button at the point of call remains in circuit under momentary pressure of the finger. These annunciators have the advantage of taking up less space than the needle type, and, as they are connected into the electric lighting system of the building, they avoid the necessity of a separate equipment of batteries for their operation.

A typical installation of this character is that which was furnished to a hotel in New York city. In each room is installed a special push button having a relay adjustment just behind it, so that when the button is pushed it is locked in by the relay and a lamp on the annunciator board is lighted at the same time that a single-stroke bell is operated. This button is kept locked until the lamp circuit is broken, whereupon it is released, making a slight click, notifying the guest that his call is receiving attention. Another feature of annunciator construction is that the lamps themselves are mounted in brass cylinders which are movable, the motion being controlled by a spring. These are used to break the circuit, so that by pushing on the glass bull's-eye in front of the lamp the light is extinguished. There are two such annunciators on each floor, one being placed in the service room for service calls and the other in the hall or corridor for the maids' calls.

At another hotel in New York city an annunciator of the lamp type has been installed with 450 indicating lamps. The resetting mechanism to this annunciator is in the form of a button at the foot of each vertical column. This has given very satisfactory service in rapidly clearing out indications that have been noted and in lessening the cost of the individual resetting type, while eliminating the locking button in the guest's room. A further refinement of the system is that which furnishes means for ascertaining the room in which the chambermaid is temporarily engaged, and consists, in brief, of an electric lamp bulb which is carried about by the maid and is inserted by her into a socket as she enters the room, these sockets being provided along the corridor, one near every door. The insertion of the bulb into the socket lights it up and at the same time closes the circuit on a corresponding lamp on the annunciator in the main offices. Thus the location of the maid is indicated at each instant and at each room, both in the office and along the corridor, the process being repeated as the lamp is removed from the socket at one door and inserted at the next.

Table 19 shows the number and value of electric clocks and time mechanisms returned at the censuses of 1900 and 1905.

TABLE 19.—*Electric clocks and time mechanisms—number and value: 1905 and 1900.*

STATE.	Number.	Value.
United States, 1905	33,145	$373,926
1900	9,180	[1]132,149
States, 1905:		
Illinois	14,195	89,222
Massachusetts	1,799	91,875
All other states[2]	17,151	192,829

[1] Includes clocks and time mechanisms to the value of $110, for which number was not reported.
[2] Includes states as follows: Colorado, Connecticut, Maryland, Missouri, Nebraska, New Jersey, New York, Ohio, and Pennsylvania.

The output of electric clocks and time mechanisms at the time of the census of 1905 was reported as having a value of $373,926, as compared with $132,149 in 1900. There was not only this marked increase in value but there was a corresponding increase in the number of pieces, 9,180 being reported in the earlier year and 33,145 in 1905. The production of this apparatus was carried on chiefly in the states of New York, Massachusetts, Illinois, and Connecticut, in the order named, these states producing 82.2 per cent of the total value for all states. There was also a fairly large output in Pennsylvania, Ohio, and Missouri.

The distribution of time by means of electric clocks is a relatively small industry without a widespread demand; but during recent years there has grown up a market for time mechanisms whose object it is to control the use of electric light and power. It may be desired, for example, to have electric lamps within a store burning for a period after the store has closed; or to keep the arc lamps burning outside a store or place of amusement up to a certain hour. For these and kindred purposes the time mechanism is inserted into the circuit and disconnects the lamps, motors, or consumption devices at the predetermined hour. In this manner the services of a lamp trimmer or attendant are dispensed with and the actual time of the use is known. There are several devices of this character. In a recent one, which may be taken as typical, the time switch has for its opening and closing devices a powerful spring-driven mechanism which tends at all times to revolve a disk carrying a crank which operates a loosely jointed connecting rod. This rod serves to open or close the switch with a snap-break movement. The motion of the driving disk is arrested by means of a spring-controlled lever, which is removed from contact with a lug on the disk by means of a hammer blow imparted by springs. The device is provided with two hammers, one for opening and one for closing the switch. The movement of each of these hammers is governed by disks driven at the rate of one revolution during each twenty-four hours. Each disk carries a pin so placed as to raise a steel pin on the corresponding hammer, thus allowing or causing the hammer to strike with a quick snap movement at the set hour for which the disk is adjusted. The two disks are independently adjustable, so that the switch can be set to open and to close at any time desired. This time mechanism is inclosed complete in an iron case ready for installation. It will be understood that there are various other time mechanisms of the same general character for registering the hour, such as watchmen's clocks, and the conveyance of information to a central point as to the increase or lessening of heat and pressure or the height of liquids in receptacles at certain hours.

Rheostats and resistances.—Table 20 shows the number and value of rheostats and resistances for 1905.

TABLE 20.—*Rheostats and resistances—number and value: 1905.*

STATE.	Number.	Value.
United States	75,695	$932,925
California	257	3,956
New York	21,205	230,015
All other states[1]	54,233	698,954

[1] Includes states as follows: Colorado, Connecticut, Illinois, Indiana, Iowa, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, Ohio, Pennsylvania, West Virginia, and Wisconsin.

In the Census report of 1900 all the kindred apparatus in the group of rheostats and resistances, electric heating and cooking apparatus, electric welding appliances, etc., was massed together, and a total value of $1,186,878 was reported. In the present report it was felt that the increase in the production and use of apparatus for heating, cooking, and welding warranted an effort to separate that class from ordinary rheostats and resistances, and the result is that these data are now presented apart. The returns show a total for the United States of $932,925 as the value of 75,695 pieces of rheostats and resistances which were produced in 39 establishments. By far the largest proportion of this apparatus was produced in the state of Wisconsin, with New York in the second rank; these 2 states accounting in value for more than three-quarters of the total product. This apparatus is a necessary adjunct to the use of heavy current for lighting and power purposes, and large numbers are particularly called for in connection with the starting and regulation of electric motors, electric elevators, etc. Many of the smaller enameled resistances, however, have been introduced for use in connection with the most delicate electrical instruments and are now manufactured for employment as balance coils in telegraph service, and as shunting and ringing resistances in telephone circuits and relay signals. They are also to be found in use as resistances for locomotive electric headlights, for the control of phonographs, for small dental furnaces, etc.

The general principle adopted in the manufacture of all such apparatus is the embedding of fine wire offering high resistance to the passage of the current, in such insulating material as will also serve to take up and dissipate quickly the generated heat due to the interception of the flow of current by the high resistance wire. An idea of the difficulties encountered in such work is afforded by the requirement of the United States Navy Department that starting resistances, for use on shipboard, must be capable when called on of carrying 50 per cent overload of current for one minute and 100 per cent overload for twenty seconds. All resistances and all insulation used on them and their connecting wires must be noncombustible, and all connecting wires must be capable of carrying full-load current continuously without becoming dangerously hot. The method of mounting and insulating the resistances has to be such that the result of a burn-out would be practically the same in negligible effect as would occur with an entirely inclosed resistance. In general, the evil effect of heating must be minimized, both as regards the apparatus protected and in respect to any danger of conflagration from the concentration of so much heat at a given point. An extensive use of rheostats and resistances is made in connection with storage battery equipments for general purposes and more recently in connection with public garages, or plants for automobile charging.

Quite a distinct class of apparatus in this line is that employed on lighting circuits, especially those in theaters, where the increase or decrease in the volume of light, changes in colors, and many other effects are obtained by the use of "dimmer" resistances, which interrupt momentarily and partially the flow of current from the dynamos to the lamps or other illuminating devices. Very few theaters of any pretensions can now be found in the United States without electric lighting, and wherever this is installed "dimmers" will also be found in operation. Some idea of the extent to which they are employed may be formed from the fact that a theater in Chicago has a dimmer bank of 20 plates, with a total capacity sufficient for 810 lamps. A theater in Boston has 66 plates, with a total capacity sufficient for 2,670 lamps; one in New York has no fewer than 124 dimmers; and another, a dimmer board of 50 plates, with a total capacity sufficient for 2,400 lamps. One of the most interesting and capacious theater dimmers was that installed during the census year at Oakland, Cal., said to be the most compact apparatus of its kind, having a capacity sufficient to handle 3,000 lamps, that is, 36 dimmers, each caring for from 75 to 90 lamps, and taking up a space of only 5 feet 9 inches in width by 6 feet in height, and 18 inches in depth. This dimmer is worked independent of any switchboard and is made with as many as 60 to 250 steps, all parts being brought within reach of the hand and all wires and connections being within sight of the operator. Moreover, being mounted upon rollers, it can be moved around to any part of the stage by one man. The usual construction of theater dimmers, as indeed of resistances and rheostats in general, is to build them up in circular plate form, the wire of metallic alloy, which does not rust or fluctuate in its resistance, being embedded in the insulating material within the iron shell of the plate. When used with stationary electric motors, such resistances are placed on the side of the motor or machine or its base, or at some adjacent point, stands and boxes being manufactured for such purposes. In theater dimmers the resistances are usually mounted edgewise in banks, standing up somewhat as dishes on a dresser. The contact fingers move over the face of the plates or disks so as to cut in or out more or less of the resistance. A certain space is allowed between the disks for effective cooling, affording facilities also for insertion or removal of any single plate. These mechanisms are made to work singly or to operate with interlocking gears.

In some forms of apparatus for power purposes the starting and regulating rheostats for the motor are associated in one piece of apparatus. Such apparatus consists typically of a motor starter with a series of field buttons, controlled by a field resistance lever mounted on the same hub post as the starter lever and cooperating therewith. The motor is started and brought up to speed by moving the starter handle, which is also attached to the field regulator. They thus move as one piece, and during the operation of starting the field resistance is short-circuited by an auxiliary contact mounted on the starter lever and by a curved sector located just below the armature contacts. When the two levers have been moved to the position in which all resistance is cut out of the armature circuits, a magnetic keeper on the starter lever is attracted by the retaining magnet and the lever is thus held in position. At this moment the auxiliary contact has left the curved sector, thus throwing the short-circuit off the field resistance. The field lever is now free to move over the field rheostat buttons on the face of the plate or disk, at the will of the operator, and can be left at any determined point, thus regulating the speed of the motor as desired. If the retaining magnet is deenergized, either by failure of voltage or by the operation of the overload—release devices which protect the apparatus and motor—the starter lever is released and returns to the original starting position, carrying with it the field rheostat lever. This compact and handy type of apparatus is used where it can be placed within reach of the machine attendant, and is usually mounted on the machine tool, whose driving motor it is intended to control. A further development of the disk rheostats has been their connection, on dynamo switchboards and dynamo testing boards, with a plunger or guide brought out to the front of the board so as to operate one or more of the plates and dispense with the former arrangement employing concentric shafts or gear wheels.

Heating apparatus.—Table 21 shows the number and value of electric heating, cooking, and welding apparatus reported in 1905.

TABLE 21.—*Electric heating, cooking, and welding apparatus—number and value: 1905.*

STATE.	Number.	Value.
United States	57,336	$395,827
Michigan	14,630	76,402
New York	5,043	160,960
All other states [1]	37,663	158,465

[1] Includes states as follows: California, Illinois, Maryland, Massachusetts, and Pennsylvania.

The production of apparatus in the United States for electric heating, cooking, and welding bids fair to become one of the largest departments in this field of industry. For while the present output is relatively small, the ramifications of the electric heating art are most numerous, and nearly every week sees a new application that had not previously been attempted or expected. According to the figures of the present census, no fewer than 15 establishments were engaged in the manufacture of these appliances, of which 57,336 were reported as having a total value of $395,827. This apparatus was produced almost entirely in 3 states, New York leading, followed closely by Massachusetts, while Michigan produced about half as much as either of them. Very few pieces of this apparatus were made elsewhere. The increased use of electric stoves, chafing dishes, grills, etc., flatirons and curling irons, soldering, sealing, and branding devices is largely due to the growing appreciation on the part of central station companies of the opportunities thus afforded them for the sale of energy in the daytime when the load upon the generating plant is lighter than at night. An idea of the extent to which such a development is going on is afforded by the fact that the report of the special committee on electric heating of the National Electric Light Association at Denver, in 1905, showed that out of 480 central station companies to which inquiries were addressed no fewer than 112 reported heating and cooking apparatus installed on their circuits. With average prices of electricity applied to apparatus here enumerated, it would appear that a small one-hole electric cooking stove, costing about $4, can be operated for half an hour for 4 cents. An electric flatiron heater costs 2 cents to operate for fifteen minutes. A water heater costs 5 cents an hour; an electric waffle iron, 5 cents for half an hour; a curling iron for the hair, $\frac{6}{10}$ cent for half an hour. This scale of cost does not compare favorably with gas or coal ranges on a basis of steady use; but the great advantages are that the electric current is immediately available, has peculiar advantages in the summer time, and is particularly applicable in places where fuel devices can not be permitted. Of late there has been a marked tendency in large hotels and in clubs toward the introduction of electric grills in the café or restaurant, where the heat given out by an open grill is objectionable, and where a large number of chops, steaks, and other viands are required simultaneously and with expedition. One of the largest of such appliances is capable of cooking over a hundred chops and steaks at the same time, each in its individual compartment. The piece to be cooked is inserted between the walls of a small compartment lined with electric resistances, which, being brought rapidly to a white heat, cook expeditiously and economically while preserving the juices and subjecting every part to the same temperature. The whole apparatus takes far less space than an open grill and is so inclosed that the heat is confined to do its work without radiating freely to the outer atmosphere; and to the casual eye the apparatus has rather the aspect of a refrigerator or a bank of letter boxes than a huge stove.

An effective illustration of the range of such apparatus in variety and utility is afforded by many an American home, and one may be instanced. All the apparatus thus employed is in regular manufacture, so that, provided electric energy is available, it can be installed anywhere. For example, the living room has an electric radiator for medium warming purposes and an electric cigar lighter placed on the chimney mantel. A spacious veranda around the entire front of the house inclosed by glass is also heated when desired by a luminous electric radiator. In the sewing room is an electric pressing iron. In one of the sleeping rooms are an electric radiator and electric heating pads, which can be slipped between the bedclothes or placed upon the body, and an electric flatiron. The bathroom is fitted up with a small luminous radiator for warmth and a water heater for shaving. The laundry is equipped with electric flatirons, wash boilers, and emergency boiler heater. In a number of rooms the branch lighting circuits are tapped for the insertion of a wall receptacle, to which many of these devices can be temporarily attached, so that their use is not limited to any particular room or part of the house. In the kitchen no coal or gas is used, but everything is cooked by electricity. The cooking and baking outfit, which has been in use for over two years, consists of an electric oven, a cereal cooker, frying pans, vegetable boilers, small disk stoves, gridirons, and meat broilers. This outfit has been operated since its introduction, and for two consecutive Christmas dinners the electric oven has been employed with highly satisfactory results, including the cooking of a 14-pound turkey. The electric gridiron is 9 by 12 inches and is hot enough to fry cakes in two minutes. The cereal cooker is a combination device. In getting breakfast ready it is first used in heating water for the coffee and it is then used as a cereal cooker, and when the cereal is ready the interior dish is removed and eggs are boiled or steamed, using the boiling water then available. Later on potatoes are steamed, either for breakfast or for later meals. The frying pan and vegetable boiler are used frequently, particularly the pan, which is well heated in about a minute and is used principally in preparing bacon and eggs. For the washing of the dishes and utensils, particularly during the summer months, all the water is obtained by means of the emergency boiler heater, there being a receptacle near the sink for this purpose, and almost a momentary use of the current furnishes water adequate to the cleansing out of all the cooking utensils. The question naturally arises as to the cost involved in utilizing apparatus of this character, and it may be noted that twenty-four consecutive monthly bills for electricity during the two years show that the amounts range generally from $3.40 to $9.90, the average being $6.62 per month. This, however, includes the energy consumed for lighting; the bills for illumination previously being about $35 per year. Upon the installation of the heating and cooking apparatus, being largely a day load, the local public service corporation made a special rate of 5 cents per kilowatt hour. The price of apparatus may be arrived at from the statement that for a small family it would cost about $30 and for a large family about $60 for the special equipment, this comparing favorably with large size ranges or combination coal and gas stoves.

Perhaps the best exemplification of electric heating for industrial work is afforded by the equipment of the Government Printing Office in Washington. This office was equipped in 1904 with the largest electric heating system of the kind applied to such work, since when other devices have been added. The use of electric heat in the Office falls broadly into two groups or classes, one of these embracing and including matrix drying tables, wax stamping table, wax-melting kettles, case-warming cabinets, tool heaters, "sweating-on" machines, wax knives, and soldering-iron heaters. The other class, in the binding room, includes embossing and stamping heads, glue-heater equipments, glue-cooking pots, shaping machines for book covers, fitters, tool heaters, pamphlet-covering machines, sealing-wax molders, and other devices. The equipment of these electric heating appliances in the Office supplants steam and gas in all processes, except the stereotype melting pots, which are heated by gas.

The statistics of electric-welding apparatus are included in this section, but are not brought to account separately. Apparatus of this kind is in general use in the United States, and more particularly in connection with the welding of lengths of wire and cable in insulated wire factories and in bicycle and automobile shops. During the past ten years the employment of a number of complex metal parts in the construction of bicycles, and more lately of automobiles, has opened up a new field for the use of electric-welding apparatus. At the time of the Report on Electrical Manufactures in 1900 the rims of the steel supports for the rubber tires were the only parts then treated by this process. Since that time the extension of the art has made the application of electric welding embrace a much wider range, and it is stated that an ordinary automobile may now have as many as from four to twenty different parts that have been united in electric-welding apparatus. The process employed is usually that of bringing the two abutting pieces of the metal to a melting temperature secured by passing a definite and heavy current through them for a short period when pressed together, and thus closing the circuit. This welding is as effective, economical, and durable as can be secured in any other way, with a restriction of the heat required to the exact point of juncture. This method is still employed, or has been until a quite recent date, in the welding of street-car rails in situ, and elaborate sets of apparatus mounted in cars have been devised for such purposes.

Fuses and lightning arresters.—Table 22 presents statistics concerning fuses and lightning arresters reported in 1900 and 1905.

TABLE 22.—*Fuses and lightning arresters—number and value: 1905 and 1900.*

STATE.	Total value.	FUSES.		LIGHTNING ARRESTERS.	
		Number.	Value.	Number.	Value.
United States, 1905	$1,455,203	21,675,765	$868,079	1,324,523	$587,124
1900	595,497	(1)	(1)	(1)	(1)
States, 1905:					
Illinois	207,539	2,098,183	38,230	470,601	169,309
Massachusetts	119,071	1,682,832	119,071	(2)	(2)
New Jersey	236,939	11,960,685	236,939	(2)	(2)
New York	62,550	1,487,500	62,550	(2)	(2)
All other states	829,104	[3] 4,446,565	[3] 411,289	[4] 853,922	[4] 417,815

[1] Not reported separately.
[2] Included in "all other states."
[3] Includes states as follows: California, Connecticut, Georgia, Indiana, Missouri, Ohio, Oregon, Pennsylvania, and Texas.
[4] Includes states as follows: Colorado, Indiana, Iowa, Massachusetts, Missouri, Nebraska, New Jersey, New York, Ohio, Rhode Island, South Carolina, and Wisconsin.

The value of fuses and lightning arresters reported in 1905 was $1,455,203, showing a marked increase over the previous report, when it was returned as $595,497. This increase is due largely, if not wholly, to the general increase in electrical application and also to the recognition of the fact that it is a policy of economy to protect all classes of apparatus against lightning strokes, dangerous sneak currents, or sudden increases of the electrical energy flowing through the circuit. The lightning arrester equipment of a telephone exchange is an important and extensive part of the equipment, but it is probable that in many cases it has been included under the head of telephonic apparatus noted elsewhere, such arresters being made in certain types exclusively for telephonic work. There is, however, a very large field of application left, particularly in electric light, power, and traction, for which the insurance requirements are necessarily severe and exacting. The general type of fuse in the United States to-day is that which is known as "inclosed," the flash or action of the current discharge which opens the circuit taking place within a small chamber, like a cartridge shell. The tube is usually made of fiber, and contains a fusible strip surrounded by a filling material which combines with the material at the moment of "blowing" and thus absorbs or smothers the arc. These fuses are mounted on small stands or in boxes, according to their specific use, and are so arranged as to be readily or even automatically renewed or replaced after the protective action has occurred. In connection with street railway work these fuses are employed in fuse boxes and often in conjunction with circuit breakers, so that the heavier short circuits can be guarded against without damaging result to the apparatus or the persons in the vicinity.

Many fuses are employed of the metal strip type, fusing metal of a special composition being cut into strips, or wire, and held in the circuit between binding posts, so that any undue surplusage of electrical current will cause it to melt, and thus instantaneously open the circuit. These principles and appliances are employed in various ways, but, as noted, the particular form depends upon the use to which it is put and upon the volume of current against which the apparatus must be guarded. The national electrical code on the subject of the use of fuses makes the following provision, which will illustrate in a general way the application of these devices:

> An approved cut-out (fuse) should be provided on service directly inside the building. Care should be taken to bring service in at point suitable for safe and convenient location of cut-out. An approved main switch should be provided as near as possible to where service enters, and be within easy reach of floor, so arranged that the entire equipment, including meter, can be disconnected when necessary. This switch should be protected by the main fuses. A separate branch cut-out should be provided for each 660 watts, i. e., the equivalent of about 11 or 12 sixteen candlepower lamps or 1 arc lamp. It is always good practice to have cut-outs assembled in groups, depending somewhat on the nature of the building, and placed in approved cabinets lined with slate, marble, or ⅛-inch asbestos.

Lightning arresters are of various construction. In one well-known type a magazine of fusible lightning arresters is provided so that they can become operative successively, one fuse providing for each lightning discharge. The arrester consists of two pieces of soft brass wire wrapped at their inner ends to form a discharge gap and inclosed hermetically in a small glass tube. One end of each fuse, or arrester, rests upon a common ground terminal, and the other is connected to the line terminal through a small carbon ball operated by gravity. In another type the arresters are composed of a series of special carbonized rings placed alternately in series with mica rings on an insulated tube, supported by two circular saw-toothed metal caps or brackets secured to the insulated base. The carbonized rings, by their composition and shape, afford an inner as well as an outer discharge circuit for the static charges, but will not permit arcs to form, nor a dynamo current to precede or follow. These arresters have no moving parts. Another form in general use is of the circuit breaker type, in which the air gap is fixed and the circuit is opened by the discharge in an inclosed chamber. This allows the use of a small air gap while providing an easy path to earth for the discharge. A resistance is used in series with the arrester coil to limit the current flow and in shunt to provide a noninductive path around the coil for the discharge. The parts are mounted on the base in such a manner as to avoid breakdown between parts of opposite potential on the surface. One type of lightning arrester manufactured in the United States has no air gap, its essential part being a specially constructed rod of very high ohmic but noninductive resistance, placed between the line and the ground, allowing a constant flow of current to escape through it to the ground, although to a very small degree. The inclosed circuit form of construction, while providing a path that will take care of a little static discharge and a heavier lightning discharge, as compared with an arrester with an air gap, has the advantage of being nonarcing and of having no moving parts. The fact that the current is in constant flow through the arrester affords an additional assurance that the lightning will follow that path. Another type of lightning arrester which is installed in the power house, on poles carrying feeder lines, or on street railway cars, consists of two round terminals which form an adjustable spark gap, a noninductive resistance, and a magnetic blow-out coil, all inclosed in a porcelain box. The choke coils are interposed between the points where the arrester is connected to the circuit and the generator and motor to be protected. The spark gap terminals are mounted on the under side of the cover of the porcelain box, rendering them readily accessible for cleansing and inspection. For outdoor service the arrester is inclosed in a substantial wooden box. In electric railway work another form of lightning arrester in general use employs choke coils to flatten out the potential wave, while the arrester associated with it affords an easy path to the ground, and prevents the line current from following the discharge.

Included in the total for fuses of Table 22 is a large value, amounting to something over $300,000, reported by several establishments, representing electric fuses or exploders that are employed for setting off dynamite and other explosive charges, submarine mines, etc. The entire amount for 1 state represents fuses of this character. It will, of course, be understood that these fuses are of a somewhat different nature from those which are employed to open the circuit, rendering innocuous an abnormal flow of current or a lightning discharge. Electric fuses of the explosive or detonator character are operated either by means of direct spark from a small magneto-machine or by the incandescence of a thin wire placed in the circuit. This wire usually receives its current from a small battery upon which the circuit can be closed when it is desired to cause the explosion at the point in the circuit where the fuse and the explosive charge have been inserted. These two classes of fuses are known as high tension magneto, or low tension battery. Fulminate of mercury is employed frequently for such electric fuses, and it is a common practice to place a number of them in circuit at the same time, so that in mining and blasting operations several can be exploded simultaneously at different points. A fuller account of such apparatus was given in the chapter on electricity in mining contributed by the present writer to the special report, issued by the Bureau of the Census, on Mines and Quarries, 1902, pages 151 and 152.

Electric measuring instruments.—Table 23 shows the number and value of electric measuring instruments reported at the censuses of 1900 and 1905.

TABLE 23.—ELECTRIC MEASURING INSTRUMENTS—NUMBER AND VALUE: 1905 AND 1900.

STATE.	Total value.	CENTRAL STATION APPARATUS.		METERS FOR CONSUMERS' CIRCUITS.		TESTING AND SCIENTIFIC.	
		Number.	Value.	Number.	Value.	Number.	Value.
United States, 1905	$5,004,763	22,090	$418,998	336,929	$3,585,080	58,067	$1,000,685
1900	1,842,135	(1)	(1)	(1)	(1)	(1)	(1)
States, 1905:							
Illinois	9,050	712	9,050	(2)	(2)	(2)	(2)
Massachusetts	187,469	(2)	(2)	(2)	(2)	16,179	187,469
New York	56,535	1,433	15,854	…	…	3,386	40,681
All other states	4,751,709	[3] 19,945	[3] 394,094	[4] 336,929	[4] 3,585,080	[5] 38,502	[5] 772,535

[1] Not reported separately.
[2] Included in "all other states."
[3] Includes states as follows: California, Connecticut, Indiana, Massachusetts, Missouri, New Hampshire, New Jersey, Pennsylvania, and Wisconsin.
[4] Includes states as follows: Illinois, Indiana, Massachusetts, Minnesota, New Hampshire, New Jersey, and Pennsylvania.
[5] Includes states as follows: Connecticut, Georgia, Illinois, Indiana, Missouri, New Hampshire, New Jersey, Ohio, and Pennsylvania.

The production of electric measuring instruments for 1905 shows a large increase over 1900, the gain being from $1,842,135 to $5,004,763, or 171.7 per cent. This gratifying increase may be due in part to the fact that a number of instruments included in the previous report in "all other products" have been here separated more distinctly from the general output of concerns making more than one class of apparatus. The fact remains, however, that the past five years have seen in every department of electricity an adoption of methods for indicating the value and total quantity of electrical energy generated and distributed. No central station or isolated plant can be found without its measuring instruments. This is equally true of electric railway work, while in the field of telegraphy and telephony the employment of such instruments is considered vitally essential to the proper conduct of the business. In the field of electric light and power the earlier practice of selling energy or light at a flat rate is disappearing rapidly; even in small towns and villages it has become the practice to supply the consumer with a meter indicating his consumption of electricity, upon whose readings the bills are based.

At the census of 1900 no attempt was made to distinguish between the three main groups of electrical measuring instruments, namely, those for central stations, those for the consumers' circuits, and those intended for testing and scientific purposes. In the present returns figures have been obtained and are presented in the separate groups, thus giving an idea of the relative importance of these branches of industry. It would appear that 19 concerns were engaged in the production of central station apparatus, 14 in that for metering on consumption circuits, and 28 in instruments for testing and scientific purposes. Of the central station apparatus, the value reported was $418,998 and the number of instruments was 22,090. By far the larger proportion of these in number and value was made in New Jersey, the states next in importance according to value being Pennsylvania and Massachusetts. To measure at the consumer's end of the line the output indicated by the central station instruments, there were made 336,929 meters, having a total value of $3,585,080, or an average value of about $10.50. The production of this apparatus was distributed widely and was participated in by several states, but owing to the small number of plants in each state the statistics can not be shown separately. Massachusetts, however, was the leading state, being followed by Pennsylvania, New Jersey, Indiana, and Illinois, in the order named, these 5 states accounting for over nine-tenths of the entire output. As a matter of fact, while these meters are being installed throughout the country, the larger cities are the chief centers of their use. New York, for example, with over 50,000 customers for central station supply, requires at least that number of meters. The central station indicating apparatus is practically uniform throughout the country, the leading types being voltmeters, ammeters, wattmeters, and watt-hour meters; but with regard to consumers' meters, although one or two types are predominant, greater variety prevails, depending somewhat upon the system adopted by the local company in charging for its service. A great many of the earlier meters were of the chemical type, but these have disappeared except where the expansion of a liquid by heat is employed to give an indication of the amount of current that has been required at different times and seasons, the charge being adjusted thereto on a sliding scale.

The testing and scientific apparatus is a very large group and includes numerous types and hundreds of varieties, employed not only in practical work, but in laboratories and in physical and scientific research. At one time practically the whole of this apparatus was imported from Europe, but, as will be noted, today there are more factories making it than are engaged in the production of meters of a more strictly commercial nature—an interesting and encouraging evidence of the growing skill of American manufacturers in a peculiarly fine and exacting industry. It is also worthy of note that instruments in all these three general groups are exported in increasing quantities and can be found in use throughout the world. During the year 1905, 58,067 instruments for testing and scientific purposes were made, having a value of $1,000,685. The chief center of their production was New Jersey, and through the commanding genius and inventive ability of one man that state is indeed one of the leaders in all three classes of products shown in Table 23. The other states giving special attention to this particular group of apparatus were Massachusetts, Pennsylvania, Connecticut, and New York.

The class of apparatus of most direct interest to the public is that which determines the amount of its consumption of energy for light and power. The watt-hour meter is one of the best known types of this and embodies a motor device of simple construction and of minute form. It consists essentially of two coarse wire coils placed in series with the circuit whose consumption is to be measured, and a fine wire coil connected in shunt around the circuit. The passage of electricity through the coarse wire coils creates the field of magnetic force which causes the fine wire coil to revolve. This shunt fine wire coil is supported in jeweled bearings, and its rate of rotation is proportional to the current in the circuit. A copper or aluminum disk is mounted on the same shaft as the shunt coil and rotates between the poles or arms of a permanent magnet. The current produced in the disk acts as a drag upon it, the drag being adjusted or calculated to give a speed proportional to the electrical energy supplied to the consumer. The number of revolutions is recorded by a clockwork escapement connected with small dials visible at the top of the meter case, and at any time the customer or the meter inspector can take a reading of the record of kilowatt hours that have been furnished.

A great deal of ingenuity in devising and in producing these small meters has been exercised, and the delicacy of operation involved has given employment to a large number of women, all the parts being of delicate construction, involving deftness of touch in their treatment and assembling. The relation of one industry to another is indicated by the large demand made in these instruments for jewels, such as Eastern sapphires, out of which the bearings are made, while the finest steel piano wire, about 0.03 inch in diameter, is employed for the pivots. A further development of such meters has been in the prepayment class, in which the insertion of a coin, closing the circuit, permits the use of a certain predetermined amount of energy. These meters, developed originally in Europe, are now being used and manufactured in this country also.

Circuit fittings.—Table 24 gives the statistics of production and value of circuit fittings at the census of 1905.

TABLE 24.—*Circuit fittings of all kinds—number and value: 1905.*

STATE.	Number.	Value.
United States	6,820,312	$3,525,446
Massachusetts	99,000	22,411
New York	1,035,220	2,493,242
Ohio	5,846	24,841
Pennsylvania	1,025,875	662,092
All other states[1]	4,654,371	322,860

[1] Includes states as follows: California, Colorado, Connecticut, Delaware, Illinois, Indiana, Michigan, Missouri, Nebraska, New Jersey, Oregon, and Virginia.

A classification which did not appear in the report of 1900 is that of "circuit fittings of all kinds." These were included in the last census under the general heading of "all other products," but, as will be seen, they now constitute quite an important class, 6,820,312 items being returned, having a value of $3,525,446. The general and increasing utility of electricity for a variety of purposes too numerous to specify has necessitated the invention and manufacture of appliances to which the general name "circuit fittings" has been given, to designate that which is not part of the appliance itself, or part of the generating plant, or part of the distributing circuits and pole lines, but which at the same time is required in order to enable contractors and the public to install such apparatus advantageously. There are endless varieties of brackets, arms, reflectors, keys, connectors, insulating devices, stands, supports, receptacles, rosettes, bell switches, etc.; these multiply daily, each new branch of industry bringing with it novel requirements. There were in the United States 45 establishments engaged in this branch of work, chiefly in the states of New York, Pennsylvania, and Connecticut. By far the largest output was that of New York state, where 12 establishments reported a product of 1,035,220 pieces, having a value of $2,493,242. In Pennsylvania there were 9 establishments reporting 1,025,875 pieces, with a value of $662,092. The figures for Connecticut can not be shown separately.

All other products.—Table 25 shows, for 1900 and 1905, the value of all other electrical machinery, apparatus, and supplies not included in the preceding tables.

TABLE 25.—*All other products—value: 1905 and 1900.*

STATE.	Total value.	Electric switches, signals, and attachments (value).	Magneto ignition apparatus, including spark coils (value).	Electro-therapeutic apparatus (value).	All other products, not specified (value).
United States, 1905	$26,634,963	$1,451,337	$678,077	$1,036,962	$23,468,587
1900	14,783,005	1,129,891	(1)	(1)	13,653,114
States, 1905:					
California	143,275	....	....	8,600	134,675
Connecticut	569,003	(2)	(2)	(2)	569,003
Delaware	435,926	....	....	....	435,926
Illinois	1,694,341	....	....	502,880	1,191,461
Indiana	723,579	....	159,610	15,285	548,684
Maine	13,000	....	....	....	13,000
Maryland	32,400	....	....	(2)	32,400
Massachusetts	4,817,128	(2)	156,670	34,997	4,625,461
Michigan	123,160	....	47,710	(2)	75,450
Minnesota	219,087	(2)	....	(2)	219,087
Missouri	65,690	(2)	....	(2)	65,690
Nebraska	32,650	....	....	(2)	32,650
New Jersey	1,287,464	(2)	(2)	(2)	1,287,464
New York	6,322,666	....	224,739	306,768	5,791,159
Ohio	4,063,181	....	56,022	2,200	4,004,959
Pennsylvania	3,932,187	(2)	(2)	80,681	3,851,506
Rhode Island	89,790	....	....	(2)	89,790
Tennessee	67,433	....	....	....	67,433
Wisconsin	251,396	....	....	(2)	251,396
All other states	1,751,607	[3] 1,451,337	[4] 33,326	[5] 85,551	[6] 181,393

[1] Not reported separately.
[2] Included in "all other states."
[3] Includes states as follows: Connecticut, Kentucky, Massachusetts, Minnesota, Missouri, New Jersey, and Pennsylvania.
[4] Includes states as follows: Connecticut, Georgia, New Jersey, and Pennsylvania.
[5] Includes states as follows: Colorado, Connecticut, Georgia, Iowa, Louisiana, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, Rhode Island, and Wisconsin.
[6] Includes states as follows: Colorado, Georgia, Iowa, Kansas, Kentucky, Louisiana, New Hampshire, North Carolina, Oregon, Texas, Virginia, and Washington.

One of the largest groups included in this report is that shown in Table 25, for which a total of $26,634,963 was returned for 1905, as compared with $14,783,005 in the preceding Census report. This may seem a large aggregate, deserving of finer and more instructive subdivision, but as a matter of fact it is made up of a large number of individual items, few of which are relatively important. The three groups embraced in the 1905 total which were enumerated separately are "electric switches, signals, and attachments," valued at $1,451,337; "magneto ignition apparatus, including spark coils," valued at $678,077; and "electro-therapeutic apparatus," valued at $1,036,962. The electric switches and signals are in themselves auxiliary portions of what may be said to constitute telegraph systems for conveying intelligence as to the movements of trains, cars, elevators, and other transportation mechanisms. These systems are, as is well understood, elaborate combinations of electrical and mechanical parts.

The rapid development of the hydrocarbon automobile has created an enormous demand for ignition apparatus, the spark from which fires the explosive mixture of the air and gasoline vapor in the carburetter. The general principle is that when the piston is at the top of its stroke the mixture of vapor and air is ignited by the electrical discharge in it, and the violent explosion or expansion drives the piston down with great force, thus imparting motion to the reciprocating and revolving parts of the propulsive mechanism. Various methods of ignition are employed, based upon the electric principle. In what is known as the low-tension system, the car, while running, supplies its own electric sparking current from a small magneto, the moving part of which, in some forms, receives its oscillating action from a cam on the half-time shaft. These oscillations produce an intermittent current in the wire of the magneto-armature, which in turn causes a spark in the cylinder of the carburetter. The high-tension ignition system is that which employs primary or storage batteries, the current from which is sent through an induction coil, thereby inducing or creating a high frequency current. A commutating device, making and breaking contact, produces a high-tension spark within the combustion chamber at the right moment once during every four revolutions of the fly wheel, and the device is so arranged that the time of the spark can be varied by the chauffeur, who thus is able to cause the explosion to take place at an earlier and later point in the explosive stroke in the carburetter, this being known as advancing or retarding the spark. For the provision of a proper spark in the carburetter cylinder, the leading-in wires run to what is known as a sparking plug, which is a small metal device screwed into the top of the combustion chamber and containing a core of mica or porcelain through which the wire is led to a platinum point fixed in close proximity to another platinum point which is connected directly with the metal of the automobile motor and car, so as to complete the circuit. The ignition spark jumps across the gap between these two platinum points. It is in these classes of apparatus that the magneto ignition devices and spark coils are employed, so that while the hydrocarbon automobile has proved a most serious rival with the electric vehicle it is to-day wholly dependent upon electricity for its ability to operate. No gasoline automobile of the modern type is complete that does not employ in the energization of its mechanism some of the devices included in this category.

The group of electro-therapeutic apparatus, valued at $1,036,962, was produced by no fewer than 66 establishments, chiefly in Illinois and New York. A great deal of this apparatus is still imported from Europe, chiefly from French and German sources, but in general the American medical practitioner has been more ready than those of the Old World to adopt electricity for surgical and curative purposes, and the advance in this country from both the technical and the industrial standpoint has been correspondingly rapid. A large number of medical men may be said to employ electricity solely in their work, and there are numerous clinics where electricity is the sole subject dealt with. Some of the equipments of leading men in this field are of the most elaborate and costly character, arranged in numerous separate compartments each fitted up with its specific or distinctive devices for X-ray work, electric light baths, charged liquid baths, the application of frictional or static electricity, and the treatment of disease where the direct internal or external application of current is deemed necessary. An idea of the importance now attached to this whole class of work may be formed from the fact that one of the sections of the International Electrical Congress held at St. Louis in 1904 was devoted to electro-therapeutics, while the transactions of the section constituted a large part of the report subsequently issued. Incidental to the work of this section was that in other branches of an allied character, such as the purification of water by electrical appliances and current, the study of microbes, treatment by phototherapy, and the effect of fluorescence in human organisms. The development of this whole field has indeed brought with it the requirement for a classification and nomenclature of the principles, phenomena, and apparatus that have become recognized during the past few years.

Laying aside the three classes which have just been referred to above, there remains a total of "all other products, not specified," amounting to $23,468,587. This was manufactured by no fewer than 376 establishments. This large number is in itself an evidence of the miscellaneous character of these factories and their products, and gives an average value of over $60,000 per establishment. It must not be understood that these 376 establishments were engaged exclusively in the production of this miscellaneous class of products, for the majority of them produced other specified electrical products, which have been included in their respective groups in the foregoing tables. The states contributing chiefly were New York, with 93 establishments, whose product was valued at $5,791,159; Massachusetts, 33, with product of $4,625,461; Ohio, 45, with product of $4,004,959; Pennsylvania, 37, with product of $3,851,506; New Jersey, 21, with product of $1,287,464; Illinois, 34, with product of $1,191,461; Connecticut, 15, with product of $569,003; and Indiana, 8, with product of $548,684. It will be observed from the table that these products were fairly well distributed through no fewer than 12 states in which the production exceeded $100,000, and that there were scattered establishments in others with a production aggregating several hundreds of thousands of dollars.

In many cases, especially of the larger companies, the schedules did not show the nature of the "all other products, not specified." Enough were specified, however, to give a fair idea of the character of products which make up the aggregate. They may be roughly grouped and enumerated as follows: Street railway supplies other than car equipment, to the value of $3,115,100, which includes such products as rail bonds and bonding tubes, line material, trolley-wire hangers, brackets and insulators, trolley gears and pinions, trolley wheels, contact alloys, etc. It is possible that one or two of these products are not strictly electrical in their nature, but they seem to be exclusively electrical in destination and use, and could hardly be included in any other industry. Another large class is that of machinery, tools, etc., to the value of $1,948,953. This group includes small electric engines or locomotives, elevators exclusive of motors, machinery for making incandescent lamps, magnetic ore separators, small electric pumps, electric disinfecting machines such as those which generate ozone by sparking, coal mining and cutting machinery, drills, tools, etc. A smaller group of somewhat similar nature consists of dynamo and motor parts and supplies, including armatures and field coils, pole pieces, etc., to a value of $283,224. In the same general group might be placed special controllers for dynamos, motors, and elevators to the value of $296,053, while it would not be an improper stretch of this wide classification also to include in it electrical novelties and toys, amounting to the respectable value of $424,202. The mechanical toys of the present time are largely electrical in their nature, consisting of little dynamos and motors, electric railways, trolley cars, electric launches, portable lamps, and kindred devices. Insulating materials were specified to the value of $760,543, embracing materials of rubber, cloth, paper, compound, rubber substitute, etc.

A large variety of apparatus was reported as electrical household goods to the value of $213,039. This total is made up of such items as bells and push-button appliances, electric speaking tubes, electric door and mail box openers, electric filters, acousticons (for intensifying telephone transmission), and other miscellaneous appliances of the most heterogeneous character, and far too numerous to give even brief mention. A total of $203,659 was returned for electric signs. It is possible that some of the incandescent and miniature lamps are included in this total and to that extent involve duplication of the value reported under the heading of electric lamps. But the bulk of this item is made up of the framework of such signs or of the individual metal letters constituting them. This is a growing industry, but outside of the framework or background for the signs it consists largely in the assembling of other material from which the sign is built up, such as lamps, switches, insulators, wires, and cables. It is the almost universal practice to-day to employ carbon for the brushes making contact with the commutators of dynamos and motors, but other brushes are still in use to some extent, made of strip copper, wire gauze, and kindred material, and for these a value was returned of $84,283. There were also other miscellaneous products named, to the value of $610,902, embracing such items as electrical lining and attachments for wooden cabinets, safes, and vaults, for burglar protection, detailed parts for arc lamps, and jewels for electrical instrument purposes, etc.

Custom work and repairing.—Table 26 shows the amount reported for custom work and repairing at the censuses of 1900 and 1905.

TABLE 26.—*Amount received for custom work and repairing: 1905 and 1900.*

STATE.	Value.
United States, 1905	$2,798,922
1900	2,063,736
States, 1905:	
California	89,558
Colorado	8,350
Connecticut	12,301
Illinois	261,696
Indiana	65,211
Kentucky	8,450
Maryland	11,250
Massachusetts	116,737
Michigan	8,869
Minnesota	37,400
Missouri	100,941
New Jersey	146,619
New York	1,234,460
Ohio	335,251
Pennsylvania	204,634
Rhode Island	41,444
Wisconsin	58,970
All other states [1]	56,781

[1] Includes states as follows: Delaware, Georgia, Iowa, Louisiana, Maine, Nebraska, New Hampshire, North Carolina, Oregon, Tennessee, Texas, Virginia, and Washington.

The amount shown for 1905, $2,798,922, was reported by 331 establishments. These figures call for little comment, as it is a well understood fact that in the large majority of cases every factory has more or less work of this character, where the apparatus or parts of it are returned occasionally for repair or renewal, or where the production of individual pieces of apparatus is undertaken which does not fall within the ordinary line of manufacture. At one time this repair class of work constituted a large and profitable branch of employment for the limited number of electrical factories then in existence, but at the present all the larger electric lighting and power central stations, the electric traction systems, the telegraph systems, and the telephone exchanges have their own repair shops, and forces of men whose work is executed on the spot, not only because it is more economical to do this, but because the apparatus is required promptly in the work.

Table 27 is a detailed summary of the general statistics of the 784 establishments classified as electrical machinery, apparatus, and supplies, by states, for 1905.

TABLE 27.—ELECTRICAL MACHINERY, APPARATUS, AND

		United States.	California.	Colorado.	Connecticut.	Illinois.	Indiana.	Kentucky.
1	Number of establishments	784	24	7	32	104	34	3
	Capital:							
2	Total	$174,066,026	$716,440	$141,800	$4,183,535	$21,644,783	$3,174,505	$203,701
3	Land	$8,157,833	$10,253	$5,500	$138,315	$1,808,263	$118,774	$5,754
4	Buildings	$19,902,359	$23,787	$7,000	$596,067	$2,758,715	$386,453	$25,443
5	Machinery, tools, and implements	$28,787,956	$111,170	$65,300	$568,868	$5,254,379	$858,380	$37,906
6	Cash and sundries	$117,217,878	$571,230	$64,000	$2,880,285	$11,823,426	$1,810,898	$134,598
7	Proprietors and firm members	400	6	1	10	46	13	1
	Salaried officials, clerks, etc.:							
8	Total number	10,619	112	14	225	1,631	384	9
9	Total salaries	$11,090,885	$112,836	$18,450	$278,011	$1,406,868	$382,421	$8,348
	Officers of corporations—							
10	Number	793	17	5	37	109	40	5
11	Salaries	$2,104,554	$27,037	$6,900	$117,182	$280,117	$92,216	$4,200
	General superintendents, managers, clerks, etc.:							
12	Total number	9,826	95	9	188	1,522	344	4
13	Total salaries	$8,986,331	$85,799	$11,550	$160,829	$1,126,751	$290,205	$4,148
	Men—							
14	Number	8,140	87	8	143	1,189	263	3
15	Salaries	$8,058,540	$81,989	$11,300	$141,322	$936,459	$245,404	$3,784
	Women—							
16	Number	1,686	8	1	45	333	81	1
17	Salaries	$927,791	$3,810	$250	$19,507	$190,292	$44,801	$364
	Wage-earners, including pieceworkers, and total wages:							
18	Greatest number employed at any one time during the year	78,360	540	123	1,991	7,380	1,822	111
19	Least number employed at any one time during the year	51,890	310	71	1,408	5,419	1,198	51
20	Average number	60,466	403	89	1,707	6,131	1,416	73
21	Total wages	$31,841,521	$244,123	$54,574	$724,426	$3,203,435	$663,834	$34,518
	Men 16 years and over—							
22	Average number	48,976	364	48	1,197	4,941	1,232	60
23	Wages	$28,316,772	$232,164	$37,074	$593,872	$2,780,370	$615,925	$31,273
	Women 16 years and over—							
24	Average number	10,902	32	41	403	1,186	184	13
25	Wages	$3,410,081	$10,483	$17,500	$112,210	$422,187	$47,909	$3,245
	Children under 16 years—							
26	Average number	588	7	....	107	4	....	....
27	Wages	$114,668	$1,476	....	$18,344	$878	....	....
	Average number of wage-earners, including pieceworkers, employed during each month:							
	Men 16 years and over—							
28	January	50,438	368	40	1,204	5,028	1,243	53
29	February	49,337	383	40	1,216	5,223	1,309	54
30	March	49,171	327	40	1,230	5,101	1,261	54
31	April	49,161	332	51	1,203	5,220	1,201	54
32	May	48,740	300	51	1,219	5,286	1,217	59
33	June	48,787	308	72	1,232	5,272	1,228	63
34	July	48,735	357	72	1,231	4,806	1,253	64
35	August	48,065	388	42	1,138	4,777	1,234	65
36	September	48,168	389	44	1,185	4,677	1,214	58
37	October	48,602	401	43	1,164	4,637	1,192	64
38	November	49,074	412	42	1,166	4,563	1,206	66
39	December	49,434	403	39	1,176	4,702	1,226	66
	Women 16 years and over—							
40	January	11,143	33	45	397	1,232	178	4
41	February	11,094	33	45	396	1,181	176	3
42	March	10,984	33	45	414	1,110	185	3
43	April	10,943	31	33	403	1,136	179	21
44	May	10,791	31	32	390	1,164	188	12
45	June	10,689	31	32	376	1,207	189	2
46	July	10,362	31	32	381	1,202	190	1
47	August	10,598	31	32	403	1,260	193	8
48	September	10,637	31	49	410	1,179	191	6
49	October	11,059	33	49	420	1,183	184	34
50	November	11,273	33	49	420	1,162	183	35
51	December	11,251	33	49	426	1,216	172	27
	Children under 16 years—							
52	January	600	7	....	99	3	....	....
53	February	540	7	....	108	3	....	....
54	March	559	7	....	114	4	....	....
55	April	529	7	....	88	4	....	....
56	May	561	7	....	86	5	....	....
57	June	549	7	....	80	6	....	....
58	July	567	6	....	92	5	....	....
59	August	602	6	....	110	6	....	....
60	September	629	8	....	122	3	....	....
61	October	628	8	....	119	3	....	....
62	November	651	7	....	135	3	....	....
63	December	641	7	....	131	3	....	....
	Miscellaneous expenses:							
64	Total	$17,948,708	$74,523	$10,900	$431,226	$1,969,790	$459,061	$14,033
65	Rent of works	$789,349	$18,034	$2,940	$20,560	$181,608	$7,888	....
66	Taxes	$545,488	$2,280	$965	$10,142	$99,895	$13,095	$323
67	Rent of offices, interest, insurance, and all other sundry expenses not hitherto included.	$16,347,461	$49,859	$6,795	$400,524	$1,549,153	$435,458	$10,710
68	Contract work	$266,410	$4,350	$200	....	$139,134	$2,620	$3,000
	Materials used:							
69	Aggregate cost	$66,830,926	$434,241	$65,480	$2,754,122	$7,649,446	$1,066,034	$84,406
	Principal materials—							
70	Total cost	$48,390,836	$385,107	$51,575	$2,499,907	$7,013,141	$890,992	$63,020
71	Purchased in raw state	$1,665,695	$2,245	....	$45,316	$20	$16,415	....
72	Purchased in partially manufactured form	$46,725,141	$382,862	$51,575	$2,454,591	$7,013,121	$874,577	$63,020
73	Fuel	$1,503,111	$3,048	$905	$31,414	$152,922	$49,583	$748
74	Rent of power and heat	$479,091	$7,410	$2,440	$12,060	$61,038	$9,310	$720
75	Mill supplies	$623,394	$1,807	$180	$16,009	$38,228	$8,439	$183
76	All other materials	$15,216,698	$28,037	$10,370	$172,851	$339,246	$106,536	$18,835
77	Freight	$623,796	$8,832	$10	$21,881	$44,871	$1,774	$900
78	Value of products, including amount received for custom work and repairing.	[1]$140,809,369	$1,004,284	$178,759	$4,939,831	$16,700,027	$2,857,174	$169,788

[1] Includes establishments distributed as follows: Delaware, 1; District of Columbia, 2; Georgia, 2; Iowa, 2; Louisiana, 2; Maine, 2; Nebraska, 2; Oregon, 2; South Carolina, 1; Tennessee, 2; Virginia, 2; Washington, 1; West Virginia, 1.

SUPPLIES—DETAILED SUMMARY, BY STATES: 1905.

	Maryland.	Massachusetts.	Michigan.	Minnesota.	Missouri.	New Hampshire.	New Jersey.	New York.	Ohio.	Pennsylvania.	Rhode Island.	Texas.	Wisconsin.	All other states.[1]	
	6	72	14	15	20	5	42	175	92	80	11	3	23	22	1
	$191,315	$12,735,427	$413,732	$389,211	$1,644,031	$162,486	$18,457,821	$30,643,167	$10,408,184	$58,393,011	$3,608,034	$7,800	$6,329,351	$617,692	2
	$12,500	$345,900	$1,300	$14,000	$64,350	$6,038	$698,551	$1,699,654	$235,569	$2,674,606	$68,832	....	$225,800	$23,874	3
	$43,000	$1,874,094	$6,500	$29,000	$97,523	$3,082	$2,458,166	$4,625,852	$1,291,827	$4,419,640	$621,188	....	$553,273	$81,749	4
	$52,669	$2,603,557	$81,847	$125,658	$437,671	$50,015	$3,489,171	$4,702,014	$2,893,023	$5,455,045	$779,461	$3,000	$1,052,856	$165,966	5
	$83,146	$7,911,876	$324,085	$220,553	$1,044,487	$103,351	$11,811,933	$19,615,647	$5,987,765	$45,843,720	$2,138,553	$4,800	$4,497,422	$346,103	6
	6	37	8	11	5	3	11	95	50	56	3	5	14	19	7
	23	871	60	32	183	14	1,012	1,668	1,023	2,746	119	....	396	97	8
	$26,248	$962,650	$58,588	$35,960	$193,244	$12,359	$1,002,693	$1,730,441	$1,079,006	$3,089,535	$153,096	....	$450,644	$80,487	9
	7	67	14	18	26	4	49	143	100	79	16	....	37	20	10
	$15,280	$187,270	$23,515	$27,000	$60,740	$2,900	$214,629	$315,731	$253,222	$297,304	$52,071	....	$97,040	$30,200	11
	16	804	46	14	157	10	963	1,525	923	2,667	103	....	359	77	12
	$10,968	$775,380	$35,073	$8,960	$132,504	$9,459	$788,064	$1,414,710	$825,784	$2,792,231	$101,025	....	$353,604	$59,287	13
	13	633	29	7	120	8	808	1,327	655	2,408	77	....	306	56	14
	$9,816	$688,024	$27,278	$5,340	$113,639	$8,845	$698,363	$1,303,569	$690,651	$2,625,575	$87,037	....	$329,183	$50,962	15
	3	171	17	7	37	2	155	198	268	259	26	....	53	21	16
	$1,152	$87,356	$7,795	$3,620	$18,865	$614	$89,701	$111,141	$135,133	$166,656	$13,988	....	$24,421	$8,325	17
	180	10,540	677	202	968	128	7,586	25,246	6,375	10,832	1,631	23	1,463	542	18
	139	7,277	418	146	643	54	5,339	14,514	3,985	8,437	1,201	11	982	287	19
	161	8,798	529	170	795	83	6,268	16,301	5,114	9,404	1,409	13	1,204	398	20
	$65,813	$5,003,190	$176,817	$103,015	$411,804	$32,224	$2,894,139	$9,286,912	$2,268,497	$5,299,668	$557,065	$4,450	$672,812	$140,205	21
	139	7,107	372	168	546	44	3,833	14,405	3,747	8,252	1,002	13	1,140	366	22
	$62,198	$4,437,918	$148,852	$102,040	$327,099	$22,235	$2,203,102	$8,700,862	$1,874,381	$4,909,121	$442,441	$4,450	$655,891	$134,604	23
	14	1,499	143	2	239	39	2,353	1,854	1,352	1,069	398	....	59	22	24
	$2,600	$521,185	$25,366	$975	$81,565	$9,989	$676,246	$578,405	$391,776	$375,709	$112,524	....	$15,844	$4,363	25
	8	192	14	....	10	....	82	42	15	83	9	....	5	10	26
	$1,015	$44,087	$2,599	....	$2,240	....	$14,791	$7,645	$2,340	$14,838	$2,100	....	$1,077	$1,238	27
	140	7,928	328	170	484	56	3,894	14,241	3,736	9,104	971	11	1,089	350	28
	140	6,607	334	170	501	51	4,111	14,348	3,725	8,650	958	11	1,156	370	29
	148	6,635	364	165	522	46	4,107	14,299	3,792	8,469	970	15	1,250	376	30
	148	6,727	410	169	546	38	4,006	14,285	3,715	8,446	978	15	1,244	373	31
	148	6,773	419	170	573	37	3,930	14,024	3,670	8,236	1,043	15	1,208	362	32
	145	6,931	432	172	604	39	3,959	14,080	3,768	8,001	1,015	17	1,097	352	33
	149	7,018	414	162	598	42	3,855	14,536	3,768	8,053	919	12	1,080	346	34
	122	7,163	404	168	555	45	3,601	14,482	3,725	7,753	933	18	1,093	359	35
	126	7,150	389	169	525	43	3,586	14,576	3,832	7,726	1,011	11	1,083	374	36
	126	7,286	322	167	542	44	3,511	14,752	3,846	7,950	1,063	8	1,084	400	37
	138	7,474	321	169	554	46	3,652	14,731	3,710	8,221	1,080	11	1,126	386	38
	138	7,592	327	165	548	41	3,784	14,506	3,677	8,415	1,103	12	1,170	344	39
	15	1,694	111	2	242	29	2,264	1,817	1,578	1,059	370	....	50	23	40
	15	1,476	113	2	235	24	2,608	1,753	1,535	1,054	368	....	55	22	41
	15	1,462	120	2	236	27	2,651	1,751	1,431	1,043	380	....	53	23	42
	15	1,462	174	2	241	39	2,596	1,729	1,372	1,048	383	....	58	21	43
	15	1,468	179	2	221	41	2,425	1,732	1,344	1,082	388	....	58	19	44
	16	1,454	181	2	210	46	2,296	1,745	1,341	1,075	417	....	52	17	45
	16	1,462	169	2	217	47	2,287	1,806	977	1,063	403	....	55	21	46
	11	1,470	166	2	257	46	2,183	1,775	1,258	1,066	356	....	60	21	47
	11	1,470	165	2	249	41	2,120	1,899	1,292	1,060	378	....	60	24	48
	11	1,510	116	2	244	48	2,202	2,088	1,348	1,087	406	....	66	28	49
	14	1,544	111	2	258	43	2,307	2,075	1,374	1,104	464	....	70	25	50
	14	1,516	111	2	258	37	2,297	2,078	1,374	1,087	463	....	71	20	51
	8	241	11	....	10	....	77	43	14	68	7	....	5	7	52
	8	163	11	....	10	....	84	41	13	68	7	....	10	7	53
	8	167	13	....	10	....	85	45	10	70	9	....	10	7	54
	8	171	18	....	9	....	82	39	11	67	10	....	8	7	55
	8	175	16	....	10	....	90	43	15	82	9	....	8	7	56
	8	174	16	....	12	....	76	43	13	90	8	....	3	13	57
	8	174	16	....	12	....	80	40	15	93	8	....	3	15	58
	8	189	16	....	10	....	83	40	17	92	7	....	3	15	59
	8	203	16	....	10	....	81	43	20	90	11	....	3	11	60
	8	212	12	....	9	....	80	45	16	92	11	....	2	11	61
	8	215	11	....	10	....	84	42	18	95	11	....	2	10	62
	8	220	12	....	8	....	82	40	18	89	10	....	3	10	63
	$20,679	$1,448,091	$97,031	$30,146	$227,048	$14,496	$1,581,525	$3,263,950	$1,685,514	$5,580,353	$201,343	$1,710	$758,306	$78,983	64
	$1,585	$65,160	$10,310	$5,164	$23,401	$2,080	$30,736	$165,311	$126,178	$80,106	$22,344	$1,400	$9,801	$5,743	65
	$737	$67,135	$2,201	$1,160	$7,154	$348	$38,491	$149,240	$73,194	$50,194	$10,355	$30	$10,811	$1,738	66
	$18,157	$1,289,816	$84,520	$23,822	$196,493	$12,068	$1,510,448	$2,924,023	$1,426,642	$5,431,612	$168,644	$280	$737,435	$71,002	67
	$200	$25,980	....	....	....	....	$1,850	$25,376	$59,500	$3,441	....	....	$259	$500	68
	$92,600	$7,324,167	$294,374	$186,561	$606,424	$88,388	$6,872,638	$17,846,213	$4,690,140	$11,365,212	$4,017,178	$11,635	$1,020,359	$357,708	69
	$57,511	$4,540,404	$269,100	$172,075	$501,219	$79,804	$5,550,986	$11,939,895	$2,767,217	$6,637,141	$3,839,104	$1,420	$804,105	$327,113	70
	....	$245,527	....	....	$3,800	....	$533,469	$811,518	....	$7,347	$38	....	....	....	71
	$57,511	$4,294,877	$269,100	$172,075	$497,419	$79,804	$5,017,517	$11,128,377	$2,767,217	$6,629,794	$3,839,066	$1,420	$804,105	$327,113	72
	$785	$268,882	$3,838	$3,970	$10,048	$722	$137,029	$424,520	$178,254	$167,150	$13,039	....	$52,847	$3,407	73
	$1,617	$67,674	$4,487	$2,230	$13,721	$1,672	$19,096	$205,401	$27,098	$20,368	$8,072	$190	$8,655	$5,832	74
	$490	$62,300	$1,170	$546	$4,943	$983	$106,535	$97,982	$57,752	$197,947	$8,267	$25	$18,611	$997	75
	$32,147	$2,308,094	$6,052	$5,840	$71,181	$4,038	$992,550	$4,991,757	$1,637,799	$4,233,726	$98,801	$10,000	$130,983	$17,855	76
	$50	$76,813	$9,727	$1,900	$5,312	$1,169	$66,442	$186,658	$31,020	$108,880	$49,805	....	$5,158	$2,504	77
	$224,859	$15,882,216	$702,102	$423,933	$1,740,583	$149,871	$13,803,476	$35,348,276	$11,019,235	$26,257,569	$5,435,474	$23,055	$3,194,132	$754,725	78

[1] Exclusive of electrical machinery, apparatus, and supplies, valued at $18,742,033, made by establishments engaged primarily in the manufacture of other products. This value was distributed as follows: California, $81,600; Connecticut, $591,094; Illinois, $1,056,263; Indiana, $252,208; Maryland, $400; Massachusetts, $14,900; Michigan, $217,131; Missouri, $205,745; New Hampshire, $28,185; New Jersey, $5,130,814; New York, $5,494,909; Ohio, $1,557,660; Pennsylvania, $2,683,549; Rhode Island, $339,666; Texas, $32,750; Wisconsin, $599,000; "all other states," $456,159.

TABLE 27.—ELECTRICAL MACHINERY, APPARATUS, AND

		United States.	California.	Colorado.	Connecticut.	Illinois.	Indiana.	Kentucky.
	Power:							
79	Number of establishments reporting	710	22	7	31	91	33	1
80	Total horsepower	145,816	278	70	2,748	10,646	4,879	280
	wned—							
	Engines—							
	Steam—							
81	Number	395	2	....	17	20	20	2
82	Horsepower	77,009	70	....	1,806	4,615	2,720	115
	Gas or gasoline—							
83	Number	111	5	1	4	3	12	....
84	Horsepower	2,940	51	3	13	64	112	....
	Water wheels—							
85	Number	52	....	....	3	....	1	....
86	Horsepower	1,155	....	....	180	....	20	....
	Water motors—							
87	Number	7	....	....	1	....	....	....
88	Horsepower	26	....	....	1	....	....	....
	Electric motors—							
89	Number	6,141	....	....	16	1,220	165	59
90	Horsepower	40,440	....	....	243	4,393	1,837	120
91	Other power, horsepower	50	....	....	....	....	....	....
	nted—							
	Electric motors—							
92	Number	2,331	47	13	24	19	30	8
93	Horsepower	21,313	157	67	315	1,195	190	45
94	Other kind, horsepower	2,883	....	....	190	379	....	....
95	Furnished to other establishments, horsepower	4,868	5	....	112	3	....	....

SUPPLIES—DETAILED SUMMARY, BY STATES: 1905—Continued.

Maryland.	Massachusetts.	Michigan.	Minnesota.	Missouri.	New Hampshire.	New Jersey.	New York.	Ohio.	Pennsylvania.	Rhode Island.	Texas.	Wisconsin.	All other states.	
6	69	13	11	18	5	42	150	86	70	10	3	22	20	79
329	15,795	401	140	826	172	8,008	40,811	9,405	43,828	3,317	15	3,372	495	80
1	37	3	1	3	1	40	52	43	126	7	....	16	4	81
60	7,822	225	15	287	4	5,547	21,021	5,596	23,046	1,920	....	1,925	215	82
1	10	3	1	3	1	3	20	15	20	....	....	8	1	83
15	151	20	15	24	3	44	129	490	1,697	....	....	104	5	84
4	6	....	....	....	1	29	1	6	....	....	....	1	....	85
200	145	....	....	....	100	397	18	75	....	....	....	20	....	86
....	1	....	....	5	....	....	....	....	....	....	....	....	....	87
....	10	....	....	15	....	....	....	....	....	....	....	....	....	88
....	1,245	8	....	1	....	206	1,466	652	807	14	....	190	2	89
....	6,454	22	....	2	....	1,461	7,752	2,267	14,590	94	....	1,199	6	90
....	....	....	....	....	....	40	....	....	10	....	....	....	....	91
31	166	25	35	136	2	43	1,419	164	67	8	4	13	77	92
54	1,127	134	110	498	55	311	11,333	791	4,350	177	15	124	265	93
....	86	....	....	....	10	208	558	186	135	1,126	....	....	5	94
15	108	....	....	....	13	....	4,009	89	210	....	....	302	2	95

METAL WORKING MACHINERY

METAL WORKING MACHINERY.

By Fred J. Miller, Expert Special Agent.

The present report on metal working machinery embraces statistics relating to the manufacture of power operated machines for working metals, including also the parts and small tools necessary for the operation of the same. The term "metal working machinery" does not include machines or tools for use in the hand trades, such as plumbers' and tinsmiths' tools and watchmakers' lathes and tools, or rolling mill machinery, cranes, hoists, etc.

The statistics presented at the census of 1905 relate only to products, and no figures are given, as in the 1900 report, for capital, salaried employees, salaries, wage-earners, wages, miscellaneous expenses, and cost of materials used. The manufacture of metal working machinery is so closely connected with the manufacture of foundry and machine shop products that it was found impracticable in 1905 to separate the statistics concerning the manufacture of metal working machinery, except for products. Moreover, the statistics for 1905 are more comprehensive than those for 1900, it being the endeavor in the former to include returns for all establishments in which metal working machinery, including machine tools, is manufactured either as the principal or as a minor product; whereas the statistics for 1900 are confined to establishments in which metal working machinery alone was the principal product.

While the total production of metal working machinery reported at the census of 1905 shows an increase as compared with that for the census of 1900, it must be taken into consideration that the statistics include small machine tools, such as chucks, bits, dies, etc., and all working and interchangeable parts manufactured for metal working machines, which constitute a large proportion of the total product. These tools and parts were doubtless included to a greater extent in 1905 than in 1900, inasmuch as in 1905 there was a specific request made on the schedule calling for the value of the same manufactured during the census year; whereas no separate statistics are available for small tools for metal working machines manufactured in 1900, except under the general heading of "all other metal working machinery," and the large increase this item shows in 1905 in comparison with 1900 is due to some extent to a more complete canvass of the manufacture of this class of products.

In 1900 the statistics chronicled a period of great activity in the iron and steel industries and incidentally in the manufacture of metal working machinery. There was, however, a serious depression in business conditions in 1903, especially in all branches of the iron and steel industry, and although an improvement was noticeable toward the middle of 1904, the effect upon the returns for the manufacture of metal working machinery for that year was not marked.[1]

With these explanations the statistics of metal working machinery production in the United States are presented in 20 tables, which illustrate the industry as reported at the censuses of 1900 and 1905. Table 1 presents the value of products by selected states, with the proportion the value for each state forms of the total for the United States at the censuses of 1900 and 1905, and also the per cent of increase during the five-year period.

Table 1.—*Metal working machinery—value of products, by states, with per cent of total and per cent of increase: 1905 and 1900.*

STATE.	1905		1900		Per cent of increase.
	Value.	Per cent of total value.	Value.	Per cent of total value.	
United States...	$32,408,766	100.0	$24,737,904	100.0	31.0
Connecticut..........	3,965,742	12.2	3,162,003	12.8	25.4
Illinois..........	2,015,201	6.2	1,133,589	4.6	77.8
Massachusetts..........	4,819,687	14.9	2,844,319	11.5	69.4
New Jersey..........	1,406,005	4.3	1,297,401	5.2	8.4
New York..........	3,287,064	10.2	1,754,624	7.1	87.3
Ohio..........	8,197,637	25.3	7,213,157	29.2	13.6
Pennsylvania..........	3,005,278	9.3	3,324,570	13.4	[1]9.6
Rhode Island..........	1,915,052	5.9	1,449,891	5.9	32.1
All other states..........	[2]3,797,100	11.7	[3]2,558,350	10.3	48.4

[1] Decrease.
[2] Includes the value of products of establishments located in Arkansas, California, Colorado, Delaware, Georgia, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, North Carolina, North Dakota, Oregon, Tennessee, Texas, Vermont, Washington, and Wisconsin.
[3] Includes the value of products of establishments located in California, Delaware, Georgia, Indiana, Iowa, Kentucky, Maine, Maryland, Michigan, Minnesota, Missouri, New Hampshire, North Carolina, Oregon, Vermont, Washington, and Wisconsin.

The greatest production of metal working machinery at the census of 1905 was reported for Ohio, which state was also first in 1900. The value of products for

[1] Statistics of the American Iron Trade for 1904.

Ohio formed over 25 per cent of the total value for the United States, and was greater than the combined value of New York, New Jersey, and Pennsylvania. In Ohio this industry is concentrated to a large degree in Cincinnati and Cleveland, these two cities together reporting 72.5 per cent of the total value of metal working machinery produced in the state in 1905, or 18.3 per cent of the total for the United States. Cincinnati was the leading city in the country in this industry at both censuses, and reported products valued at $3,200,889 in 1905, while Cleveland ranked second in the industry at the last census, with products valued at $2,740,618. Other cities in Ohio which are prominent in the manufacture are Hamilton, Toledo, Canton, Alliance, Springfield, and Warren, in the order named.

The state showing the greatest absolute increase in the manufacture of metal working machinery in 1905 was Massachusetts, the fourth state in rank in 1900, advancing to second place in 1905. The increase, however, was largely for "all other metal working machinery," which was more fully reported at the census of 1905 than at 1900. Worcester, the leading city in this industry in Massachusetts, reported a value of metal working machinery amounting to $1,079,772. There are also a number of large establishments in Worcester county, the products of which, if added to those for the city proper, would make the immediate locality one of the most important centers of this industry in the United States. New Bedford and Greenfield are also prominent in the manufacture of metal working machinery and tools.

Connecticut was the third state in the metal working machinery industry in both 1905 and 1900. The leading city in Connecticut was Hartford, the sixth city in the United States in this industry, and Waterbury, Bridgeport, New Haven, and Torrington also reported a large production. New York state has advanced from fifth place in 1900 to fourth in 1905, reporting an absolute increase in the value of metal working machinery manufactured, second only to that for Massachusetts. New York city, the third city in the United States in this industry, reported 61.3 per cent of the total production for the state, the bulk of this manufacture being in Brooklyn borough. The cities of Rochester and Buffalo also reported a large production of metal working machinery.

One of the noticeable features of the statistics is the fact that Pennsylvania, the second state in the manufacture of metal working machinery in 1900, ranked only fifth in 1905, a slight decrease being shown in the value of products reported for this state. The greater part of this decrease was in Philadelphia, which however, retained fourth rank among the cities of the United States in 1905, with products valued at $1,668,908.

Illinois reported a large increase in the manufacture of metal working machinery, advancing from eighth rank in 1900 to sixth in 1905, Chicago and Rockford reporting the principal production for the state. Rhode Island was seventh among the states in the metal working machinery industry in 1905. Of the total value for the state, 86.2 per cent was reported for Providence, the fifth city of the United States in this industry. New Jersey was the eighth state in the manufacture of metal working machinery in the United States, with Plainfield and Newark as the principal centers. Michigan, the ninth state in rank in 1905, shows a larger per cent of increase than any other state, the gain being due largely to the establishment of a large plant in Detroit in 1902. The production reported for Delaware, the tenth state in rank, was entirely for the city of Wilmington. The states of Wisconsin, Vermont, Indiana, New Hampshire, and Missouri ranked eleventh, twelfth, thirteenth, fourteenth, and fifteenth, respectively, in the production of metal working machinery in the United States as reported at the census of 1905.

Table 2 shows for each fiscal year between 1899 and 1905 the exports of iron and steel manufactures, and machinery of all kinds, including metal working machinery in comparison with the imports of iron and steel manufactures and machinery of all classes.

TABLE 2.—*Exports and imports of iron and steel manufactures and total machinery, and exports of metal working machinery: 1900 to 1904.*[1]

YEAR.	EXPORTS.			IMPORTS.	
	Iron and steel manufactures.	Machinery.		Iron and steel manufactures.	Machinery, all classes.
		Total, all classes.	Metal working machinery.		
1904	$111,948,586	$56,230,291	$3,716,709	$27,028,312	$3,184,968
1903	96,642,467	50,988,606	2,826,111	51,617,312	4,085,825
1902	98,552,562	47,591,534	2,977,290	27,180,247	3,646,572
1901	117,319,320	49,814,489	4,054,313	17,874,789	3,324,765
1900	121,913,548	55,485,495	7,193,390	20,478,728	3,569,096

[1] "Commerce and Navigation of the United States," Bureau of Statistics, Department of Commerce and Labor.

As the foreign trade in iron and steel manufactures and machinery may be taken as an index of the conditions prevailing in the various branches of that industry, Table 2 shows clearly the fact that the manufacture of metal working machinery was depressed during the five-year period. In the table it is seen that the exports of iron and steel manufacture and machinery, including metal working machinery, decreased steadily year by year from 1900 to 1903, inclusive. In the same period the imports advanced largely, the value of iron and steel manufactures imported being over twice as large in 1903 as in 1900. On the other hand, in 1904, when business conditions in this country were improving in the iron and steel industry, there was a considerable increase in exports of iron and steel manufacture and machinery, including metal working machinery, and a marked decrease in imports, indicating that the production at home had increased and was supplying the domestic trade more completely than for several years previous. Nevertheless, the exports in 1904 show a considerable decrease as compared with the exports for 1900.

Table 3 shows the values reported for the several classes of metal working machinery, with the per cent the value for each forms of the total value; also, the per cent of increase during the five-year period.

TABLE 3.—*Metal working machinery—value of products by class of machines, with per cent each class is of the total and per cent of increase: 1905 and 1900.*

CLASS OF MACHINE.	1905		1900		Per cent of increase.
	Value.	Per cent of total.	Value.	Per cent of total.	
Total	$32,408,766	100.0	$24,737,904	100.0	31.0
Hammers—steam, power, and drop	832,698	2.6	671,287	2.7	24.0
Forging machines, including bolt headers	437,097	1.4	424,774	1.7	2.9
Stamping, flanging, and forming machines	2,003,861	6.2	1,180,960	4.8	69.7
Punching and shearing machines	1,425,510	4.4	1,219,605	4.9	16.9
Bending and straightening rolls	190,578	0.6	202,230	0.8	[1]5.8
Riveting machines	238,829	0.7	139,295	0.6	71.5
Lathes:					
Hand	190,576	0.6	306,081	1.2	[1]37.7
Engine	3,523,470	10.9	4,451,867	18.0	[1]20.9
Turret, including all automatic or semiautomatic lathes for making duplicate pieces	2,210,814	6.8	2,449,121	9.9	[1]9.7
Boring and turning mills or vertical lathes	913,695	2.8	1,123,314	4.6	[1]18.7
Boring and drilling machinery, including all machines using drills or boring bars	2,369,712	7.3	2,779,983	11.2	[1]14.8
Planers, including plate edge planers	1,551,616	4.8	1,808,955	7.3	[1]14.2
Slotters and shapers	845,860	2.6	1,136,350	4.6	[1]25.6
Milling machines, including all machines using a milling cutter	2,476,626	7.6	2,171,966	8.8	14.0
Sawing machines	165,428	0.5	222,563	0.9	[1]25.7
Grinding and polishing machinery, including all machines using abrasive cutters	1,310,903	4.0	880,965	3.6	48.8
Bolt, nut, and pipe threading and tapping machines	899,197	2.8	698,362	2.8	28.8
Pneumatic hand machines	1,732,107	5.3	143,325	0.6	1,108.5
All other metal working machinery	9,090,189	28.1	2,726,901	11.0	233.4

[1] Decrease.

Table 3 shows a number of decreases in several important items, and if it were not for the marked increase in the value of "all other metal working machinery" the total value for 1905 would show only a small increase over 1900. As stated above, the increase in this class of product is due very largely to the greater comprehensiveness of the figures for 1905.

As shown in Table 3, lathes were the principal class of metal working machinery manufactured in both 1905 and 1900. The combined value of this class amounted to 18.3 per cent of the total value in 1905 and 29.1 per cent of the total in 1900. More than one-half of the total value reported for lathes was for engine lathes and over one-third for turret lathes, which includes the automatic and semiautomatic types, while a comparatively small proportion of the value was for hand lathes.

Table 4 shows the number and value of lathes manufactured by selected states for the censuses of 1900 and 1905.

TABLE 4.—*Production of lathes, including automatic, hand, engine, turret, and semiautomatic, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	14,486	$5,924,860	19,721	$7,207,069
Connecticut	1,326	700,785	2,108	1,030,314
Illinois	1,061	84,383	1,596	173.071
Massachusetts	4,690	856,946	4,534	1,348,168
New York	523	164,852	2,067	224,504
Ohio	4,639	2,571,883	6,121	2,624,064
Pennsylvania	122	129,112	293	358,759
Rhode Island	610	414,156	702	333,836
Vermont	319	321,765	367	284,411
Wisconsin	148	193,386	238	239,542
All other states	1,048	487,612	1,695	590,400

Over one-half of the total number of lathes manufactured in 1905 were engine lathes, 7,676 in all; 3,912 were hand lathes; and 2,898 turret lathes. The number of engine lathes manufactured in 1900 was 12,089; of hand lathes, 3,945; and of turret lathes, 3,687. It is thus seen that there was a decrease for each class, the greater part of the decrease being for engine lathes.

As seen in Table 4, Ohio was first in the manufacture of lathes, reporting 32 per cent of the total number manufactured at the census of 1905 and 43.4 per cent of the total value. This state also predominated in 1900, when the number reported formed 31 per cent of the total for the United States, and the value, 36.4 per cent of the total. Massachusetts was second in value of lathes manufactured in both 1900 and 1905, and although there was an increase in the number of such machines manufactured in that state, the value reported decreased slightly. The third state in rank in this production was Connecticut, where a considerable increase was shown in value reported of the lathes manufactured.

The class of metal working machinery second in value of products in 1905 was milling machines.

Table 5 shows, by selected states, the number and value of milling machines manufactured in 1900 and 1905.

TABLE 5.—*Production of milling machines, including all machines using a milling cutter, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	4,032	$2,476,626	4,119	$2,171,966
Connecticut	557	218,451	431	141,402
Massachusetts	745	376,222	437	317,818
New Jersey	71	115,722	155	167,510
New York	443	116,840	783	297,621
Ohio	856	529,157	1,060	438,725
Pennsylvania	50	110,282	79	110,605
Rhode Island	889	586,263	698	445,342
All other states	421	423,689	476	252,943

Table 5 shows that in spite of a slight decrease in the number of milling machines manufactured in 1905 as compared with 1900, there was an increase in the value of such machines as reported at the two censuses. Rhode Island, Ohio, Massachusetts, and Connecticut, in the order named, were the leading states, and each shows an increase in the value of this class of products.

The class of metal working machinery, which was third in value of products, was boring and drilling machines, including all machines using drills or boring bars.

Table 6 shows by states the number and value of this class of machinery manufactured in 1900 and 1905.

TABLE 6.—*Production of boring and drilling machinery, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	23,579	$2,369,712	22,890	$2,779,983
Connecticut	764	153,800	1,093	166,786
Illinois	14,281	334,614	2,936	145,083
Massachusetts	2,837	257,024	7,383	489,504
New Jersey	103	110,504	149	132,193
New York	653	50,112	1,792	83,308
Ohio	3,097	905,680	7,847	1,120,280
Pennsylvania	522	317,304	458	397,455
Rhode Island	130	65,518	128	75,135
All other states	1,102	175,147	1,104	170,233

The term "boring and drilling machinery" includes all metal working machines using drills or boring bars. As shown in Table 6, there was an increase in the number of boring and drilling machines for metal working manufactured in 1905 as compared with 1900, but the value of this class of products was somewhat less at the later census.

Ohio, which was the leading state at both censuses, shows a decrease both in number and value of boring and drilling machines, while Illinois, the second state in rank, shows a considerable increase, advancing from fifth place in 1900. Pennsylvania was third in both 1900 and 1905, while Massachusetts, which was second in 1900, dropped to fourth place in 1905.

Table 7 shows, by states, the number and value of stamping, flanging, and forming machines for plate and sheet metal, manufactured at the censuses of 1900 and 1905.

TABLE 7.—*Production of stamping, flanging, and forming machines for plate and sheet metal, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	8,235	$2,003,861	7,895	$1,180,960
Connecticut	711	140,703	645	210,728
Illinois	1,466	284,433	1,205	122,240
New Jersey	145	61,078	196	77,329
New York	4,487	1,057,508	2,362	541,226
Ohio	713	239,685	1,709	67,622
All other states	713	211,454	1,778	155,815

As shown in Table 7, more than one-half of the total value of stamping, flanging, and forming machines manufactured in 1905 was reported for New York, which state was first also in 1900. A considerable increase is shown also for Illinois, which state advanced to second place in 1905, superseding Connecticut, which held that rank in 1900. Ohio, which was prominent in the manufacture of other kinds of metal working machinery, ranked third in the value of stamping, flanging, and forming machines; while Connecticut, second in 1900, is now fourth in rank in this manufacture.

The most marked increase shown for any class of metal working machinery was for pneumatic hand machines, the manufacture of which was of little importance in 1900, but was of such prominence in 1905 as to be entitled to fifth rank in the industry.

Table 8 shows the number and value of this class of machines, as reported at the censuses of 1900 and 1905.

TABLE 8.—*Production of pneumatic hand machines: 1905 and 1900.*

	Census.	Number.	Value.
United States	1905	19,297	$1,732,107
	1900	6,751	143,325

The enormous advance in the manufacture of pneumatic hand machines is indicated in Table 8, the number of such machines manufactured having increased 12,546, or almost twofold, and the value, $1,588,782, or over elevenfold. The principal increase is shown for Michigan and Ohio, the statistics for which states are not presented separately, to avoid the possibility of disclosing individual operations. The increasing use of pneumatic hand machines is described fully in a later section of this report.

The type of metal working machinery next in rank in 1905, according to value of products reported, was planers, including plate edge planers.

Table 9 shows, by states, the number and value of planers manufactured at the last two censuses.

TABLE 9.—*Production of planers, including plate edge planers, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	1,100	$1,551,616	1,543	$1,808,955
Connecticut	41	25,253	60	52,782
Massachusetts	257	243,140	368	262,100
Ohio	385	466,836	646	691,362
Pennsylvania	63	252,746	188	248,812
All other states	354	563,641	281	553,899

The decrease shown in Table 9 in the manufacture of this class of metal working machinery is largely for Ohio, which was the principal state in this production in both 1900 and 1905. Pennsylvania and Massachusetts were second and third, respectively, in rank, the former state showing a slight increase in 1905 over the value reported in 1900.

The production of punching and shearing machines is shown, by states in Table 10, for 1900 and 1905.

TABLE 10.—*Production of punching and shearing machines, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	4,328	$1,425,510	5,269	$1,219,605
Connecticut	127	36,017	1,156	149,400
Illinois	602	142,526	134	68,771
Massachusetts	113	37,075	132	7,008
Michigan	106	9,153	45	18,000
New Jersey	577	69,677	432	82,242
New York	851	294,521	861	154,773
Ohio	330	312,405	395	319,690
Pennsylvania	106	79,267	82	44,499
Wisconsin	667	82,362	288	31,700
All other states	849	362,507	1,744	343,522

Ohio, New York, and Illinois, in the order named, were the three leading states in the value of this production in 1905; in 1900 the first two held the same positions, while Illinois ranked fifth. The first named shows a slight decrease in value of products, while the other two states show large increases.

Table 11 shows by states the number and value of grinding and polishing machines manufactured at the last two censuses.

TABLE 11.—*Production of grinding and polishing machinery, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	19,193	$1,310,903	10,014	$880,965
Connecticut	537	126,296	722	77,442
Illinois	109	5,584	1,963	92,464
Massachusetts	1,981	225,258	1,798	124,447
Michigan	983	82,963	301	11,568
New Jersey	232	13,325	50	6,601
New York	4,880	70,732	1,353	54,604
Ohio	1,273	114,840	295	17,126
Pennsylvania	362	267,213	797	143,468
Rhode Island	2,897	343,334	1,868	266,804
Wisconsin	948	32,532	219	48,410
All other states	4,991	28,826	648	38,031

The term "grinding and polishing" includes all metal working machines using an abrasive cutter. This branch of the metal working machinery industry increased largely at the census of 1905 compared with that of 1900, the increase in the number of grinding and polishing machines manufactured being 91.7 per cent and in the value 48.8 per cent. The leading state in the value of these products, both in 1900 and 1905, was Rhode Island, with Pennsylvania second.

Table 12 shows, by states, the number and value of boring and turning mills or vertical lathes for 1900 and 1905.

TABLE 12.—*Production of boring and turning mills or vertical lathes, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	611	$913,695	534	$1,123,314
New Jersey	15	24,805	54	177,089
Ohio	99	248,807	140	412,800
Pennsylvania	117	182,600	14	23,985
All other states	380	457,483	326	509,440

There was an increase in the number of boring and turning mills manufactured, but a decrease in value reported in 1905 as compared with 1900. Ohio was the principal state in the value of this production in 1905 as well as in 1900, despite a large decrease. Connecticut, the second state in rank, is not shown separately, as to do so would disclose individual operations. The production for Pennsylvania, the third state in rank in 1905, increased considerably. Delaware, the fourth state in this manufacture, is included with "all other states."

Table 13 shows the number and value of bolt, nut, and pipe threading and tapping machines for 1900 and 1905.

TABLE 13.—*Production of bolt, nut, and pipe threading and tapping machines, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	2,687	$899,197	2,088	$698,362
Connecticut	943	209,137	62	19,002
New York	203	128,030	259	128,709
Ohio	855	246,598	975	363,896
Pennsylvania	238	109,343	266	97,034
All other states	448	206,089	526	89,721

An increase is shown in the total number and value of bolt, nut, and pipe threading and tapping machines reported at the census of 1905, as compared with 1900; but in Ohio, the principal state in this manufacture, a decrease is noted. Connecticut, however, shows marked increases, which, with the increases reported for the other states, was sufficient to cause the totals for the United States to show a gain.

The production of slotters and shapers is shown, by states, in Table 14 for 1900 and 1905.

TABLE 14.—*Production of slotters and shapers, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	2,012	$845,860	3,076	$1,136,350
Connecticut	167	61,877	457	149,664
Massachusetts	124	33,575	238	79,050
Michigan	108	66,487	159	59,250
New York	64	13,518	334	78,165
Ohio	1,060	331,569	1,354	421,229
Pennsylvania	109	197,826	115	177,732
All other states	380	141,008	419	171,260

The production of slotters and shapers shows a decrease during the period reported, both in the number and the value of machines manufactured. The principal state in the value of these products at both censuses was Ohio, with Pennsylvania second in rank. This branch of the metal working machinery industry is concentrated largely in these two states, the value of their combined products representing 52.7 per cent of the total for these manufactures in 1900 and 62.6 per cent in 1905.

Table 15 shows the number and value of hammers—steam, power, and drop—for 1900 and 1905.

TABLE 15.—*Production of hammers—steam, power, and drop—by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	1,934	$832,698	857	$671,287
Connecticut	131	114,277	140	115,559
Illinois	208	53,000	24	45,446
Iowa	175	20,700	25	2,300
New Jersey	39	11,730	18	4,200
New York	378	238,642	233	109,968
Ohio	36	63,300	58	53,552
Pennsylvania	205	232,249	225	300,021
All other states	762	98,800	134	40,241

An increase is shown in Table 15, both in the number and value of hammers—steam, power, and drop—reported in 1905, as compared with 1900. The three leading states in this manufacture—New York, Pennsylvania, and Connecticut—together reported 70.3 per cent of the production in 1905 and 78.3 per cent in 1900. In 1905 New York ranked first, having advanced from third place in 1900, and showing an increase in the value of production of 117 per cent. Pennsylvania, first in rank in value of products in 1900, occupies second rank in 1905 with a considerably reduced production, and Connecticut, although holding second place as in 1900, shows a slightly diminished value of products in 1905.

The next class of metal working machines is bolt headers and other machines for forging hot metal with dies and with pressure. This manufacture is shown in Table 16 for the last two censuses.

TABLE 16.—*Production of forging machines, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	390	$437,097	821	$424,774
Ohio	195	305,397	230	290,300
All other states	195	131,700	591	134,474

The term "forging machines" includes bolt headers and all other machines for forging hot metal with dies and with pressure. A slight increase is noticeable in the value of this class of machinery manufactured at the census of 1905 as compared with 1900, but the number of machines is considerably less. This branch of the industry is concentrated to a large degree in Ohio, and although these machines are reported as manufactured in a number of other states the statistics can not be shown separately.

Riveting machines are considered as a class of metal working machinery, and the production as reported at the censuses of 1900 and 1905 is shown by states in Table 17.

TABLE 17.—*Production of riveting machines, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	645	$238,829	202	$139,295
Connecticut	257	100,657	76	20,728
New York	133	63,172	25	13,200
Ohio	36	9,525	6	300
Pennsylvania	148	42,980	81	102,370
All other states	71	22,495	14	2,697

The manufacture of riveting machines in the United States, though of small extent, increased materially during the five-year period reported. In 1905 Connecticut reported the principal production, superseding Pennsylvania, which was the leading state in 1900.

In Table 18 the number and value of bending and straightening rolls manufactured in 1900 and 1905 is shown by states.

TABLE 18.—*Production of bending and straightening rolls, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	174	$190,578	914	$202,230
Ohio	71	81,527	65	73,382
Pennsylvania	16	7,217	16	31,898
All other states	87	101,834	833	96,950

This type of metal working machinery shows a considerable decrease in number of machines reported and only a small decrease in the total value of the same in

1905 as compared with 1900. Ohio, the leading state in this manufacture, shows an increase in the value of production, while a decided decrease is shown for Pennsylvania.

The statistics for sawing machines, a class of metal working machinery which also shows a decrease in the five-year period from 1900 to 1905, are presented by states in Table 19.

TABLE 19.—*Production of sawing machines, by states: 1905 and 1900.*

STATE.	1905		1900	
	Number.	Value.	Number.	Value.
United States	2,806	$165,428	2,846	$222,563
Connecticut	49	1,830	277	11,947
Illinois	701	17,680	1,998	77,310
Ohio	101	23,648	16	2,203
Pennsylvania	209	77,220	193	99,953
All other states	1,746	45,050	362	31,050

The leading state in this manufacture, both in 1900 and 1905, was Pennsylvania; Ohio was second in importance in 1905, superseding Illinois, which was second in 1900.

There are numerous metal working machines not specially classified which are included under the general head of "all other metal working machinery," and this item is seen from Table 3 to form 28.1 per cent of the total for 1905. It may be that certain machines have inadvertently been included under this heading which by a strict ruling might properly belong under some of the itemized classifications, it being very difficult for certain manufacturers to accurately divide their product under the specific headings as required by the schedule. There is also included under this general head small tools, such as chucks, bits, and dies, which make up more than half of the total value reported; precision tools and machines; and duplicate parts, which are made to replace the wear on metal machinery already in use. This latter is a considerable item, inasmuch as most of the machinery in use to-day is standardized; that is, the parts are made largely to be interchangeable, and if a portion of the machine becomes worn or unserviceable it is not necessary to buy an entire new machine or to have a part made to order, as the manufacturer stands ready to furnish duplicate parts without delay.

Table 20 distributes the total value for "all other metal working machinery" among these several specified items for 1905, no separate report having been made for the same in 1900.

TABLE 20.—*Production of "all other metal working machinery," by states: 1905.*

STATE.	Total.	Small tools for metal working machines.	Precision tools and machines.	All other metal working machines and duplicate parts.
United States	$9,090,189	$4,693,186	$995,430	$3,401,573
Connecticut	1,845,650	906,486	34,295	904,869
Illinois	651,609	254,672	21,727	375,210
Massachusetts	2,646,919	1,587,999	687,915	371,005
Michigan	221,703	106,833		114,870
Missouri	115,391	59,096		56,295
New York	1,036,397	405,091	5,256	626,050
Pennsylvania	392,793	275,024	3,075	114,694
Rhode Island	419,037	129,572	187,276	102,189
All other states	1,760,690	968,413	55,886	736,391

As seen in Table 20, Massachusetts was the principal state in the manufacture of small tools for metal working machines and also in precision tools and machines, with Connecticut second in rank in the former and Rhode Island in the latter manufacture. Connecticut leads in the manufacture of duplicate parts and all other metal working machines, with New York second and Illinois third, while Massachusetts is fourth in rank.

The total value of small tools for metal working machines manufactured in the United States in 1905 was $4,693,186, which was 14.5 per cent of the total for all classes of metal working machines. It was intended that only tools for use in power driven machinery were to be reported under this head, but it is possible that some hand tools have been included. However, as there may be some manufacture of this class of apparatus not reported, it is believed that the value presented is a fairly accurate report of this important branch of metal working machinery manufacture.

The value of duplicate parts and metal working machinery, not specified, as reported at the census of 1905, amounted to 10.5 per cent of the total for all classes of metal working machinery.

The following is a synopsis of the development of the metal working machinery industry from a technical standpoint:

DEVELOPMENT OF THE INDUSTRY.

Foreign use of American tools.—American made metal working machinery is found in almost every portion of the civilized world. Some of the best automobile factories of France, watch factories of Switzerland, small arms factories in Berlin, Germany and Liege, Belgium, and bicycle factories in Coventry, England, are equipped with American built machinery. It is largely through the use of highly specialized machinery that American manufacturers are able to compete with the products of European shops. Whatever the cause underlying the superiority of American machinery, whether higher grade labor, the great incentive for workingmen to improve the machines they use, or because many mechanics have become manufacturers, or for all these reasons combined, the fact stands out that American tools are used extensively in foreign countries and that their effectiveness is recognized everywhere.

One of the greatest obstacles to the growth of the foreign trade of the United States in metal working machinery has been the difficulty of adjusting American tools to European shop methods, or of educating the European mechanic in the use of American tools. The influence of one upon the other is seen in the modification of American machinery to meet European ideas and the gradual change in European shop methods to meet the requirements of American machines and tools. An evidence of the close touch into which the machine and tool makers of the old and new worlds have been brought is found in the fact that an American technical journal, covering the field of machine tool construction, has 5,000 subscribers in Europe and is the medium for a constant exchange of ideas between the manufacturers and mechanicians of both hemispheres.

Specialization in manufacture.—One of the most striking features of the development of the metal working machinery industry is the specialization in manufacture that has taken place in recent years. This specialization has gone on to such an extent that there is not a single establishment in the United States in which a complete line of metal working machinery is constructed.

In this practice of confining an establishment to the manufacture of one class or a few distinct classes of machines, American builders have pursued a policy quite different from that of foreign builders, who usually are ready to undertake the manufacture of any machinery required by a customer. The tendency in the United States is toward a still greater specialization, and there is some indication of a disposition on the part of British and continental tool builders to adopt the same plan.

The progressiveness of American manufacturers is shown also in their readiness and ability to manufacture special machinery for use in a new machine building industry. This was true of the bicycle industry and is now true of the automobile industry.

High speed steel.—The invention of high speed steel has had a marked effect upon the development of the metal working machinery industry. The first of these steels was invented by Messrs. F. W. Taylor and Maunsel White, at Bethlehem, Pa., some time previous to the Paris Exposition of 1900. At that exposition they exhibited tools made of this steel, in use in a heavy and powerful lathe, taking heavy cuts at unheard of speeds—80, 90, or 100 feet per minute, instead of the 18 to 22 feet per minute that previously had been the maximum for heavy cuts in hard material. Such work attracted a great deal of attention, not only among builders of machinery, a considerable part of whose work consists in taking heavy cuts from imperfectly shaped castings or forgings, but also among steelmakers, a large number of whom, recognizing the importance of such steel, have undertaken to manufacture it.

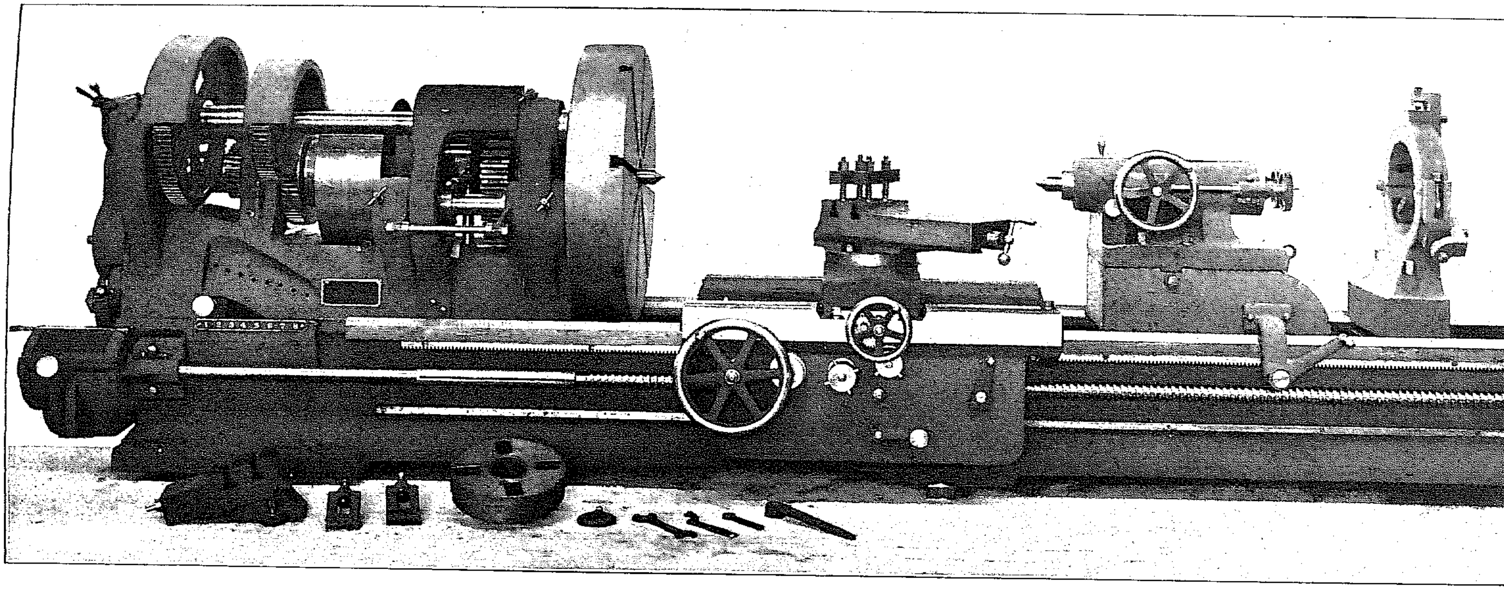
Although it is true that high speed steel is not stronger and will not take a heavier cut than the carbon steel previously used, if indeed so heavy, the fact that it will take a cut nearly as heavy at a very much higher speed has led to important modifications of certain metal working machines, especially lathes for heavy work.

One modification has been the redesigning of the driving mechanism of the lathe to make it capable of enduring for a reasonable time the stress of the greatly increased speeds. The belts and gears by means of which the power was commonly conveyed were so changed as to give the same torque, or driving force, with greatly increased speeds.

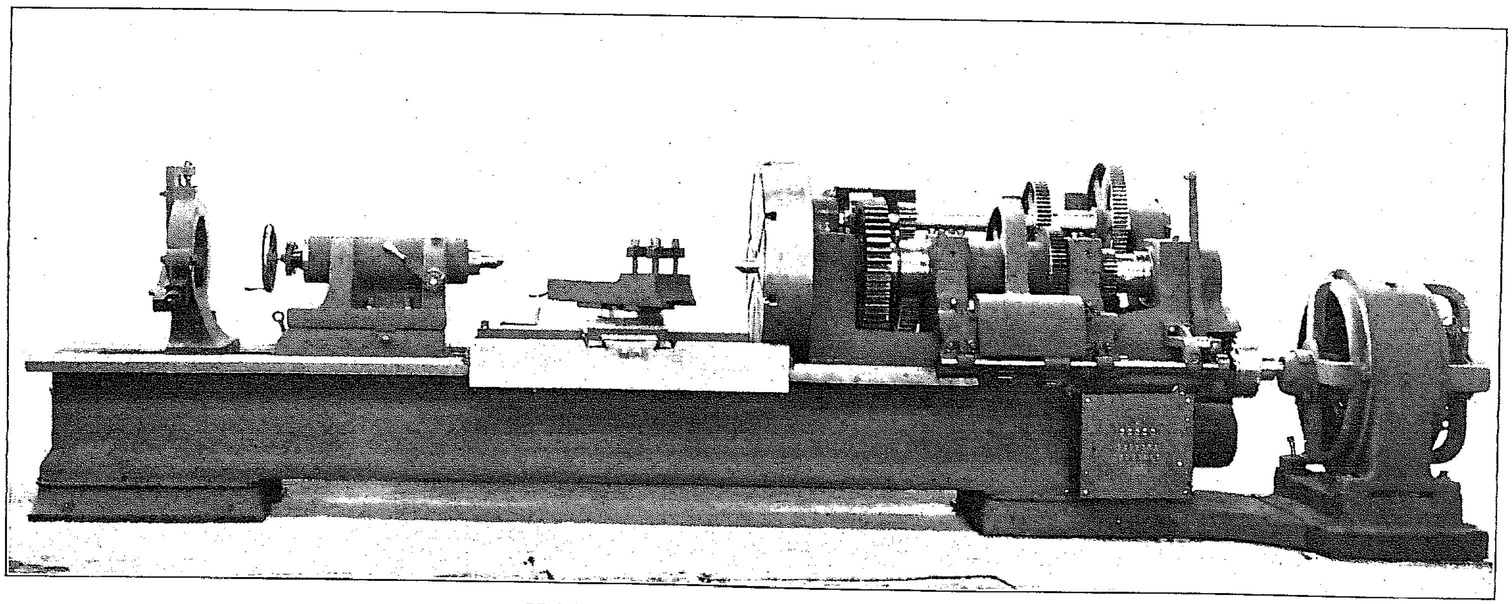
Another important modification has resulted from the fact that systematic tests made to show just how fast a heavy cut could be taken have led to a change of ideas as to what constitutes a heavy cut, and to a demand on the part of machine tool users for machines that will not only endure the higher speeds called for by the new steels but will also carry heavier cuts than were formerly thought to be practicable.

The use of high speed steel has resulted in a considerable reduction of the cost of certain kinds of work in machine construction, especially the removal of surplus metal from forgings and castings of iron and steel. This has led to some misunderstanding as to the total net effect of the use of high speed steel, the fact having often been overlooked that in the construction of many kinds of machinery, the chief item of expense is not the cost of taking such heavy cuts as may be required but the cost of the finishing processes which involve the taking of light cuts, careful gauging, grinding, hand scraping, and other operations that must be performed with care by skilled men. The cost of the finishing processes has been reduced but little by the use of high speed steels, and as in many cases they constitute the principal item of cost, high speed steel has affected the cost of producing the finer grades of machines much less than might have been expected.

Speed adjustment.—The use of high speed steels has led also to a much closer scrutiny of the speeds and feeds, or in other words, the rate of cutting and the thickness of the chip taken in cutting metals, and thus has



LATHE ARRANGED FOR DRIVING BY A CONSTANT-SPEED BELT.



REAR VIEW OF LATHE DRIVEN BY ELECTRIC MOTOR.

stimulated greatly the development of speed changing devices. Until a few years ago the stepped or so-called cone pulley, with one change by gearing, was practically the only device employed for altering the speed of a machine tool to adapt the speed to the requirements of the work in hand. Within the past five years, however, there has come the development and application of many new devices for this purpose, by means of which the operator, by merely shifting a lever, alters the speed without having to stop the machine to shift the driving belt from one to another position upon the pulleys, and without changing the speed of the driving belt itself. The belt is thus enabled, by its constant speed, to deliver energy to the machine at a uniform rate; a thing which it can not do when running upon cone pulleys, and which it is important that it should be able to do. An illustration of a lathe arranged for driving by a constant speed belt is shown on plate facing page 14.

Some of the geared heads developed by the improvement of speed changing devices are capable of imparting to the work not only a great total range of speeds, but the changes from a given rate to the next higher or the next lower are by much finer gradations; as a result there is a smaller loss of efficiency due to the fact that the available rate of speed nearest to that which would be exactly right for the work in hand is too high or too low. The ideal toward which designers are striving is an arrangement that, for any given piece of work within the capacity of the lathe or other tool, will give the exact speed for that work.

Electricity also has played an important part in the development of speed changing devices. Many machine tools are now driven by direct connected motors. In some instances the motors are incorporated as an integral part of the design, in others they appear rather as an attachment to the machine, which can with little alteration be driven either by a belt from shafting in the ordinary way or by a motor. The motors themselves are often arranged to run at varying speeds, though seldom with sufficient variation to cover the whole range required, the remaining speeds being obtained by the use of gears manipulated by shifting levers. By means of resistance boxes or of motors constructed so as to run at different speeds without the use of such boxes, together with gear devices, great ranges of speed, changing by small gradations, have been attained.

An illustration of a lathe driven by an electric motor is shown on plate facing page 14.

The front and rear views of a lathe having these modern driving arrangements are shown in the preceding illustrations; the lathe in each case being essentially the same but arranged for belt driving in one case and for motor drive in the other. Of the four uprights and bearings on the headstock, only the two outside or end ones support the spindle, the inner ones supporting only a sleeve to which the power is applied for driving, and which is bored through somewhat larger than the spindle so that there is no bearing of the one upon the other. The speed of the first motion shaft is constant and from it the varying speeds required for the work are obtained by the various gears shown, different combinations of which are obtained by means of clutches.

Portable tools.—The tendency to do things on an increasingly larger scale in all branches of industry has had a marked effect upon the machine tool industry, in that it has caused machine tools to be built larger, and has also given rise to the invention and adoption of smaller or portable tools.

Machine tools of large size are constructed to perform such work as is required at the time they are made. Since the cost of such tools is high, and their maintenance constitutes a large item of expense, the work they are called upon to do grows constantly larger. Nevertheless it has been found that certain classes of machine tools can not be built larger to advantage, since many castings which were formerly handled within the machines are now of such great size and weight as to make this method of machining them practically impossible.

To meet this condition a class of machine tools has been evolved which is designated as "portable;" these tools are portable in the sense that traveling cranes may pick them up and carry them where wanted. Such tools, instead of being constructed of such size and power as to enable them to take large castings within themselves, are designed only to hold, direct, and drive the cutting tools needed for the various operations to be performed, the pieces operated upon being held stationary upon the floor plates.

Attached or incorporated electric motors are employed usually for driving these portable tools. This enables them to be conveniently driven in any position in which it may be necessary to place them. It is now common to see a number of such portable tools working simultaneously upon one casting, so that boring, drilling, slotting, milling, key seating and other operations may all be done at one time, each independent of the others.

One of the latest and most interesting features of such work is the practice of setting in position both the work and the tools by means of a transit, much like that employed by civil engineers in surveying, but made with considerably greater refinement. This enables the attainment of the degree of accuracy required where allowable limits of error are usually stated in thousandths of an inch. These refinements have in turn raised the standard of accuracy so that in large electric generators and similar heavy work a degree of accuracy is now easily attained that would have been impracticable a few years ago.

Automatics.—A class of machines originally designed for making screws, but more recently employed also in making numerous small parts of machines and other articles, and known to the trade as "automatics," has been developed considerably during the period covered by this report.

Only a few years ago automatic machines were made to handle stock only up to about 1 inch in diameter, and an "automatic" that could handle inch stock was looked upon as a large machine of its class. At first they were used almost exclusively for making the screws, hence the name "automatic screw machines." They are now made to handle steel bars up to 6 inches in diameter and are used for an almost endless variety of small parts. A more appropriate name for such machines, therefore, would be "automatic turret lathes," as their present function is not merely to make screws, but also to do lathe work.

An important addition to the automatic screw machines is the "magazine" attached to them, by means of which castings or small forgings are fed successively to the machines. At the Paris Exposition of 1900 an American tool builder exhibited a screw machine thus equipped which did all the machining operations upon the handwheel of a sewing machine, and required no attention whatever except to keep the magazine supplied with castings and the various cutting tools sharp and properly adjusted.

The variety of automatics known as the "multiple-spindle automatic" in particular has been developed greatly. In this machine there may be as many as five spindles, each holding and driving a separate bar of stock, to which the cutting tools are presented simultaneously for action. This means that a screw or other article requiring as many as five distinct operations to complete it may be made on this machine in the time required for performing the longest operation, because the tools used for performing the four shorter operations complete these before the operation requiring the longest time is completed. In some cases the apparently impossible task of reducing this time can be accomplished, as, for instance, where the time required for the longest operation is considerably greater than that required for any other, and the total number of operations to be performed is at least one less than the number of spindles in the machine. In such a case the principal operation is divided between two spindles, each performing one-half, so that the total time required for completing the piece is reduced to that of the next shorter operation, and thus the capacity of the machine is increased greatly.

A multiple-spindle machine is shown on the plate facing page 16, the four work-holding spindles being seen at the left and the tool-holding spindles in line with them at the right. In this machine the work-holding spindles may either rotate or remain stationary during a given operation and the tool-holding spindles may do the same. This fact is taken advantage of in arranging the various cutting speeds required. A speed may be that due to the rotation of the work-holding spindle alone, to that of the tool-holding spindle alone, or it may be the sum of or the difference between the two.

In threading work the operation of this machine differs from that of all others in that the work is held stationary during this process, and that all the chips are carried away by the oil being forced through the die-holding spindle, which is hollow, and through the die. When the thread is completed, no change takes place in the rotation of the die-holding spindle, but the work-holding spindle commences to rotate at higher speed in the same direction, and thus runs the die off without reversing the rotary motion.

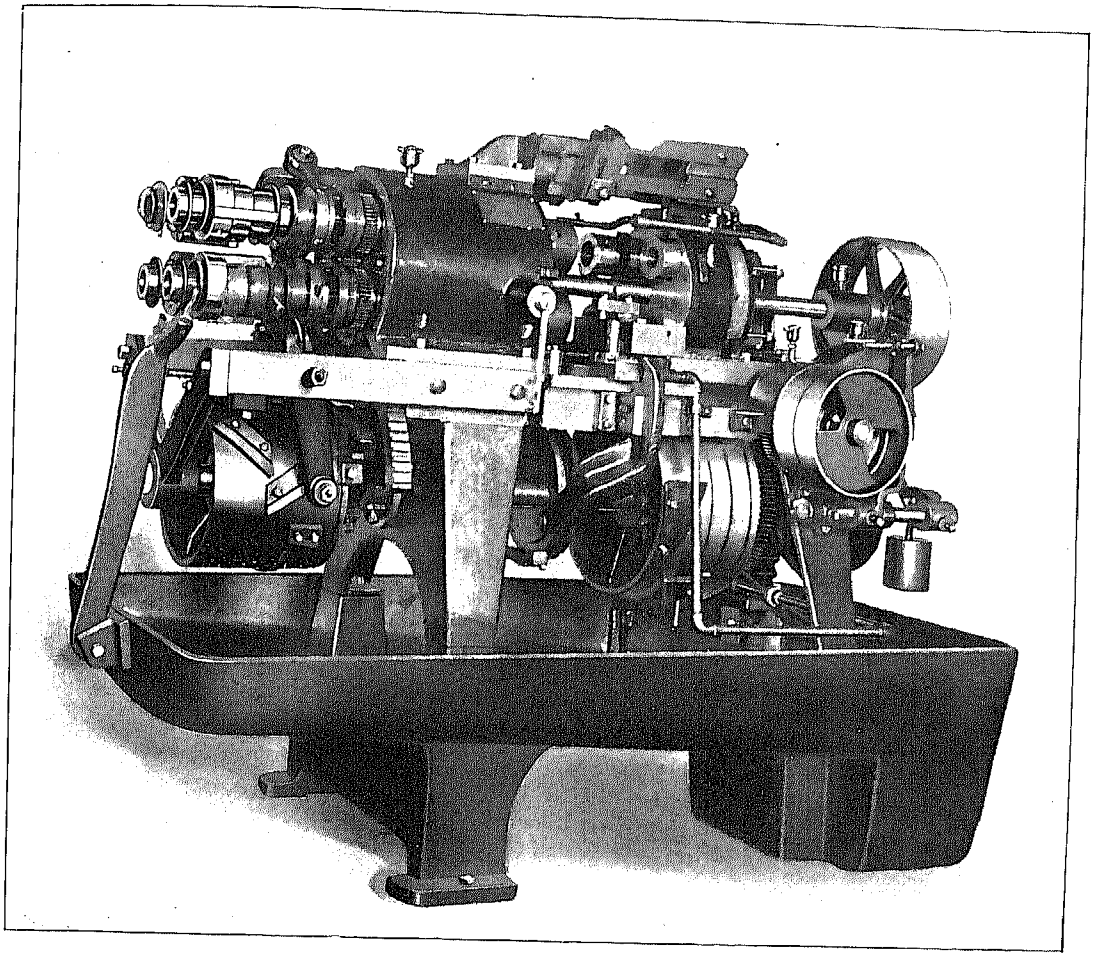
In another machine of the automatic class, which is still in the process of development, compressed air is used for moving the various parts of the machine in order to present the tools consecutively to the work and for the motions necessary for the cutting operations. The extreme lightness of air as compared with the mechanisms ordinarily employed for this purpose enables the motions usually designated as "idle motions" (to distinguish them from the motions used in actual cutting) to be made much more quickly than is otherwise possible, and thus the time consumed in the withdrawal of one tool and the presentation of another is reduced greatly.

Such improvements as these do not, however, materially reduce the labor cost of producing the work, because they do not affect the relatively small proportion of the work done by the operator. They reduce the cost only by giving a greater product with a given investment in machinery and tool equipment and within a given area of shop floor occupied. This reduction forms, however, in many cases a considerable proportion of the original total cost.

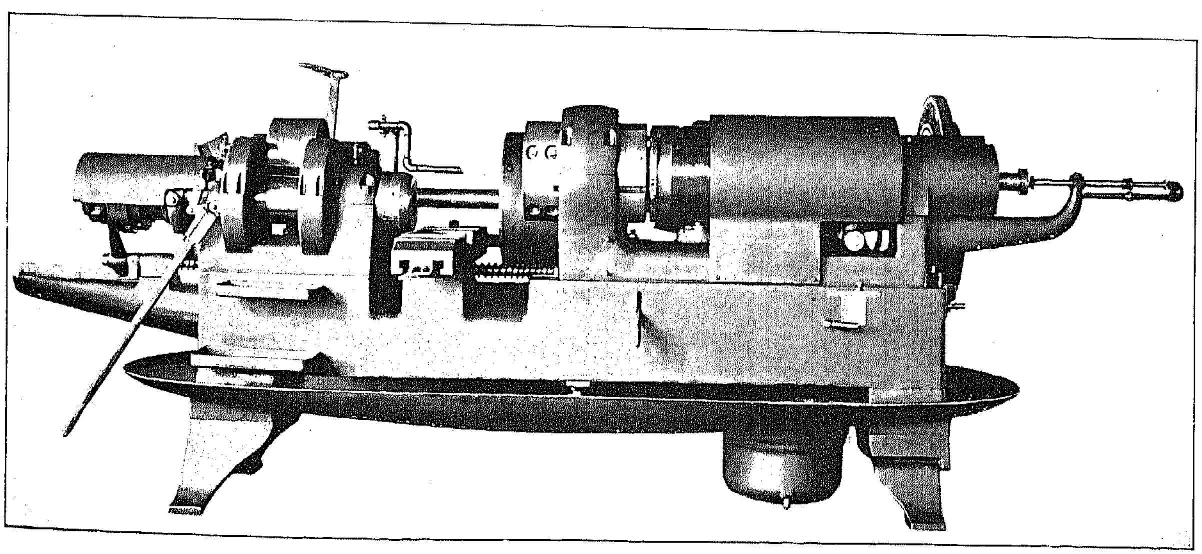
Compressed air seems likely to be used more extensively as machine tools are developed. The facility and rapidity with which it can be conveyed and its small mass makes it well adapted for use in metal working machinery. In fact, its extreme rapidity needs checking in some instances where uniformity of motion is required under varying resistance, and this check is applied by the use of a body of water or oil, which is forced by the air pressure through a restricted but usually adjustable opening and in turn acts upon the mechanism to be moved. The liquid, by resisting sudden changes in its rate of flow, regulates the speed of the motion.

The increasing use of automatic machine tools has led to the regular manufacture of automatic screw machines large enough to take bars of steel through their spindles up to 6 inches diameter and to make parts of machines from such bars. An illustration of such a machine is shown on the plate facing page 16.

The bars of stock, which may be the diameter named above and 10 feet in length and weighing about 1,000 pounds, pass through the spindle seen at the left, which is driven by incased gears that in turn are



MULTIPLE-SPINDLE AUTOMATIC SCREW MACHINE.



AUTOMATIC SCREW MACHINE FOR WORKING BARS 6 INCHES IN DIAMETER.

driven by pinions upon the shaft at the rear, on which the pulleys are to be seen. The turret in this type of machine has a horizontal axis, which is sufficiently offset from that of the spindle to bring the various cutting tools successively into line with the spindle for action. On the cross slide tools having a width up to 7 inches can be used for forming work, and the machine handles the 6-inch bars of steel entirely automatically with as much certainty and as little trouble as the smaller and more common sizes handle half-inch bars. The pipe connection at the extreme right is for forcing oil through the cutting tools, and the arrangement is such that only the tool which is in line with the spindle—i. e., in position for working—gets a supply of oil. The various levers seen are only for manipulating the machine at starting or in "setting up," its action being entirely automatic after it is started.

An automatic screw machine in which there is a partial application of compressed air for effecting the required movements is shown on the plate facing page 18.

The machine shown is equipped with a horizontal disk, which is placed above the turret and performs the function of a magazine. The machine is shown as arranged for drilling, chamfering, and tapping brass nuts for a 1-inch standard pipe thread, and all that is necessary is to place the blanks in the shallow recesses upon the surface of the disk. The machine presents them successively in position to be gripped by a vertically moving mechanism, which, taking one blank at a time, carries it down to a position in front of the chuck, from which it is placed within the chuck jaws. The chuck is then closed by air pressure, the various operations completed, and the finished nut ejected. The illustration gives a rear view of the machine, which shows the working parts better than a front view.

Some little adaptation of the turret mechanism usually has to be made for different pieces, and in the case of such a piece as a handwheel for a sewing machine the magazine is attached to the head stock instead of the turret, and the wheels move by gravity one after the other into position to be gripped by the device which carries them in front of the chuck. By some such means almost any casting or forging required in numbers sufficient to justify the outlay for tools and appliances can be finished without other manual labor than that required to place it in the magazine.

An "automatic" of a different type is shown on the plate facing page 18. This machine is intended for bars of stock up to seven-eighths of an inch in diameter and will feed this stock forward toward the tools any required distance up to 4 inches at a single movement. The machine is remarkable for its compactness, and its motions are made with great rapidity.

In general design it is a radical departure from the earlier machine shown in the special report made at the census of 1880. The turret has a horizontal instead of a vertical axis, and this axis lies at right angles to the axis of the spindle, thus bringing the turret nearer the operator for convenience in "setting up," and affording plenty of clear space for the tools.

The various motions are derived from cams which are placed upon two shafts running lengthwise to the bed. These shafts run comparatively fast, so that quick motions of the various tools are secured with very moderate angles of action upon the cams. The same illustration would answer for a number of similar machines of different sizes. Hardened steel parts are used freely to enable the machine to withstand the shocks incident to great rapidity of motion, and its freedom from noise is remarkable.

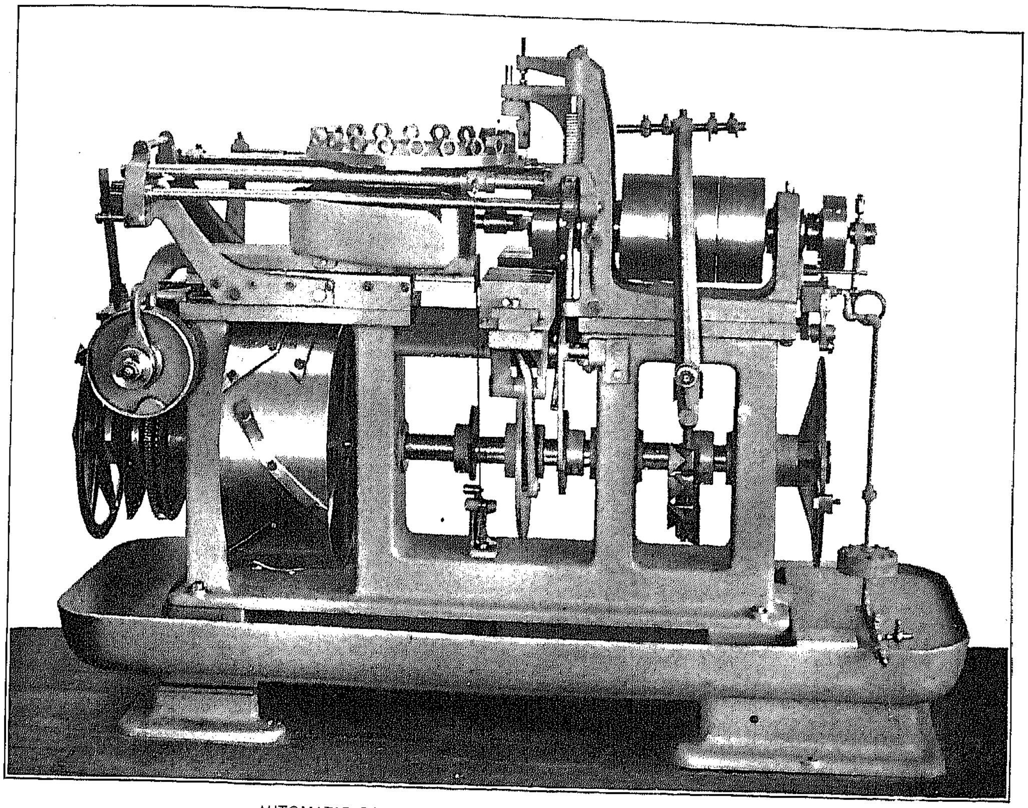
New grinding process.—The process of grinding, which was formerly applied only to the work of finishing true and to size such parts of machines and tools as were made of steel so hardened as to make cutting tools unavailable, has of recent years been developed and applied much more widely than before. It is now used for finishing to size many cylindrical parts of machines formerly finished by the much less certain and precise method of turning in a lathe.

Marvelous results in grinding have been obtained by applying great power to driving a relatively large and heavy abrasive wheel which at every turn is made to sweep over the work the full width of the wheel. For instance, in refinishing locomotive piston rods that have become badly worn or scored, a special grinding machine of this kind has been invented which does the work more quickly and with much greater precision than is possible by the older methods. In finishing automobile crank shafts, work which is tedious by ordinary methods, this process of grinding has proven remarkably efficient.

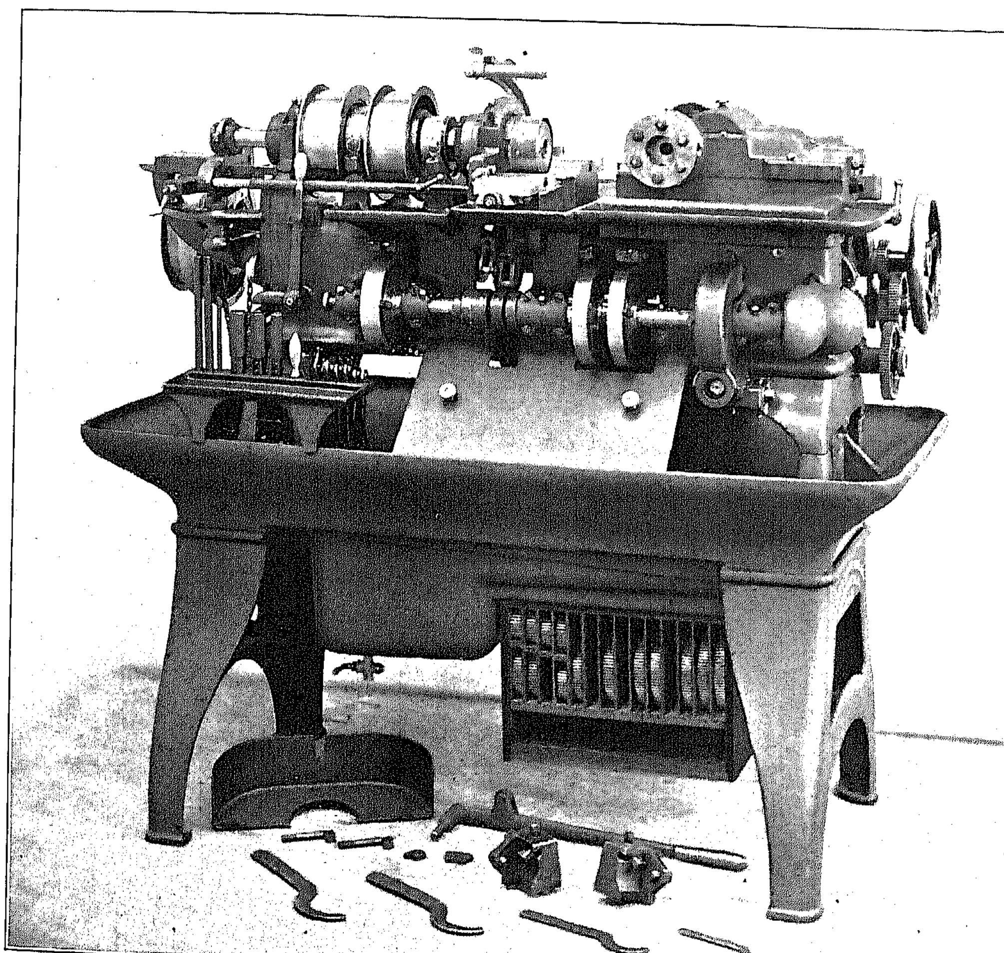
Interchangeable tools.—As a result of the specialization in machine tool manufacturing, many American tools are now made wholly or in part upon the interchangeable plan. The extent to which this plan is used in a given shop depends mainly upon the number of identical machines to be built. Most machine tool establishments have long made certain parts of their machines upon the interchangeable system. Screws, bolts, change gears, and other things, component parts of engine lathes and used in numbers much larger than the number of lathes built, have usually been made in large quantities "for stock." Such parts can be made upon the interchangeable plan with sufficient accuracy, by means of special tools and gauges which cost little, if any, more than such tools as would be required to make similar parts without regard to interchangeability. For other parts of the lathe, however, the tool equipment required for interchangeable manufacture is more elaborate. Such tools have been made and used only as the number of identical lathes to be manufactured in a given shop has increased to a point justifying the expense.

This fact has led to a great difference in practice between different shops; those building many lathes having carried the principle of interchangeable manufacture very far, while others have applied it to only a limited extent. Naturally also the size of the lathes built in a shop has considerable influence, because for large lathes, built in small numbers and for which the tools and fixtures are much more costly, a point is soon reached at which the proportionate cost for tools which must be charged to each lathe becomes prohibitive.

The development of the industry which has been going on has, however, led to an increasing application of the principle of interchangeable manufacture to the production of metal working machinery, and this is one of the most prominent, important, and interesting features of the business as now carried on. Even some of the larger machines which, a few years ago were built one at a time and only upon orders, are now manufactured in considerable numbers by the aid of special tools and fixtures and with many if not all of their parts interchangeable.



AUTOMATIC SCREW MACHINE WITH MAGAZINE ATTACHMENT.



AUTOMATIC SCREW MACHINE.

MUSICAL INSTRUMENTS, ATTACHMENTS, AND MATERIALS

MUSICAL INSTRUMENTS, ATTACHMENTS, AND MATERIALS.

By William F. Worcester.

The census of 1860 was the first to accord special treatment to the manufacture of musical instruments. Subsequently no special report upon the industry was prepared until the census of 1900, when a report entitled "Musical Instruments and Materials" was published. From the census of 1880 to that of 1900, inclusive, the establishments manufacturing this class of products were classified, according to the product of principal value, as follows: "Musical instruments and materials, not specified;" "musical instruments, organs and materials;" and "musical instruments, pianos, and materials."

The manufacture of materials for organs and pianos conducted apart from the establishments producing the finished articles is now a well defined branch of the industry, and accordingly, at the census of 1905 establishments manufacturing materials for organ and piano makers were classified as "musical instruments, organ and piano materials," instead of being merged with the manufacture of organs and pianos, as indicated above. The classifications "musical instruments, organs," and "musical instruments, pianos," of the census of 1905, therefore, are not comparable with the classifications of previous censuses covering the same products, since the latter include also the production of piano and organ materials.

THE COMBINED INDUSTRY.

In Table 1 is presented a combined comparative summary showing the progress of the industry from a statistical standpoint since 1860.

Table 1.—MUSICAL INSTRUMENTS, ATTACHMENTS, AND MATERIALS—COMPARATIVE SUMMARY, WITH PER CENT OF INCREASE: 1860 TO 1905.

	CENSUS.						PER CENT OF INCREASE.				
	1905[1]	1900[2]	1890	1880	1870	1860	1900 to 1905	1890 to 1900	1880 to 1890	1870 to 1880	1860 to 1870
Number of establishments	625	619	674	429	337	223	1.0	[3]8.2	57.1	27.3	51.1
Capital	$72,225,379	$47,706,582	$29,650,489	$14,446,765	$9,554,761	$4,431,900	51.4	60.9	105.2	51.2	115.6
Salaried officials, clerks, etc., number	2,947	1,676	[4]1,332	(5)	(5)	(5)	75.8	25.8	....	....	....
Salaries	$3,979,696	$2,156,371	[4]$1,657,735	(5)	(5)	(5)	84.6	30.1	....	....	....
Wage-earners, average number	35,220	23,714	18,096	11,350	7,167	4,461	48.5	31.0	59.4	58.4	60.7
Total wages	$19,689,146	$12,774,902	$11,648,648	$7,098,794	$5,107,201	$2,378,520	54.1	9.7	64.1	39.0	114.7
Men 16 years and over	33,212	22,398	17,661	10,925	7,001	(5)	48.3	26.8	61.7	56.0	....
Wages	$19,115,547	$12,447,965	$11,499,617	(5)	(5)	(5)	53.6	8.2	....	....	....
Women 16 years and over	1,424	781	352	175	68	(5)	82.3	121.9	101.1	157.4	....
Wages	$454,447	$219,417	$134,034	(5)	(5)	(5)	107.1	63.7	....	....	....
Children under 16 years	584	535	83	250	98	(5)	9.2	544.6	[3]66.8	155.1	....
Wages	$119,152	$107,520	$14,997	(5)	(5)	(5)	10.8	616.9	....	....	....
Miscellaneous expenses	$7,564,994	$3,783,714	$2,394,316	(6)	(6)	(6)	99.9	58.0	....	....	....
Cost of materials used	$29,116,566	$18,576,022	$14,436,163	$8,361,227	$4,834,552	$2,144,208	56.7	28.7	72.7	73.0	125.5
Value of products	$69,574,340	$44,418,978	$36,868,169	$19,254,739	$13,905,908	$6,548,432	56.6	20.5	91.5	38.5	112.4

[1] Exclusive of the statistics of 3 establishments engaged primarily in the manufacture of products other than musical instruments, attachments, and materials. These establishments made musical instruments to the value of $69,114.
[2] The totals do not agree with those published in the general tables at the Twelfth Census because of a reclassification.
[3] Decrease.
[4] Includes proprietors and firm members, with their salaries; number only reported in 1900 and 1905, but not included in this table.
[5] Not reported separately.
[6] Not reported.

It is apparent from the table that as early as 1860 the industry had assumed proportions of some importance. At that time there were 223 establishments which produced musical instruments to the value of $6,548,432. Since that date the figures in each census have exceeded those of preceding decades for every item, with the exception of the number of establishments and the number of children employed. At the census of 1900 the number of establishments decreased for the first time. This decrease is in line with the concentration movement which has characterized so many of the industries in the United States during the past fifteen years. As a result of the movement in this industry, the table shows that since 1890 the operations of the average establishment have practically doubled.

A notable feature of the table is the increase in the industry since 1900. The absolute increase of $25,155,362 in the value of products for the five years is greater by far than the absolute increase for any of the ten-year periods shown, over three times as large as that of the decade preceding, and about equal to that of the twenty years from 1880 to 1900.

In Table 2 the aggregate for the different statistical items at the census of 1905 are distributed by industries.

TABLE 2.—MUSICAL INSTRUMENTS, ATTACHMENTS, AND MATERIALS—SUMMARY, BY INDUSTRIES, WITH PER CENT OF TOTAL: 1905.

	Total.	Pianos.	Per cent of total.	Organs.	Per cent of total.	Piano and organ materials.	Per cent of total.	Instruments and materials not specified.	Per cent of total.
Number of establishments	625	249	39.9	94	15.0	101	16.1	181	29.0
Capital	$72,225,379	$49,649,135	68.7	$7,203,878	10.0	$11,628,897	16.1	$3,743,469	5.2
Salaried officials, clerks, etc., number	2,947	2,068	70.2	323	11.0	331	11.2	225	7.6
Salaries	$3,979,696	$2,846,685	71.5	$372,362	9.4	$508,883	12.8	$251,766	6.3
Wage-earners, average number	35,220	21,002	59.6	3,623	10.3	8,456	24.0	2,139	6.1
Wages	$19,689,146	$12,170,251	61.8	$2,034,559	10.3	$4,322,268	22.0	$1,162,068	5.9
Miscellaneous expenses	$7,564,994	$5,532,420	73.1	$818,276	10.8	$787,475	10.4	$426,823	5.7
Cost of materials used	$29,116,566	$19,587,770	67.3	$2,068,638	7.1	$6,330,219	21.7	$1,129,939	3.9
Value of products	$69,574,340	$46,922,471	67.4	$6,041,844	8.7	$13,128,315	18.9	$3,481,710	5.0

The statistics reveal at a glance the overwhelming importance of the piano industry when compared with the others which compose the combined industry. To the manufacture of pianos, piano players, and attachments were assignable 68.7 per cent of the aggregate capital and 67.4 per cent of the aggregate value of products of the combined industries at the census of 1905. Next in importance was the manufacture of piano and organ materials, which in value of products considerably exceeded the value of the combined output of the two remaining industries. In connection with this branch it should be noted here that, theoretically at least, the entire value of product of the industry is duplicated in the combined aggregate. The products of the establishments comprising the classification must pass through the organ or piano factory, where they are incorporated with other materials to form the final products, and thus their value is included twice in the aggregate value for the four industries. Necessarily, then, as the specialization in the manufacture of pianos and organs increases and the final producers of the instruments become more and more assemblers of parts rather than manufacturers, the duplication in the products of the combined industries will become greater. Since the manufacture of piano and organ parts has not been segregated previous to the present census, it is impossible to draw any inference from the table concerning the growth of this tendency toward specialization in the manufacture of these instruments. Significant and interesting conclusions concerning the growth may be drawn from subsequent censuses, however, in case the values returned for the products of the classification "musical instruments, piano and organ materials" constitute increasing proportions of the values reported for the products of the combined industry.

Many establishments engaged primarily in the manufacture of pianos produce also some organs, while others, whose principal products are organs, manufacture a limited number of pianos. Since the establishments are classified according to the product of greatest value, it is impossible to avoid some intermingling of products. Thus the value of products for the classification "musical instruments, pianos," will include the value of some organs, and the value of products of "musical instruments, organs," will include the value of the pianos produced as products of secondary value by the establishment in this classification.

Table 3 indicates the extent of the intermingling of products at the census of 1905, showing in detail the kind, number, and value of the pianos and organs produced by the establishments in the two industries.

TABLE 3.—*Musical instruments, pianos and organs—products of each industry, by kind, quantity, and value: 1905.*

KIND.	Total.	Pianos.	Per cent of total.	Organs.	Per cent of total.
Aggregate value	$52,964,315	$46,922,471	88.6	$6,041,844	11.4
Pianos, total value	$43,502,055	$42,874,395	98.6	$627,660	1.4
Upright—					
Number	251,957	250,204	99.3	1,753	0.7
Value	$37,397,674	$37,116,668	99.2	$281,006	0.8
Grand—					
Number	7,372	7,372	100.0	....	....
Value	$3,661,423	$3,661,423	100.0	....	....
Other varieties, including street and self-playing, players, and attachments	$2,442,958	$2,096,304	85.8	$346,654	14.2
Organs, total value	$6,625,319	$1,668,493	25.2	$4,956,826	74.8
Reed—					
Number	113,065	43,028	38.1	70,037	61.9
Value	$4,162,053	$1,489,802	35.8	$2,672,251	64.2
Pipe—					
Number	901	75	8.3	826	91.7
Value	$1,989,979	$124,736	6.3	$1,865,243	93.7
Other varieties, including street and self-playing.	$473,287	$53,955	11.4	$419,332	88.6
All other products	$2,836,941	$2,379,583	83.9	$457,358	16.1

The table shows that while only 1.4 per cent of the total value of the output of pianos of all kinds was reported by establishments primarily engaged in the manufacture of organs, practically a quarter, 25.2 per cent, of the value of all the organs produced during the census year resulted from the operations of piano factories. The value of organs built in piano factories, however, formed only 3.6 per cent of the aggregate value of the products of these factories. It is in the manufacture of reed organs that the encroachment of the piano factories upon the field of organ manufacturers is most noticeable, 43,028 of this variety of organs, or 38.1 per cent of the total production, having been produced during the census year by piano manufacturers.

In Table 4 the aggregate of the combined industries in 11 selected states that were large producers of musical instruments at the census of 1905 is shown for the censuses from 1880 to 1905. The remaining states which produced musical instruments at each census period are combined to form "all other states."

TABLE 4.—MUSICAL INSTRUMENTS, ATTACHMENTS, AND MATERIALS—COMPARATIVE SUMMARY, BY SELECTED STATES: 1880 TO 1905.

STATE.	Census.	Number of establishments.	Capital.	Salaried officials, clerks, etc.		Wage-earners and wages.		Miscellaneous expenses.	Cost of materials used.	Value of products.
				Number.	Salaries.	Average number.	Wages.			
United States	1905	625	$72,225,379	2,947	$3,979,696	35,220	$19,689,146	$7,564,994	$29,116,566	$69,574,340
	1900	619	47,706,582	1,676	2,156,371	23,714	12,774,902	3,783,714	18,576,022	44,418,978
	1890	674	29,650,489	1,332	1,657,735	18,096	11,648,648	2,394,316	14,436,163	36,868,169
	1880	429	14,446,765	...	...	11,350	7,098,794	...	8,361,227	19,254,739
California	1905	15	360,279	19	18,630	110	89,216	32,525	71,281	216,204
	1900	15	96,295	2	2,240	48	34,535	8,093	26,465	111,923
	1890	27	152,360	27	25,915	57	48,576	28,917	58,240	231,349
	1880	12	59,550	...	...	37	27,085	...	45,875	113,100
Connecticut	1905	20	5,230,996	127	240,826	2,585	1,338,150	429,706	2,403,548	5,279,085
	1900	17	3,588,630	84	145,707	1,864	889,973	171,527	1,571,674	3,399,768
	1890	14	1,960,030	51	74,048	1,128	647,762	77,916	1,094,745	2,125,460
	1880	11	745,000	...	...	846	404,294	...	644,144	1,231,520
Illinois	1905	84	17,111,229	780	937,522	7,999	4,233,273	1,624,734	5,604,685	13,997,728
	1900	72	11,516,161	413	506,178	5,100	2,608,062	971,603	3,490,343	8,670,838
	1890	39	3,849,718	116	110,316	2,031	1,083,179	227,478	1,539,782	3,786,299
	1880	23	281,450	...	...	375	217,909	...	336,178	694,975
Indiana	1905	19	3,002,068	220	231,311	1,570	776,106	297,061	1,060,584	2,731,156
	1900	11	1,032,274	82	59,351	656	351,008	97,884	402,295	1,019,535
	1890	12	402,743	29	21,920	261	131,873	39,959	142,531	479,014
	1880	12	102,850	...	...	291	136,350	...	120,400	324,300
Massachusetts	1905	77	8,449,498	299	438,245	4,307	2,565,769	901,529	3,207,222	8,538,073
	1900	95	7,343,625	212	329,533	3,423	2,037,153	541,389	2,476,904	6,640,790
	1890	125	6,158,495	271	361,788	4,077	2,726,247	727,141	3,119,160	8,071,362
	1880	86	3,277,266	...	...	3,074	1,790,548	...	2,173,011	5,056,399
Michigan	1905	20	2,441,878	98	123,583	1,178	585,612	317,979	785,537	2,108,139
	1900	16	1,265,090	64	69,931	793	393,481	130,280	480,431	1,217,552
	1890	11	699,418	32	40,070	582	311,842	66,145	354,865	963,123
	1880	5	141,000	...	...	170	67,050	...	84,677	207,679
Missouri	1905	9	99,534	13	13,330	89	60,414	10,267	44,180	161,614
	1900	15	80,775	5	4,100	66	37,076	7,748	29,264	98,171
	1890	23	87,161	28	19,775	61	39,883	9,042	26,212	116,505
	1880	20	93,450	...	...	42	22,448	...	22,685	75,050
New Jersey	1905	24	2,838,074	148	163,314	1,866	970,310	293,066	1,191,027	2,981,022
	1900	28	2,516,771	105	83,650	1,503	725,822	248,774	927,770	2,211,699
	1890	14	160,152	24	18,602	184	108,189	47,799	152,185	382,574
	1880	11	390,222	...	...	451	179,300	...	231,768	510,000
New York	1905	216	22,247,524	875	1,316,882	10,082	6,175,848	2,519,690	11,253,410	24,277,927
	1900	193	14,313,495	481	688,135	7,244	4,200,754	1,194,288	6,868,284	15,509,839
	1890	211	11,091,456	449	643,325	7,142	5,025,059	685,269	6,160,196	15,713,919
	1880	150	7,132,345	...	...	4,508	3,485,407	...	3,861,225	8,842,249
Ohio	1905	33	3,401,418	120	154,312	2,229	1,215,695	406,678	1,638,037	3,714,255
	1900	34	1,499,872	58	64,022	811	377,341	133,978	731,568	1,521,079
	1890	27	502,623	50	51,827	312	172,229	47,034	224,741	592,885
	1880	14	113,300	...	...	168	66,175	...	66,125	166,940
Pennsylvania	1905	45	2,501,421	95	113,842	1,149	603,180	211,125	703,153	1,961,872
	1900	51	1,828,126	78	99,326	859	492,005	117,875	674,637	1,709,197
	1890	75	1,259,429	114	113,895	694	451,790	163,057	567,658	1,581,624
	1880	29	387,650	...	...	374	201,954	...	193,720	502,785
All other states	[1] 1905	63	4,451,460	153	227,899	2,056	1,075,573	520,634	1,153,902	3,607,265
	[2] 1900	72	2,625,468	92	104,198	1,347	627,692	160,275	896,387	2,308,587
	[3] 1890	96	3,326,904	141	176,254	1,567	902,019	274,559	995,848	2,824,055
	[4] 1880	56	1,662,682	...	...	1,014	500,274	...	581,419	1,529,742

[1] Includes establishments distributed as follows: Colorado, 3; Delaware, 1; Georgia, 1; Iowa, 3; Kansas, 2; Kentucky, 7; Louisiana, 2; Maine, 2; Maryland, 11; Minnesota, 9; Nebraska, 2; New Hampshire, 4; Oregon, 1; Rhode Island, 1; Vermont, 3; Virginia, 1; Washington, 3; West Virginia, 1; Wisconsin, 6.

[2] Includes establishments distributed as follows: Colorado, 4; Iowa, 7; Kentucky, 8; Louisiana, 1; Maine, 1; Maryland, 11; Minnesota, 12; Nebraska, 2; New Hampshire, 6; Oregon, 1; Rhode Island, 3; Tennessee, 1; Texas, 3; Vermont, 3; Virginia, 1; Washington, 1; Wisconsin, 7.

[3] Includes establishments distributed as follows: Arkansas, 1; Georgia, 7; Iowa, 1; Kansas, 2; Kentucky, 11; Louisiana, 6; Maine, 4; Maryland, 16; Minnesota, 8; Nebraska, 1; New Hampshire, 7; North Carolina, 1; Rhode Island, 4; South Carolina, 1; Tennessee, 1; Texas, 7; Vermont, 5; Virginia, 3; Wisconsin, 10.

[4] Includes establishments distributed as follows: Delaware, 1; District of Columbia, 1; Georgia, 1; Iowa, 1; Kansas, 1; Kentucky, 6; Maine, 5; Maryland, 13; Minnesota, 6; New Hampshire, 8; North Carolina, 1; Rhode Island, 1; Tennessee, 2; Texas, 1; Vermont, 3; Virgina, 1; Wisconsin, 4.

Throughout the twenty-five years covered by the table the state of New York has been the leader in the production of musical instruments, and at the end of the period produced instruments, materials, etc., valued at nearly twice that of the output of the state second in importance, Illinois. The progress of the latter state in the industry, however, has been remarkable. At the census of 1880 the manufacturers of musical instruments in Illinois produced an output valued at only \$694,975 and twenty-five years later an output valued at \$13,997,728, or an increase in value of nearly nineteen-fold during the period. At the census of 1880 Massachusetts was a fairly close second in the industry, but since that date has made comparatively slight gains, with the result that by 1900 the state was supplanted by Illinois, dropping to third place, which position the state maintained at the census of 1905. At the census of 1905 Ohio ranked fourth in the value of products, with an output valued at \$3,714,255, which represented an increase of more than twenty-one fold over the value reported in 1880.

The development of the export and import trade in musical instruments is compared in Table 5 with the growth in the industry in the United States as measured by the value of the products reported at each census from 1870 to 1905.

TABLE 5.—*Musical instruments, attachments, and materials—value of exports and imports compared with value of domestic production: 1870 to 1905.*

CENSUS.	Value of domestic production.	EXPORTS.[1]		IMPORTS.[1]	
		Value.	Per cent of domestic production.	Value.	Per cent of domestic production.
1905	\$69,574,340	[2] \$3,230,982	4.6	[2] \$1,366,285	2.0
1900	[3] 44,514,463	1,958,779	4.4	1,060,541	2.4
1890	36,868,169	1,105,134	3.0	1,703,129	4.6
1880	19,254,739	811,177	4.2	917,778	4.8
1870	13,905,908	267,400	1.9	[4] 1,050,218	7.6

[1] Bureau of Statistics, Department of Commerce and Labor, "Commerce and Navigation of the United States."
[2] Fiscal year ending June 30, 1904.
[3] Includes products valued at \$95,485 not included in the general tables.
[4] Figures are for 1872, the first year musical instruments were reported separately.

The percentages in the table should not be considered without some important reservations. The fact that there are large duplications of value, as set forth in the discussion of Table 2, in the census totals forbids the use of the percentages except as an indication of general tendencies. An additional reason for care in this respect is the fact that the figures for exports and imports cover fiscal years, whereas census values cover calendar years, with the exception of 1900, when the census year ended May 31. The table indicates, then, that while the ratios of the value of imports of musical instruments to the value of such products manufactured in the United States have steadily decreased for the census years since 1870, the corresponding ratios of the value of exports of the same nature have increased for this period. The value of products manufactured increased fourfold, the value of exports elevenfold, while the value of imports increased only 30.1 per cent. At the census of 1870 foreign manufacturers sold to this country musical instruments valued at nearly four times as much as the manufacturers of these products in the United States shipped to foreign countries, but at the census of 1905 this condition was reversed and the value of exports was over twice as great as the value of imports of musical instruments.

Foreign markets are being more and more closely studied by musical instrument manufacturers, especially by piano and organ makers. When an instrument is designed to be shipped to some portion of the tropics, the woodwork is coated with a moisture-resisting varnish, veneer is avoided, all glued work is reenforced, felt parts are dipped in a poison solution to prevent ravages of insects, and other precautions tending to the preservation of the instruments are taken.

Undoubtedly the exports of musical instruments would be much greater were it not that piano and organ manufacturers have in some instances found it more advantageous to establish branch factories abroad, to carry out the ideas and methods of American production gauged to suit the requirements of the foreign trade, thus saving duties and obtaining the advantage of less expensive labor.

In the sections which follow, statistics of capital, labor, materials, etc., are omitted, the foregoing tables in this section presenting the essential details concerning these particulars. Moreover, the detailed summaries at the close of this report present the statistics for each industry in as refined a form as the statistical returns for the manufacture of musical instruments allow.

The following pages show the production of the various musical instruments, attachments, and materials, by kind and value, in as great detail in each case as conditions permit, and indicate the distribution of the production among the states, together with the principal centers of each industry within the states. In addition, matter descriptive of the different varieties of instruments and of the latest forms which have appeared is included.

PIANOS.

The statistics in this section include the manufacture of finished pianos of all kinds, also self-playing and street pianos, cabinet piano players, and piano playing attachments. The manufacture of piano materials, apart from factories reporting the finished instruments, having grown to be a considerable industry in itself, is presented separately in a later section.

The piano manufacturer generally buys certain portions of his instruments ready made, inasmuch as factories equipped for manufacturing certain parts can generally make them more economically than a piano factory. Some makers, however, manufacture the principal parts of their pianos, even selecting the wood that enters into the construction of the instrument. In compiling statistics relating to the industry it has been impossible for the Census Office to recognize any distinction of this kind.

Table 6 presents a comparative summary of the value of the different varieties of pianos manufactured in the United States as reported at the censuses of 1900 and 1905, showing the percentage each class is of the total value and the per cent of increase during the five-year period.

TABLE 6.—*Pianos, including piano players and attachments—kind and value, with per cent of total and per cent of increase: 1905 and 1900.*

KIND.	1905		1900[1]		Per cent of increase.
	Value.	Per cent of total.	Value.	Per cent of total.	
Total	[2] $43,527,543	100.0	$27,692,160	100.0	57.2
Upright pianos	37,397,674	85.9	25,294,297	91.4	47.9
Grand pianos	3,661,423	8.4	1,701,420	6.1	115.2
Square pianos	12,150	([3])	28,950	0.1	[4] 58.0
Self-playing and street pianos, piano players, and attachments	2,456,296	5.7	667,493	2.4	268.0

[1] Represents value of pianos, etc., reported by all classes of establishments.
[2] Includes piano players valued at $25,488, made by establishments engaged primarily in the manufacture of piano and organ materials.
[3] Less than one-tenth of 1 per cent.
[4] Decrease.

At the census of 1905, compared with that of 1900, the proportion which the value of upright pianos formed of the value of all products shown in the table decreased, while the proportions which the value of grand pianos and the group of instruments including self-playing and street pianos, piano players, and attachments, formed of the total value increased. This was due to the rapid increase in the value of grand pianos and the last-named group, which increased at a much greater rate than the value of upright pianos.

Grand pianos were manufactured in 1905 to a value of $3,661,423, or 8.4 per cent of the total value reported for all products and attachments, and an increase of 115.2 per cent over the value reported in 1900, which constituted 6.1 per cent of the total value for all classes of pianos, players, and attachments. Piano players and attachments show the remarkable increase of 268 per cent in value of product reported. The growing importance of this class of products has been a feature of the piano industry during the past five years, and the manufacture of the group of instruments composing it has been accorded separate treatment in another section of this report.

Excluding the product of square pianos, piano players and attachments, Table 7 shows the number and value of upright and grand pianos manufactured in selected states in 1905 in comparison with the census of 1900, together with the percentage the value of product reported for each state is of the United States total.

TABLE 7.—*Pianos, upright and grand—number and value, with per cent of total value, by states: 1905 and 1900.*

STATE.	Census.	UPRIGHT PIANOS.			GRAND PIANOS.		
		Number.	Value.		Number.	Value.	
			Amount.	Per cent of total.		Amount.	Per cent of total.
United States	1905	251,957	$37,397,674	100.0	7,372	$3,661,423	100.0
	[1] 1900	166,786	25,294,297	100.0	4,251	1,701,420	100.0
Connecticut	1905	9,152	1,210,692	3.2	19	7,425	0.2
	1900	7,259	941,344	3.7	10	3,650	0.2
Illinois	1905	73,874	9,605,681	25.7	238	81,711	2.2
	1900	46,024	5,643,287	22.3	110	48,460	2,9
Massachusetts	1905	20,967	4,022,237	10.7	2,159	1,107,596	30.3
	1900	15,872	3,177,217	12.6	937	389,445	22.9
New York	1905	96,985	14,505,035	38.8	3,541	1,865,194	50.9
	1900	69,191	10,876,742	43.0	2,581	962,865	56.6
Ohio	1905	11,119	1,782,910	4.8	160	72,700	2.0
	1900	8,696	1,150,293	4.5	166	63,775	3.7
All other states	[2] 1905	39,860	6,271,119	16.8	1,255	526,797	14.4
	[3] 1900	19,744	3,505,414	13.9	447	233,225	13.7

[1] Represents number and value of pianos reported by all classes of establishments.
[2] Includes states as follows: California, Colorado, Indiana, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, Pennsylvania, West Virginia, Wisconsin.
[3] Includes states as follows: California, Colorado, Indiana, Kentucky, Maine, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, Pennsylvania, Tennessee, Vermont.

Table 7 shows that 85,171 more upright pianos and 3,121 more grand pianos were manufactured in the United States during the year ending December 31, 1904, than during the year covered by the census of 1900. At the census of 1905, establishments located in the state of New York reported the manufacture of 96,985 upright pianos, or more than one-third of the entire number reported for the United States. New York city is the principal center in the United States for the manufacture of pianos; 82,532 uprights and nearly all the grands reported for the entire state were manufactured in that city, the aggregate product being greater than that reported for any state other than New York.

At both censuses shown in the table, Illinois ranked second in the production of upright pianos. Chicago is the great center of the industry in this state, and at the census of 1905, 42,933 upright pianos were reported by manufacturers at Chicago.

In the manufacture of upright pianos Massachusetts ranks as the third state, with a production valued at $4,022,237, an increase of 26.6 per cent over the value reported for 1900. Boston, the third city in the United States in the piano industry, reported the manufacture of 12,989 uprights and grands during 1904, to a total value of $3,266,177. Cambridge, Mass., also manufactured pianos to a considerable extent.

The concentration of the manufacture of upright pianos in the 3 leading states is marked, but the table indicates a slight decline in this respect. At the census of 1900, 77.9 per cent of the total number of upright pianos produced were manufactured in these 3 states, but by 1905 this proportion had decreased to 75.2 per cent. In the manufacture of grand pianos New York and Massachusetts produced 79.5 per cent of the total number reported at the census of 1900. The ascendancy of these 2 states in the manufacture of this variety of pianos has increased, since in 1905 the proportion increased to 81.2 per cent.

In 1900 there were manufactured in the United States 101 square pianos, valued at $28,950. In 1905, as far as manufacturing was concerned, the square piano was practically obsolete. There were, however, 43 square pianos made in the United States during the census year, by 3 companies upon special order, with a total value of $12,150.

The grand is conceded to be the superior instrument as regards tonal quality and musical results, but the upright is the more popular type, in that it occupies less space and is not as expensive as the grand. The apparent difference between the two is the horizontal position of the frame, sounding board, and strings of the former, as compared with the vertical construction of the latter, but the essential and most important differences are the greater length of strings, larger sounding board, and action method of the grand piano in comparison with that of the upright instrument. Piano manufacture has become standardized to a great extent, the same style piano of different factories usually possessing but few distinguishing outer characteristics other than the name on the fall board. Although practically similar in design, there is, however, a great difference between the high grade pianos and those of a lower grade. This difference is not only in the quality of materials and workmanship, but in the tonal results obtained through the expert assembling and regulating of the various parts into the perfect instrument. The best manufacturers thoroughly inspect every piano before it is allowed to leave the shop. This painstaking care and steadfast regard for the quality of each instrument has come to be recognized and appreciated, not only by dealers and agents, but by the purchasing public.

There are many dealers in musical instruments that have pianos made for them under contract with manufacturers who turn out what is known by the trade as the stencil piano, any name desired being placed on the plate, the dealer generally assuming the responsibility for the qualities of the piano.

In recording the various steps in the manufacture of a high grade piano the selection and seasoning of the various kinds of wood is the first and one of the most important. Only those grains and textures are used which have been found to possess the resonant quality necessary for the production of the desired tones. The wood used is almost entirely of American growth, the only notable exceptions being the expensive veneers for the case and the ebony for the black keys. The seasoning of this lumber requires several years, as the condition of the wood is a very important consideration in obtaining the best results.

This seasoned wood is sawed into widths, and the parts are usually made of a number of these widths fitted and glued together in order to withstand the influence of atmospheric changes, to obtain the best tonal results, and to add to the strength. Very few metal bolts or screws are used in the manufacture of a piano, even the timbers of the framework being glued together under heavy pressure. It is found that better results are thus obtained, as the glue properly applied makes a permanent joint, whereas bolts or screws are liable to work loose in their fittings.

The heavy wooden framework of a grand piano and that of an upright are necessarily different in form and construction, but the principles used are the same, for the solid, massive construction of the frame must assist the metal plate in bearing the strain of the strings.

The plate is a casting of metal, principally iron, and is made to fit over the frame. This portion of the piano is very generally manufactured by foundry and machine shops which make a specialty of piano plates and piano hardware. The smoothing down, machine drilling, and finally the bronzing and japanning of the plate are the important operations in the preparation of this casting for use in the pianos.

The spruce pine used in the sounding board is the subject of most careful selection, and the building of this slightly convex and highly sensitive wooden surface and the arrangement of the bridges may be considered among the delicate features of piano manufacture.

The sound production is caused by string vibration, and the wire used, necessarily of great elasticity and of highest grade, is in some instances purchased abroad. The laying out of the scale, arranging the length and weight of wire according to absolute rule, requires expert ability as well as genius. The action, or striking mechanism, the carefully balanced key, the felt covered hammers and dampers, and many other delicately adjusted parts include numerous perfected contrivances. Toning or voicing the piano to produce the tone shadings required is done by softening the felt of the hammers with needles.

The setting up or assembling of the instrument, and the regulating of the many parts to make a harmonious whole is the next step in piano manufacture. The sounding board and plate are attached to the framework, the wires are properly strung and chipped or tuned in a preliminary manner, the keyboard and action are then set in and adjusted, the final tuning of the strings is gone over by experts, and the combined results carefully tested.

Great care is expended in the finish of the case, inasmuch as the instrument is designed to please the eye as well as the ear. It is varnished, sandpapered, and rubbed until a highly polished surface is obtained. Foreign taste prefers the dull finish, and by many this is considered more artistic.

ORGANS.

This instrument is of two principal types, the reed organ, or melodeon, and the pipe organ, the former type being a free reed instrument in which musical tones are produced by thin tongues of brass or steel set in vibration by currents of air, while the latter instrument has a series of pipes of different materials, size, and construction, in which columns of compressed air are caused to vibrate, producing tones of great purity and volume. The ordinary reed organ is small and comparatively inexpensive, while the pipe organ is a much larger instrument and considerably different in structure, and capable of far greater volume and variation in character of tone.

The organ produces a sustained tone which endures as long as the air passage leading to the particular reed or pipe, controlled by the depression of a key, is kept open, admitting a current of air; whereas the tone of a piano continues only during the natural vibration of the string. The forms and measurements of the keyboards of both styles of organs and the piano conform to the same standard, and the music is for the most part interchangeable.

In playing the reed organ the feet are generally used to operate the bellows, while with the pipe organ, which is always provided with hand, mechanical, or other blowing apparatus, the feet are used to manipulate a pedal clavier arranged to command certain pipes and combinations in the same manner as the manual claviers are arranged to command the other pipes and combinations.

Statistics concerning the value of reed organs, pipe organs, and street and self-playing organs manufactured during 1900 and 1904 are shown in Table 8, together with the per cent each class is of the total valuation and the per cent of increase during the five-year period.

TABLE 8.—*Organs—kind and value, with per cent of total and per cent of increase: 1905 and 1900.*

KIND.	1905		1900[1]		Per cent of increase.
	Value.	Per cent of total.	Value.	Per cent of total.	
Total	[2] $6,774,433	100.0	$5,689,033	100.0	19.1
Reed organs	4,212,953	62.2	4,088,073	71.9	3.1
Pipe organs	2,088,193	30.8	1,188,696	20.9	75.7
Street and self-playing organs, and other varieties	473,287	7.0	412,264	7.2	14.8

[1] Represents value of organs reported by all classes of establishments.
[2] Includes reed and pipe organs valued at $149,114 made by establishments engaged primarily in the manufacture of other products; of this value, $69,114 represents organs made in establishments other than musical instruments, attachments, and materials.

The principal feature of the table is the increase since 1900 in the value of pipe organs manufactured. This increase, however, was not sufficient to place the manufacture of pipe organs on the same plane of importance as that of reed organs, which dominated the industry at both censuses, although to a decreasing extent.

Statistics regarding the number and value of reed organs for the United States and selected states are given in Table 9, for the censuses of 1900 and 1905.

TABLE 9.—*Reed organs—number and value, with per cent of total value, by states: 1905 and 1900.*

STATE.	Census.	Number.	VALUE.	
			Amount.	Per cent of total.
United States	1905	[1] 114,675	$4,212,953	100.0
	1900	[2] 107,830	[2] 4,088,073	100.0
Illinois	1905	57,219	1,787,220	42.4
	1900	53,643	1,715,876	42.0
Indiana	1905	3,835	145,476	3.5
	1900	3,697	173,339	4.2
Massachusetts	1905	2,073	150,883	3.6
	1900	3,323	190,582	4.7
Michigan	1905	12,381	511,009	12.1
	1900	9,624	397,198	9.7
Ohio	1905	1,949	94,577	2.3
	1900	1,643	98,572	2.4
Pennsylvania	1905	5,715	242,059	5.7
	1900	6,240	275,438	6.7
All other states	[3] 1905	31,503	1,281,729	30.4
	[4] 1900	29,660	1,237,068	30.3

[1] Includes 1,610 reed organs, valued at $50,900, reported by establishments engaged primarily in the manufacture of products other than musical instruments, attachments, and materials.
[2] Represents number and value of reed organs reported by all classes of establishments.
[3] Includes states as follows: Connecticut, Kentucky, Maryland, Minnesota, New Jersey, Oregon, Vermont, West Virginia.
[4] Includes states as follows: Connecticut, Maryland, Minnesota, New Jersey, New York, Vermont, Virginia.

The table shows a marked localization of the industry in Illinois, the value of the reed organs manufactured in this state at the census of 1905 constituting 42.4 per cent of the aggregate value reported for the entire United States. In Illinois the industry is localized principally in Chicago, which produced 37,622 reed organs, or 65.8 per cent of the number manufactured in the state at the census of 1905. Evidently the middle West is the principal seat of the production of reed organs, for Michigan, Indiana, and Ohio also reported a large production of these instruments, the combined value of the products of the 4 states at the census of 1905 constituting 60.2 per cent of the value of the total production for the United States. In both Massachusetts and Pennsylvania the production of reed organs is declining.

The American reed organ, with perhaps a single exception, is a suction instrument, while the harmonium, or European style of reed organ, operates with air pressure. About 1635, a harmonium maker in Paris invented the suction instrument, but the first of this class of organs manufactured in the United States was made in Boston. These have since become known as the American reed, or cabinet, organs, although at first designated as melodeons. Rapid progress has been made in the construction of the American reed organ, and it is to-day recognized as a special type of instrument, all organs of this kind now built or used abroad being designated "American organs."

Each reed organ possesses a series of stops controlling individual sets of reeds, and these stops, when drawn, cause the different combinations of tones desired. When the stops are drawn, the pressure on the key opens a pallet or valve permitting the passage of air through the reed cell, causing the reed to vibrate and produce its characteristic note. The reeds are vibratory tongues of brass or steel riveted upon perforated metallic plates, and placed in separate wooden cells made on the edges of what is called the reed board, which latter rests upon the top of the wind chest directly under the keys. There may be more than one set of reeds, and in that case one is placed in front of the other on the reed board, or if more than two, they are placed one over the other. The air pressure is ordinarily produced by a pair of exhausters, operated by the foot pedals, which exhaust the air from a reservoir under a spring tension passage communicating between this reservoir and the air chambers of the instrument containing the valve mechanism.

In addition to the keys, stops, and pedals, there are one or sometimes two knee swells or divided couplers, as they are sometimes called, whereby reeds an octave above or below the keyboard center are caused to sound in addition to the reeds directly connected with the depressed keys. Thus in operating an organ various stops and devices are used to increase or diminish quantity and to vary the character of the tone, inasmuch as no control is possible from the pressure on the keys other than to open the passage of air to certain reeds.

The timbre, or quality, of the tone is regulated by the opening in which the reed vibrates and by the size and form of the channel above the reed and its pallet hole through which the air passes, straining due to excessive or uneven operation of the foot pedal being obviated by a discharge pallet acting as a safety valve. The voicing and tuning are very important operations, the latter being obtained by filing or scraping the tongue of the reed and the former by twisting the tongue into certain curves which determine the quality of tone. The reed organ seldom gets out of tune, inasmuch as it is not susceptible to changes in temperature and atmospheric conditions.

The manufacture of the reed organ, like that of other musical instruments, is largely the result of experience and development. Probably the manipulation of the tongue of the reed to a proper size and curve and the determining of the size of the reed cells, etc., and the length and size of the qualifying cells, when such are used, are the most delicate of the intricate operations involved in its manufacture.

The vocalion is a reed organ approaching somewhat a pipe organ in its characteristic tone quality. Vocalion instruments are largely used in churches, and usually have a pedal base and often two manual claviers, or keyboards, conforming in appearance to the pipe organ. The difference between the ordinary reed organ and the vocalion is that in the latter the air current passes through qualifying cells and tubes before or after reaching the reeds.

There have also been manufactured a combination pipe and reed organ, desk and reed organ, and other somewhat unusual compound forms of the instrument. Almost all the materials used in reed organ construction are strictly American products, with the exception of ivory and ebony. Very little ivory is now used on the keyboard of reed organs, celluloid being substituted in its place, while a stained wood is generally used instead of ebony for the black keys. Very little expensive veneer is used on these instruments, unless by special order, as it greatly increases the cost of the instrument. Unlike the average piano manufacturer, organ makers usually manufacture all parts of their instrument with the exception of reeds and keys, the making of which is really a separate industry.

Statistics of pipe organ production in this section do not include instruments fitted with devices for automatic playing, inasmuch as these will be included under the head of self-playing instruments. Table 10 presents the number and value of pipe organs built in selected states, and shows the per cent the value of products for each state is of the total value reported for the United States at the censuses of 1900 and 1905.

The number of pipe organs manufactured is not great, but as a rule they are large and comparatively expensive. The table indicates that their production is not centered to a very marked degree in any one state. The value of the organs produced in Massachusetts at the census of 1905 formed 24.9 per cent of the total value for the United States, but both Illinois and Ohio contributed largely to the total, and the numerical output in the case of Ohio equaled and in the case of Illinois exceeded that of the leading state. The average value of the organs built by Massachusetts makers was, therefore, considerably larger than that of the organs manufactured in either Illinois or Ohio. Boston is one of the chief centers for the manufacture of high-grade pipe organs, 60 of these instruments having been built in this city during 1904, with a value of $313,220, a greater valuation than was reported by any state in the United States other than Massachusetts. Pipe organs were also made in Springfield, Waltham, and Cambridge, Massachusetts.

In Illinois, Chicago reported about two-thirds of the total value of pipe organs manufactured in this state, while in Ohio, which has advanced rapidly in this manufacture, Pomeroy, Alliance, and Cleveland produce the greater part of the pipe organs manufactured in the state. Vermont, Pennsylvania, Maryland, New York, and Connecticut are the next 5 states, ranked according to value of pipe organs built during 1904. Neither Vermont nor Connecticut can be shown in the table, as to do so would reveal individual operations.

TABLE 10.—*Pipe organs—number and value, with per cent of total value, by states: 1905 and 1900.*

STATE.	Census.	Number.	VALUE.	
			Amount.	Per cent of total.
United States	1905	[1] 936	[1] $2,088,193	100.0
	1900	[2] 572	[2] 1,188,696	100.0
Illinois	1905	165	310,323	14.9
	1900	87	105,157	8.8
Maryland	1905	79	166,186	8.0
	1900	50	80,035	6.7
Massachusetts	1905	137	520,887	24.9
	1900	137	365,510	30.8
New York	1905	58	133,471	6.4
	1900	73	216,120	18.2
Ohio	1905	137	251,486	12.0
	1900	23	34,250	2.9
Pennsylvania	1905	87	175,555	8.4
	1900	80	150,990	12.7
Wisconsin	1905	22	45,214	2.2
	1900	8	15,475	1.3
All other states	[3] 1905	251	485,071	23.2
	[4] 1900	114	221,159	18.6

[1] Includes 35 pipe organs, valued at $98,214, made by establishments engaged primarily in the manufacture of other products. Of this value, $18,214 represents pipe organs made by establishments other than musical instruments, attachments, and materials.

[2] Represents number and value of pipe organs reported by all classes of establishments.

[3] Includes states as follows: California, Connecticut, Delaware, Indiana, Iowa, Kentucky, Maine, Michigan, Minnesota, Missouri, New Jersey, Rhode Island, Vermont.

[4] Includes states as follows: California, Colorado, Connecticut, District of Columbia, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, Rhode Island, Texas.

The pipe organ is often spoken of as being the largest, most expensive, and most perfect of all musical instruments, and the methods of its manufacture are of considerable interest. Almost every pipe organ is practically built to order to accord with the architecture or acoustic qualities of the room or auditorium in which it is designed to be placed. The ornamental work of the pipe organ is sometimes put in by the building contractors, who are in no way identified with the organ builders.

One complete stop of one rank of pipes in the modern organ consists of 61 notes for the manual clavier and 32 for the pedal clavier, and there are as many stops as may be desired according to the size and cost of the organ; in some instances there are 100 or more. These pipes are made of wood or metal, the wood being carefully selected of various growths, and the metals, chiefly zinc, tin, and lead, being used in alloys according to the different qualities of tone desired. The arranging of the shape and size of the pipes is an operation in which experience and knowledge on the part of the builder are necessary to the manufacture of a successful instrument. The voicing and tuning of these pipes are invariably done before they are set up in the organ, and this operation is of great delicacy. Final tuning and regulating are done after the pipes are placed in the finished instrument.

The bellows of a pipe organ must be of exactly sufficient capacity to feed all the pipes, and therefore varies in construction according to the size of the organ. The operation of the bellows may be by hand, by hydraulic power, or by electricity, in which latter instance a current of from 100 to 200 volts in strength is necessary. There is an electric fan feeder recently patented which is said to be very successful in operation and which takes up much less room than the ordinary class of feeders, but the ordinary compound bellows is used in the majority of organs, and almost altogether in those built in 1904. The air does not pass directly to the pipes, but is generally led first into a regulator bellows, which makes the pressure more even and regular in strength, after which it is conveyed to the wind chest, and is then caused to pass into the pipes by the opening of valves controlled by the key or playing mechanism.

The tracker organ, in which the pallets or valves leading from the wind chest to the pipes are opened direct from the keys by means of trackers or levers, has been largely superseded by the more modern pneumatic and electric action, although there are many of the older style still in use, and some builders still make small tracker organs. During 1904 the principal pipe organ action used was of the tubular pneumatic type, in which the depression of the keys opens certain valves, causing air pressure to open larger valves, admitting the air from the wind chest to the pipes.

Probably the most recent development in pipe organ construction is the electric action, which is operated either by a storage battery or by a small generator connected with the bellows motive power. Depression of a key causes electrical contact, allowing the current to pass through a magnet in the wind chest or pallet box, which magnet operates a primary valve connected with a larger valve, which, being open, allows passage of air, thereby causing the pipe to speak. Each key of both manual and pedal claviers is fitted with this arrangement of magnet, air cells, valves, etc., and the action is simultaneous with the pressure on the key or pedal. The use of electricity in the action mechanism allows the instrument to be played with an even and light pressure on the keys, whereas, in the older style tracker organ, to operate some combinations required considerable strength. Another advantage in an electrically operated organ is that the key case, or console, may be placed at any distance from the organ proper, inasmuch as the power is transmitted by wires to the valve mechanism connected with the pipes. This arrangement is also possible in the exclusive tubular pneumatic organ, although the distance capable of being covered is necessarily somewhat limited.

SELF-PLAYING AND STREET PIANOS AND ORGANS, AND PIANO PLAYERS AND ATTACHMENTS.

The statistics concerning the kind and value of self-playing and street pianos and organs, cabinet piano players, and playing attachments, presented in preceding sections in connection with the manufacture of pianos and organs, are shown in greater detail in the three tables following. Table 11 is a comparative summary showing the value reported for each class during 1900 and 1905, with the per cent of increase during the five-year period and the per cent each class is of the total value.

TABLE 11.—*Self-playing and street pianos and organs, and piano players and attachments—kind and value, with per cent of total and per cent of increase: 1905 and 1900.*

KIND.	1905		1900		Per cent of increase.
	Value.	Per cent of total.	Value.	Per cent of total.	
Total	[1]$2,929,583	100.0	$953,772	100.0	207.2
Piano players and piano playing attachments	2,029,754	69.3	607,873	63.7	233.9
Self-playing pianos and organs	849,813	29.0	317,569	33.3	167.6
Street pianos and organs	50,016	1.7	28,330	3.0	76.5

[1] Includes piano players valued at $25,488 made by establishments engaged primarily in the manufacture of piano and organ materials.

Large increases are shown for each group of products, but the leading feature of the table is the increase since 1900 of 233.9 per cent in the manufacture of piano players and attachments, which indicates the growing popularity of automatic piano playing.

Table 12 presents the number and value of piano players and piano playing attachments manufactured in the United States at the censuses of 1900 and 1905 and the per cent each class is of the total value at both censuses.

TABLE 12.—*Piano players and piano playing attachments—number and value, with per cent of total value: 1905 and 1900.*

KIND.	Census.	Number.	VALUE.	
			Amount.	Per cent of total.
Total	1905 1900	[1]20,634 [2]6,158	[1]$2,029,754 [2]607,873	100.0 100.0
Piano players	1905 1900	17,652 5,236	1,876,974 520,139	92.5 85.6
Piano playing attachments	1905 1900	2,982 922	152,780 87,734	7.5 14.4

[1] Includes 243 piano players, valued at $25,488, made by establishments engaged primarily in the manufacture of piano and organ materials.
[2] Represents number and value of piano players and piano playing attachments reported by all classes of establishments.

According to the census designation, the piano player is a separate cabinet instrument which must be attached to a piano to be used. The value of product reported for this class of automatic players in 1905, as compared with 1900, increased 260.9 per cent. Connecticut ranks first in the manufacture of these instruments, with Meriden as the center, while New Jersey, Michigan, New York, and Illinois are respectively the second, third, fourth, and fifth states in order of principal production.

Piano playing attachments, or interior players, as they are sometimes called, were manufactured to a considerable extent at the census of 1905, when a product valued at $152,780 was reported, an increase of 74.1 per cent over the $87,734 reported in 1900. The state of New Jersey reports the principal production of interior players, with New York and Connecticut second and third in rank. The piano playing attachments thus reported do not include the entire product, inasmuch as there were manufactured 2,569 self-playing pianos and organs, as shown in Table 13, the value of which includes the value of the self-playing mechanism contained in the instrument.

Table 13 presents the number and value of self-playing pianos and organs manufactured in the United States as reported at the censuses of 1900 and 1905, with the per cent each is of the total value reported at each census.

TABLE 13.—*Self-playing pianos and organs—number and value, with per cent of total value: 1905 and 1900.*

KIND.	Census.	Number.	VALUE.	
			Amount.	Per cent of total.
Total	1905 1900	2,569 1,962	$849,813 317,569	100.0 100.0
Self-playing pianos	1905 1900	1,868 224	417,382 44,745	49.1 14.1
Self-playing organs	1905 1900	701 1,738	432,431 272,824	50.9 85.9

The great advance in the last five years in the manufacture of pianos containing self-playing mechanism is shown by the fact that the value of these instruments increased from $44,745 to $417,382, or 832.8 per cent, during the period. New York state leads in this manufacture, reporting 1,506 self-playing pianos, valued at $314,682, or 75.4 per cent of the total value of products. New Jersey, Missouri, Connecticut, and Illinois also report the manufacture of self-playing pianos, ranked in the order named. The total number of piano players, piano playing attachments, and self-playing pianos shown by Tables 12 and 13 was 22,502, compared with 6,382 reported in 1900, which comparison indicates the increased use of all kinds of piano playing mechanism, and doubtless another census will show a still greater advance, inasmuch as public attention is being turned in this direction by the satisfactory results obtained by these devices.

The value of the self-playing organs manufactured increased during the five years, but the number decreased. This decrease in number is explained by the fact that these instruments are now largely of the pipe organ variety, which are more expensive than reed organs, the latter not being fitted with playing mechanism to as great an extent as in 1900, attention being directed more to piano playing devices. In the manufacture of self-playing organs New Jersey ranks first, Massachusetts second, and New York third, while 8 other states also show a product of this style of musical instruments.

Piano players and playing attachments are becoming quite numerous, and many ingenious devices have been invented. The cabinet player, with felt plungers to strike the keys of the ordinary piano, was the first to be generally used and is still very popular, especially for use in playing a grand piano. Most of the instruments and attachments are now operated primarily by pneumatic pressure or suction, or by a combination of pneumatic and electric action. The air, passing through the holes of the perforated music paper running over corresponding holes in a tracker board, is communicated, usually by means of rubber tubes, to the playing mechanism. There are, however, ingenious electric devices for automatic piano playing which have been prominently displayed and are now being manufactured, but during the year 1904 the action used in playing mechanism was principally pneumatic.

The organ lends itself more readily to automatic playing because of its valvular arrangement, the quantity and quality of tone being controlled by stops and knee swells, rather than by the strength and character of stroke, as in piano playing. The wind motor furnishing pneumatic pressure or suction may be operated by electricity, an ordinary storage battery being generally used to furnish the current required, which is not more than from 4 to 8 volts in strength. In a self-playing organ the automatic mechanism, by means of this pneumatic action, controls the organ action in technically the same manner that it would if played by hand, except that the air control does not operate the keys but is taken directly to the valves which ordinarily would be controlled by the keys. It is claimed that there are no effects possible to organ playing by hand which may not be obtained by self-playing mechanism under expert guidance, and it may readily be seen that orchestral arrangements too complex for one organist can be executed by the playing attachment.

The piano case containing a playing attachment is so constructed that when closed up it is an ordinary piano which can be played by hand. If it is desired to use the instrument automatically, a panel in the upper part of the case may be opened and a roll of music fitted in and attached to run over the tracker board and wind on a receiving spool. By letting down a hinged panel in the lower portion of the instrument, the pedal arrangement is disclosed by means of which wind power may be provided to operate the bellows furnishing pneumatic power to the playing mechanism. Thus the upright piano is in this combination instrument capable of being operated either by hand or by automatic action.

Expression is put into the automatically played music by means of levers, and accellerando and ritardando as well as forte and pianissimo effects are thus obtainable, and modern devices enable individual notes or a certain air to be made prominent with the accompaniment subdued. This ability to bring out a theme or melody is a new power which has been given the automatic instrument.

An electric playing mechanism using about one-third the power of a small incandescent lamp has been recently put on the market, but none was reported as manufactured during 1904, except in experimental work. This apparatus does away with the necessity of pumping a bellows, and is considered successful not only in convenience and correct operation but the claim is also made that music played by this attachment may be transposed to a higher or lower key by a simple mechanical arrangement. This player was exhibited by the United States Patent Office at St. Louis in 1904 and at the Lewis and Clark Exposition at Portland in 1905.

The perforated music for automatic attachments and players, whether cabinet or interior, pneumatic or electric, is becoming standardized to a great extent and the same music generally may be used with any style of player. There are, however, music arrangements in two sizes, taking in a range of six and one-half to seven and one-third octaves. There is an expensive attachment which marks this music paper from the actual playing on a piano, but more accurate and satisfactory results are obtained by marking the music from the original score by hand, on a master roll which is proof read, tested, and corrected.

Expression marks are decided by interpretation experts and on important selections the composer's ideas are obtained wherever possible. The music is then cut automatically, 15 rolls at a time, from the perfect master roll and the expression and other marks are put on from a cardboard pattern. Extensive classification has been made of the many selections and arrangements in perforated music, and circulating libraries and educational departments in the principal cities have catalogues of roll music listed in grades.

PIANO AND ORGAN MATERIALS.

The value of piano and organ materials is shown separately for the first time at this census. These statistics do not include the total value of these products, for only those factories which manufacture parts and materials are included, the parts made by factories manufacturing the finished instrument being included with pianos and organs.

It is probably true that this first presentation of the subject may not include certain piano parts made by establishments primarily engaged in the manufacture of other products, and this fact should be taken into consideration in the examination of the figures. Certain foundry and machine shops may have cast piano plates or other piano hardware which are not specified separately from the other products of the establishment, or furniture manufacturers may have made cases or piano stock to some extent not specifically mentioned in their reports, and such partial products would not be included in the value reported for piano and organ parts and materials.

Table 14 is a summary for the United States and selected states showing the value of piano materials and parts, and all other products including organ materials and parts, and piano and organ materials and parts, not specified, and other products of a miscellaneous nature.

TABLE 14.—*Piano and organ materials—value of products, by states: 1905.*

STATE.	Total.	Piano materials and parts.	All other products, including organ materials and parts, and piano and organ materials and parts, not specified.
United States	[1] $13,128,315	$11,397,907	[2] $1,730,408
Connecticut	2,397,822	1,653,286	744,536
Illinois	998,239	655,911	342,328
Massachusetts	2,165,393	1,874,014	291,379
New Jersey	288,959	285,559	3,400
New York	5,226,947	5,142,812	84,135
Ohio	1,412,839	1,295,905	116,934
All other states [3]	638,116	490,420	147,696

[1] In addition, piano and organ materials and parts to a value of $572,686, unfinished pianos to a value of $179,547, and unfinished organs to a value of $152,621 were made by establishments engaged primarily in the manufacture of pianos and organs; and piano materials to a value of $281,016 were made by establishments engaged primarily in the manufacture of musical instruments and materials, not specified.

[2] Includes organ materials and parts to a value of $581,373, and piano and organ materials and parts, not specified, amounting to $647,612.

[3] Includes states as follows: California, Indiana, Michigan, New Hampshire, *Pennsylvania, Vermont.*

The product of establishments manufacturing piano and organ materials and parts in the United States is divided in the following proportions: Piano materials and parts, 86.9 per cent; organ materials and parts, 4.4 per cent; piano and organ materials and parts, not specified, 4.9 per cent; and all other products, 3.8 per cent. The principal item of this manufacture is therefore piano materials and parts. It is interesting to note that the value reported under this head is 26.2 per cent of the total value of pianos manufactured in the United States during 1904. This indicates the tendency to specialization in the manufacture of piano materials and parts.

As New York predominates in the piano industry, it is natural that this state should also lead in the manufacture of piano materials and parts. The chief center is New York city, where piano materials and parts were manufactured in 1904 to a value of $3,491,493, which amount is nearly one-third of the United States total for this class of products. This amount includes the product of two supply factories on Long Island, where piano parts are manufactured, and eventually transferred to another factory belonging to the same establishment, to be assembled. Tonawanda, Rochester, Dolgeville, Castleton, Brockport, and St. Johnsville and other towns in New York also report a considerable product of piano materials and parts. Massachusetts ranks second in this industry, the chief cities being Cambridge and Leominster. The third state in rank is Connecticut, where Ivoryton reports the principal production, with Stamford second. In Ohio, the fourth state in this industry, the localities of chief production are Springfield and Cincinnati. Chicago, Ill., Lisbon, N. H., and Grand Rapids, Mich., are also important centers.

Organ materials and parts are manufactured to only a small extent separate from the finished instrument. The principal localities for this production are Worcester, Reading, and Westfield, in Massachusetts; Chicago, in Illinois; Ivoryton, Mansfield, and Deep River, in Connecticut; and Alliance, in Ohio. At the census of 1905 the total value of the product for the United States amounted to but $581,373. The large item in Connecticut for all other products, including piano and organ materials, not specified, as shown in Table 14, is largely for piano and organ keyboards.

Table 15 presents statistics concerning the value of specific piano materials and parts manufactured in the United States, showing the per cent each item is of the total reported for this class of products.

TABLE 15.—*Piano materials and parts—distribution of value, by kind: 1905.*

KIND.	Value.	Per cent of total.
Total	$11,397,907	100.0
Actions and action parts	3,439,394	30.2
Cases and piano stock	2,732,493	24.0
Ivory and keys, including keyboards	2,048,795	18.0
Plates, hardware, and strings	2,023,646	17.7
Sounding boards and bridges	447,347	3.9
Piano materials and parts, not specified, including partially manufactured pianos for which a separate division of parts is not obtainable	706,232	6.2

The table shows that the manufacture of actions and action parts forms the most important branch of the production of piano materials and parts. New York state reports the manufacture of piano actions and action parts to a value of $2,160,614, which is 62.8 per cent of the total value reported for the entire United States. Of this amount New York city claims a value of $1,714,419, and a considerable product is also reported for Castleton, St. Johnsville, and Nassau, and other localities in New York state. Outside of New York state Cambridge, Mass., Ivoryton, Conn., and Chicago, Ill., are the chief centers for the manufacture of actions, and there are establishments also in Cincinnati, Ohio, Fort Lee, N. J., Rockford, Ill., and Boston, Mass.

Piano cases, frames, backs, and legs, including ribs, trusses, and trimmings, are manufactured to a value of $2,732,493, and of this amount $1,022,877 was for New York state, chiefly in New York city, Rochester, Brockport, Cortland, and Dolgeville, in the order named. Leominster, Arlington, and Westfield are the centers in Massachusetts, the second state in this manufacture.

The principal locality in the United States for the manufacture of piano ivory and keys, including keyboards, is Ivoryton, Conn., while Tonawanda, N. Y., and Cambridge, Mass., are respectively second and third.

Piano plates are manufactured very largely in Springfield, Ohio, New York, N. Y., Stamford, Conn., and are also reported in Chicago, Ill., as well as in a number of other cities in lesser values.

Sounding boards and bridges are reported chiefly by establishments located in Lisbon, N. H., and Dolgeville, N. Y., although several other localities reported considerable product.

Table 16 presents the kind and value of organ materials and parts manufactured by factories not reporting the finished instrument.

TABLE 16.—*Organ materials and parts—distribution of value, by kind: 1905.*

KIND.	Value.	Per cent of total.
Total	$581,373	100.0
Pipes, reeds, and reed boards	366,137	63.0
Ivory and keys, including stops, knobs, couplers, tremolos, etc.	185,680	31.9
Organ materials and parts not specified	29,556	5.1

The principal organ parts which are reported as manufactured separate from the finished instrument are pipes, reeds, and reed boards. Chicago reported the principal manufacture of reeds and reed boards, with Worcester, Mass., second, while Reading, Mass., reported organ pipes to a considerable extent.

Tables 17, 18, 19, and 20, which follow, present detailed statistics, by states, for each of the four industries embraced in the group of musical instruments, attachments, and materials.

TABLE 17.—MUSICAL INSTRUMENTS, PIANOS—

		United States.	California.	Connecticut.	Illinois.
1	Number of establishments	249	6	8	36
2	Capital, total	$49,649,135	$65,770	$3,049,225	$14,908,172
3	Land	$3,083,605	$8,000	$51,702	$766,209
4	Buildings	$5,375,990	$4,800	$386,617	$1,820,096
5	Machinery, tools, and implements	$3,032,643	$4,852	$189,029	$712,443
6	Cash and sundries	$38,156,897	$48,118	$2,421,877	$11,609,424
7	Proprietors and firm members	137	4	....	9
	Salaried officials, clerks, etc.:				
8	Total number	2,068	3	68	645
9	Total salaries	$2,846,685	$2,675	$121,722	$761,417
	Officers of corporations—				
10	Number	297	1	15	67
11	Salaries	$1,020,923	$375	$47,605	$213,543
	General superintendents, managers, clerks, etc.—				
12	Total number	1,771	2	53	578
13	Total salaries	$1,825,762	$2,300	$74,117	$547,874
	Men—				
14	Number	1,498	2	43	492
15	Salaries	$1,690,475	$2,300	$69,317	$502,982
	Women—				
16	Number	273	....	10	86
17	Salaries	$135,287	....	$4,800	$44,892
	Wage-earners, including pieceworkers, and total wages:				
18	Greatest number employed at any one time during the year	24,249	28	1,347	6,913
19	Least number employed at any one time during the year	18,018	21	950	5,654
20	Average number	21,002	17	1,169	6,268
21	Total wages	$12,170,251	$14,669	$648,684	$3,279,418
	Men 16 years and over—				
22	Average number	20,253	17	1,057	5,944
23	Wages	$11,956,149	$14,669	$610,928	$3,200,770
	Women 16 years and over—				
24	Average number	469	....	90	136
25	Wages	$156,912	....	$31,589	$40,564
	Children under 16 years—				
26	Average number	280	....	22	188
27	Wages	$57,190	....	$6,167	$38,084
	Average number of wage-earners, including pieceworkers, employed during each month:				
	Men 16 years and over—				
28	January	19,591	14	1,025	5,554
29	February	19,732	13	1,092	5,677
30	March	20,000	14	1,094	5,761
31	April	20,067	16	1,098	5,837
32	May	19,980	12	1,122	5,767
33	June	19,860	12	1,112	5,867
34	July	19,107	14	940	5,865
35	August	19,542	15	1,052	5,933
36	September	20,431	16	1,053	6,125
37	October	21,221	27	1,032	6,241
38	November	21,700	26	1,034	6,321
39	December	21,805	25	1,030	6,380
	Women 16 years and over—				
40	January	457	....	70	128
41	February	491	....	89	132
42	March	507	....	103	132
43	April	514	....	105	134
44	May	504	....	106	133
45	June	489	....	104	127
46	July	410	....	80	128
47	August	421	....	82	144
48	September	437	....	87	141
49	October	449	....	85	145
50	November	465	....	84	140
51	December	484	....	85	148
	Children under 16 years—				
52	January	259	....	20	178
53	February	268	....	21	186
54	March	270	....	33	174
55	April	286	....	32	190
56	May	284	....	32	189
57	June	285	....	31	190
58	July	269	....	15	181
59	August	293	....	16	198
60	September	285	....	16	188
61	October	285	....	16	191
62	November	288	....	16	195
63	December	288	....	16	196
64	Miscellaneous expenses, total	$5,532,420	$4,266	$241,480	$1,464,899
65	Rent of works	$469,576	$1,680	$15,493	$55,534
66	Taxes	$192,692	$265	$9,473	$58,747
67	Rent of offices, interest, insurance, and all other sundry expenses not hitherto included.	$4,575,963	$1,971	$216,514	$1,278,695
68	Contract work	$294,189	$350	....	$71,923
69	Materials used, total cost	$19,587,770	$16,016	$976,515	$4,503,165
70	Principal materials	$16,868,593	$11,971	$709,875	$3,722,348
71	Fuel	$304,217	$175	$29,308	$92,306
72	Rent of power and heat	$41,896	$229	$1,170	$8,799
73	Mill supplies	$63,524	$5	$2,849	$26,428
74	All other materials	$2,226,667	$3,316	$225,618	$631,405
75	Freight	$82,873	$320	$7,695	$21,879

[1] Includes establishments distributed as follows: Colorado, 1; Kentucky, 3; Louisiana, 1; Maine, 1; Maryland, 4; Minnesota, 3; Missouri, 2; Nebraska, 1; New Hampshire, 2; West Virginia, 1; Wisconsin, 1.

DETAILED SUMMARY, BY STATES: 1905.

Indiana.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	Pennsylvania.	All other states.[1]	
8	21	7	8	104	14	17	20	1
$2,519,979	$5,749,266	$1,190,809	$1,368,220	$15,504,312	$1,631,907	$1,498,346	$2,163,120	2
$31,526	$518,565	$34,770	$74,000	$1,361,975	$71,908	$62,646	$102,304	3
$418,490	$432,667	$133,186	$177,380	$1,380,229	$198,049	$201,104	$223,372	4
$287,618	$350,954	$46,768	$347,661	$713,984	$184,838	$60,892	$133,604	5
$1,782,345	$4,447,080	$976,085	$769,179	$12,048,124	$1,177,112	$1,173,704	$1,703,849	6
1	7	5	4	79	2	11	15	7
175	210	31	53	671	66	55	91	8
$182,021	$308,025	$52,500	$65,011	$1,030,747	$94,777	$76,455	$151,335	9
20	36	5	3	111	21	7	11	10
$53,440	$156,978	$21,000	$12,700	$409,138	$49,384	$16,600	$40,160	11
155	174	26	50	560	45	48	80	12
$128,581	$151,047	$31,500	$52,311	$621,609	$45,393	$59,855	$111,175	13
125	134	19	43	498	34	38	70	14
$115,229	$132,323	$28,180	$47,814	$587,795	$41,593	$56,491	$106,451	15
30	40	7	7	62	11	10	10	16
$13,352	$18,724	$3,320	$4,497	$33,814	$3,800	$3,364	$4,724	17
1,407	2,403	504	933	8,044	934	791	945	18
938	1,794	454	619	5,433	784	593	778	19
1,196	2,156	487	821	6,466	845	703	874	20
$614,673	$1,374,562	$251,968	$455,373	$4,188,926	$473,511	$367,937	$500,530	21
1,150	2,114	482	742	6,389	831	675	852	22
$599,673	$1,359,368	$250,468	$425,733	$4,166,617	$469,121	$361,560	$497,242	23
46	39	5	73	65	9	4	2	24
$15,000	$14,635	$1,500	$28,600	$20,315	$3,365	$864	$480	25
....	3	....	6	12	5	24	20	26
....	$559	....	$1,040	$1,994	$1,025	$5,513	$2,808	27
1,073	2,099	476	769	6,246	814	662	859	28
1,086	2,063	481	768	6,221	807	668	856	29
1,095	2,122	475	765	6,338	792	687	857	30
1,079	2,071	474	772	6,353	806	691	870	31
1,088	2,109	476	769	6,240	826	720	851	32
1,084	2,074	475	761	6,155	829	685	806	33
1,103	2,027	483	602	5,809	802	683	779	34
1,052	1,960	479	696	6,015	822	677	841	35
1,195	2,117	486	693	6,354	850	650	862	36
1,274	2,233	491	717	6,823	863	641	879	37
1,340	2,258	489	784	7,050	871	643	884	38
1,331	2,235	499	808	7,064	890	663	880	39
51	45	5	82	62	8	4	2	40
51	40	5	93	66	9	4	2	41
46	41	5	100	66	8	4	2	42
47	41	5	102	66	8	4	2	43
45	41	5	94	66	8	4	2	44
43	41	5	89	65	9	4	2	45
40	34	5	46	64	7	4	2	46
41	24	5	46	64	9	4	2	47
43	37	5	44	64	10	4	2	48
47	39	5	46	65	11	4	2	49
48	43	5	62	66	11	4	2	50
50	42	5	72	66	10	4	2	51
....	2	....	7	13	4	19	16	52
....	2	....	6	12	4	19	18	53
....	3	....	6	12	4	19	19	54
....	3	....	5	13	4	19	20	55
....	3	....	5	12	5	20	18	56
....	3	....	6	12	5	20	18	57
....	3	....	6	12	5	30	17	58
....	3	....	6	12	5	29	24	59
....	3	....	6	12	6	29	25	60
....	3	....	7	12	6	28	22	61
....	4	....	6	11	6	28	22	62
....	4	....	6	11	6	28	21	63
$201,759	$611,104	$96,735	$60,925	$2,122,342	$260,461	$143,476	$324,973	64
$480	$58,696	....	$16,037	$285,994	$21,193	$7,551	$6,918	65
$7,996	$35,480	$8,369	$5,213	$48,565	$7,119	$2,048	$9,417	66
$156,783	$454,247	$88,366	$39,675	$1,666,959	$230,238	$133,877	$308,638	67
$36,500	$62,681	....	....	$120,824	$1,911	....	....	68
$861,763	$1,851,940	$381,320	$535,920	$8,461,342	$988,814	$479,409	$531,566	69
$789,450	$1,536,167	$310,015	$501,835	$7,488,004	$881,743	$421,251	$495,934	70
$32,814	$38,614	$6,107	$4,852	$62,192	$14,198	$12,296	$11,355	71
....	$1,210	$360	$11,647	$14,706	$1,415	$160	$2,200	72
$4,985	$4,020	$4,525	$3,019	$12,985	$2,210	$1,258	$1,240	73
$34,439	$260,725	$57,584	$11,050	$864,577	$84,726	$37,713	$15,514	74
$75	$11,204	$2,729	$3,517	$18,878	$4,522	$6,731	$5,323	75

TABLE 17.—MUSICAL INSTRUMENTS, PIANOS—

		United States.	California	Connecticut.	Illinois.
76	Value of products, including amount received for custom work and repairing	$46,922,471	$44,146	$2,684,973	$11,332,507
	Power:				
77	Number of establishments reporting	176	2	8	32
78	Total horsepower	19,280	13	1,043	5,764
	Owned—				
	Engines—				
	Steam—				
79	Number	154		11	28
80	Horsepower	15,906		845	4,590
	Gas and gasoline—				
81	Number	11			
82	Horsepower	216			
	Water wheels—				
83	Number	8		2	1
84	Horsepower	279		50	75
	Water motors—				
85	Number	3			
86	Horsepower	21			
	Electric motors—				
87	Number	140		11	48
88	Horsepower	1,813		100	694
	Rented—				
	Electric motors—				
89	Number	106	2	8	24
90	Horsepower	764	13	48	287
91	Other kind, horsepower	281			118
92	Furnished to other establishments, horsepower	70			10

DETAILED SUMMARY, BY STATES: 1905—Continued.

Indiana.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	Pennsylvania.	All other states.	
$2,216,804	$5,312,244	$1,016,824	$1,188,051	$17,954,219	$965,097	$1,303,029	$1,904,577	76
6	17	6	4	64	13	14	10	77
2,332	1,825	517	1,308	3,871	968	509	1,130	78
11	15	5	6	50	8	11	9	79
2,135	1,470	515	985	3,335	810	420	801	80
1	....	....	....	6	1	2	1	81
87	....	....	....	68	25	28	8	82
....	1	....	....	3	....	1	....	83
....	34	....	....	105	....	15	....	84
....	2	....	....	....	....	....	1	85
....	13	....	....	....	....	....	8	86
5	36	....	18	1	....	2	19	87
100	275	....	321	3	....	27	293	88
....	6	2	1	29	25	5	4	89
....	23	2	2	225	133	19	12	90
10	10	....	....	135	....	....	8	91
....	....	....	20	40	....	....	....	92

TABLE 18.—MUSICAL INSTRUMENTS, ORGANS—DETAILED SUMMARY, BY STATES: 1905.

	United States.	Connecticut.	Illinois.	Indiana.	Massachusetts.	Michigan.	New York.	Ohio.	Pennsylvania.	All other states.[1]
Number of establishments	94	3	13	4	10	3	14	7	11	29
Capital, total	$7,203,878	$157,292	$1,026,052	$97,311	$823,737	$1,025,429	$178,788	$317,232	$788,012	$2,790,025
Land	$293,428	$15,500	$44,250	$16,500	$18,700	$14,519	$18,600	$14,800	$50,100	$100,459
Buildings	$758,104	$28,700	$134,434	$26,500	$53,233	$79,242	$28,400	$36,351	$88,606	$282,638
Machinery, tools, and implements	$663,852	$18,156	$98,799	$21,668	$79,823	$94,463	$27,230	$17,255	$37,882	$268,576
Cash and sundries	$5,488,494	$94,936	$748,569	$32,643	$671,981	$837,205	$104,558	$248,826	$611,424	$2,138,352
Proprietors and firm members	87	4	7	2	6	4	17	6	9	32
Salaried officials, clerks, etc.:										
Total number	323	14	53	5	42	51	7	19	27	105
Total salaries	$372,362	$13,801	$69,512	$5,300	$56,223	$57,051	$8,730	$17,360	$27,178	$117,207
Officers of corporations—										
Number	51	2	15	1	9	5	....	4	5	10
Salaries	$119,996	$3,600	$31,900	$2,600	$22,460	$15,400	....	$3,744	$12,967	$27,325
General superintendents, managers, clerks, etc.—										
Total number	272	12	38	4	33	46	7	15	22	95
Total salaries	$252,366	$10,201	$37,612	$2,700	$33,763	$41,651	$8,730	$13,616	$14,211	$89,882
Men—										
Number	206	7	27	3	22	43	7	9	17	71
Salaries	$218,538	$6,586	$30,928	$2,400	$26,944	$40,599	$8,730	$10,786	$12,168	$79,397
Women—										
Number	66	5	11	1	11	3	....	6	5	24
Salaries	$33,828	$3,615	$6,684	$300	$6,819	$1,052	....	$2,830	$2,043	$10,485
Wage-earners, including pieceworkers, and total wages:										
Greatest number employed at any one time during the year	4,111	115	570	56	683	519	137	231	343	1,457
Least number employed at any one time during the year	3,112	94	474	29	484	279	88	179	202	1,223
Average number	3,623	106	508	41	552	462	102	205	305	1,342
Total wages	$2,034,559	$67,067	$314,230	$15,132	$365,194	$229,659	$71,437	$108,975	$157,423	$705,442
Men 16 years and over—										
Average number	3,503	100	499	41	529	435	100	188	300	1,311
Wages	$1,993,647	$64,753	$311,714	$15,132	$356,768	$220,531	$70,937	$103,663	$156,663	$693,486
Women 16 years and over—										
Average number	108	5	6	....	21	27	2	17	2	28
Wages	$38,998	$2,106	$2,016	....	$8,114	$9,128	$500	$5,312	$378	$11,444
Children under 16 years—										
Average number	12	1	3	....	2	....	....	....	3	3
Wages	$1,914	$208	$500	....	$312	....	....	....	$382	$512
Average number of wage-earners, including pieceworkers, employed during each month:										
Men 16 years and over—										
January	3,532	100	511	53	582	386	114	201	313	1,272
February	3,524	99	522	49	507	446	100	202	308	1,291
March	3,472	101	486	45	500	457	95	203	314	1,271
April	3,505	103	484	43	495	458	99	203	319	1,301
May	3,452	106	485	43	461	448	94	202	314	1,299
June	3,412	106	492	43	415	471	93	186	303	1,303
July	3,439	107	496	40	508	434	101	182	277	1,294
August	3,507	99	497	41	564	428	106	189	279	1,304
September	3,517	98	497	37	583	430	108	152	285	1,327
October	3,535	95	503	31	579	433	100	156	291	1,347
November	3,569	94	508	32	579	429	94	188	296	1,349
December	3,572	92	507	35	575	400	96	192	301	1,374
Women 16 years and over—										
January	103	6	6	....	20	21	2	18	2	28
February	108	4	6	....	21	27	2	18	2	28
March	110	4	6	....	20	30	2	18	2	28
April	106	4	6	....	20	27	2	17	2	28
May	104	5	6	....	21	23	2	16	2	29
June	107	5	6	....	20	28	2	15	2	29
July	104	5	6	....	22	27	2	15	2	25
August	110	6	6	....	21	29	2	16	2	28
September	112	5	6	....	22	29	2	17	2	29
October	113	5	6	....	22	30	2	18	2	28
November	113	6	6	....	22	29	2	18	2	28
December	106	5	6	....	21	24	2	18	2	28
Children under 16 years—										
January	9	1	1	....	2	....	....	....	2	3
February	9	1	1	....	2	....	....	....	2	3
March	12	1	2	....	3	....	....	....	3	3
April	12	1	2	....	3	....	....	....	3	3
May	12	1	3	....	2	....	....	....	3	3
June	12	1	3	....	2	....	....	....	3	3
July	14	1	4	....	2	....	....	....	4	3
August	14	1	4	....	2	....	....	....	4	3
September	12	1	4	....	1	....	....	....	3	3
October	13	1	4	....	2	....	....	....	3	3
November	12	1	4	....	1	....	....	....	3	3
December	13	1	4	....	2	....	....	....	3	3
Miscellaneous expenses, total	$818,276	$28,597	$65,515	$7,274	$130,153	$200,102	$20,974	$23,062	$37,585	$305,014
Rent of works	$54,524	$1,640	$4,007	$72	$22,266	$4,700	$6,233	$750	$1,522	$13,334
Taxes	$20,815	$534	$2,787	$266	$3,172	$5,576	$734	$626	$1,264	$5,856
Rent of offices, interest, insurance, and all other sundry expenses not hitherto included	$724,899	$26,423	$57,258	$3,336	$104,215	$189,826	$13,787	$20,186	$29,924	$279,944
Contract work	$18,038	....	$1,463	$3,600	$500	....	$220	$1,500	$4,875	$5,880
Materials used, total cost	$2,068,638	$54,945	$368,115	$21,797	$218,723	$310,455	$63,818	$104,070	$166,288	$760,427
Principal materials	$1,544,558	$33,899	$281,103	$19,024	$169,916	$211,431	$49,954	$39,168	$135,652	$604,411
Fuel	$66,784	$1,739	$12,456	$1,675	$8,614	$7,798	$1,179	$1,420	$5,875	$26,028
Rent of power and heat	$9,970	$600	$4,435	$50	$516	....	$1,224	$480	....	$2,665
Mill supplies	$10,997	$228	$1,761	$45	$1,045	$180	$334	$369	$1,496	$5,539
All other materials	$405,497	$16,379	$65,561	$450	$38,327	$79,244	$9,697	$61,119	$22,034	$112,686
Freight	$30,832	$2,100	$2,799	$553	$305	$11,802	$1,430	$1,514	$1,231	$9,098

[1] Includes establishments distributed as follows: California, 4; Delaware, 1; Iowa, 1; Kansas, 2; Kentucky, 3; Maine, 1; Maryland, 4; Minnesota, 2; Missouri, 2; New Jersey, 3; Rhode Island, 1; Vermont, 2; Virginia, 1; Wisconsin, 2.

TABLE 18.—MUSICAL INSTRUMENTS, ORGANS—DETAILED SUMMARY, BY STATES: 1905—Continued.

	United States.	Connecticut.	Illinois.	Indiana.	Massachusetts.	Michigan.	New York.	Ohio.	Pennsylvania.	All other states.
Value of products, including amount received for custom work and repairing	$6,041,844	$190,040	$992,612	$53,191	$800,991	$824,777	$208,338	$306,270	$453,513	$2,212,112
Power:										
Number of establishments reporting	73	3	12	3	10	3	7	6	7	22
Total horsepower	4,454	100	998	114	403	518	94	154	399	1,074
Owned—										
Engines—										
Steam—										
Number	40	1	5	3	5	5	...	2	5	14
Horsepower	3,145	50	335	110	295	500	...	60	365	1,430
Gas and gasoline—										
Number	18	1	1	...	2	...	3	4	2	5
Horsepower	266	12	10	...	20	...	38	77	20	89
Water wheels—										
Number	3	...	1	...	2	...	...	...	...	...
Horsepower	235	...	200	...	35	...	...	...	...	...
Water motors—										
Number	2	...	...	...	1	...	...	...	1	...
Horsepower	11	...	...	...	1	...	...	...	10	...
Electric motors—										
Number	44	...	3	...	15	9	...	...	1	16
Horsepower	369	...	202	...	37	18	...	...	4	108
Other power, horsepower	6	...	6	...	...	...	...	...	...	...
Rented—										
Electric motors—										
Number	35	6	12	1	...	...	5	2	...	9
Horsepower	200	13	83	4	...	...	36	17	...	47
Other kind, horsepower	222	25	162	...	15	...	20	...	...	...
Furnished to other establishments, horsepower	12	...	...	...	12	...	...	...	...	...

TABLE 19.—MUSICAL INSTRUMENTS, PIANO AND ORGAN MATERIALS—DETAILED SUMMARY, BY STATES: 1905.

	United States.	Connecticut.	Illinois.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	All other states.[1]
Number of establishments	101	6	7	24	3	6	42	5	8
Capital, total	$11,628,897	$2,019,779	$536,456	$1,733,215	$147,846	$153,897	$5,339,886	$1,407,418	$290,400
Land	$1,159,848	$83,900	$59,335	$120,050	$7,191	$5,500	$794,689	$75,923	$13,260
Buildings	$1,858,768	$193,147	$58,301	$280,510	$57,000	$31,302	$1,033,046	$155,000	$50,462
Machinery, tools, and implements	$1,766,829	$196,656	$120,936	$236,647	$32,036	$43,705	$835,622	$243,262	$57,965
Cash and sundries	$6,843,452	$1,546,076	$297,884	$1,096,008	$51,619	$73,390	$2,676,529	$933,233	$168,713
Proprietors and firm members	79	2	2	24	5	2	37	2	5
Salaried officials, clerks, etc.:									
Total number	331	44	41	40	2	12	148	31	13
Total salaries	$508,883	$104,303	$55,094	$64,301	$3,600	$12,115	$216,846	$38,264	$14,360
Officers of corporations—									
Number	80	12	8	14	....	6	30	5	5
Salaries	$215,521	$59,300	$11,636	$33,360	....	$5,730	$86,315	$11,000	$7,280
General superintendents, managers, clerks, etc.—									
Total number	251	32	33	26	2	6	118	26	8
Total salaries	$293,362	$45,003	$43,458	$30,941	$3,600	$6,385	$130,531	$26,364	$7,080
Men—									
Number	224	28	31	22	2	5	105	24	7
Salaries	$279,060	$42,283	$41,980	$29,047	$3,600	$6,350	$123,297	$25,523	$6,980
Women—									
Number	27	4	2	4	....	1	13	2	1
Salaries	$14,302	$2,720	$1,478	$1,894	....	$35	$7,234	$841	$100
Wage-earners, including pieceworkers, and total wages:									
Greatest number employed at any one time during the year	9,368	1,452	829	1,571	129	349	3,303	1,336	399
Least number employed at any one time during the year	7,280	1,062	662	1,374	98	251	2,666	888	279
Average number	8,456	1,308	732	1,463	120	289	3,046	1,160	338
Total wages	$4,322,268	$621,003	$338,021	$748,501	$54,910	$104,798	$1,664,577	$622,550	$167,908
Men 16 years and over—									
Average number	7,566	1,152	594	1,198	120	252	2,759	1,154	337
Wages	$4,075,807	$575,366	$300,789	$668,782	$54,910	$90,754	$1,596,613	$621,387	$167,206
Women 16 years and over—									
Average number	656	151	138	224	....	15	121	6	1
Wages	$197,925	$44,188	$37,232	$71,920	....	$5,835	$36,885	$1,163	$702
Children under 16 years—									
Average number	234	5	....	41	....	22	166	....	....
Wages	$48,536	$1,449	....	$7,799	....	$8,209	$31,079	....	....
Average number of wage-earners, including pieceworkers, employed during each month:									
Men 16 years and over—									
January	7,572	1,237	634	1,198	126	290	2,771	941	375
February	7,743	1,171	619	1,187	126	285	2,775	1,211	369
March	7,598	1,112	626	1,199	126	262	2,705	1,195	373
April	7,516	1,088	597	1,211	127	244	2,729	1,175	345
May	7,379	1,061	571	1,194	127	247	2,704	1,142	333
June	7,271	1,077	559	1,159	129	240	2,672	1,117	318
July	7,282	1,155	561	1,162	126	222	2,689	1,057	310
August	7,402	1,184	560	1,192	126	231	2,684	1,104	321
September	7,548	1,182	585	1,194	114	239	2,750	1,148	336
October	7,772	1,184	605	1,232	114	238	2,840	1,226	333
November	7,792	1,193	605	1,216	100	251	2,848	1,258	321
December	7,917	1,180	606	1,232	99	275	2,941	1,274	310
Women 16 years and over—									
January	705	166	165	238	....	15	120	....	1
February	662	140	158	228	....	15	120	....	1
March	647	133	155	221	....	15	122	....	1
April	625	131	141	224	....	14	114	....	1
May	612	129	135	212	....	15	115	5	1
June	600	122	120	214	....	15	123	5	1
July	650	176	119	210	....	14	125	5	1
August	651	173	120	219	....	15	116	7	1
September	611	126	125	216	....	15	121	7	1
October	681	174	125	233	....	15	123	10	1
November	711	172	143	237	....	16	126	16	1
December	717	170	150	236	....	16	127	17	1
Children under 16 years—									
January	226	4	....	37	....	27	158	....	....
February	236	4	....	39	....	27	166	....	....
March	234	4	....	41	....	25	164	....	....
April	237	6	....	40	....	24	167	....	....
May	239	6	....	44	....	20	169	....	....
June	222	6	....	43	....	20	153	....	....
July	223	5	....	41	....	20	157	....	....
August	228	5	....	40	....	20	163	....	....
September	241	5	....	41	....	20	175	....	....
October	230	5	....	35	....	19	171	....	....
November	251	5	....	45	....	21	180	....	....
December	241	5	....	46	....	21	169	....	....
Miscellaneous expenses, total	$787,475	$159,363	$37,686	$138,429	$9,683	$21,230	$267,241	$112,096	$41,747
Rent of works	$79,623	....	$2,969	$11,165	$1,020	$5,568	$44,008	$13,153	$1,740
Taxes	$58,200	$8,369	$2,558	$10,272	$610	$594	$24,856	$8,329	$2,612
Rent of offices, interest, insurance, and all other sundry expenses not hitherto included	$620,099	$145,249	$31,992	$116,992	$8,053	$15,068	$181,001	$90,614	$32,030
Contract work	$28,653	$5,745	$167	....	....	....	$17,376	....	$5,365
Materials used, aggregate cost	$6,330,219	$1,370,263	$526,457	$1,043,283	$58,665	$121,346	$2,425,135	$532,335	$252,735
Principal materials, total cost	$5,601,467	$1,226,385	$400,077	$951,002	$50,419	$106,976	$2,158,794	$485,069	$222,745
Purchased in raw state	$949,053	$710,482	....	....	....	....	$238,571	....	....
Purchased in partially manufactured form	$4,652,414	$515,903	$400,077	$951,002	$50,419	$106,976	$1,920,223	$485,069	$222,745
Fuel	$142,030	$36,383	$15,803	$18,000	$3,565	$10,106	$38,648	$17,639	$1,886
Rent of power and heat	$38,276	....	$1,250	$3,190	....	$300	$22,810	$8,920	$1,806
Mill supplies	$15,664	$2,092	$1,044	$2,258	$481	$663	$7,542	$1,040	$544
All other materials	$464,691	$89,433	$105,820	$60,321	$600	$3,111	$182,592	$13,667	$9,147
Freight	$68,091	$15,970	$2,463	$8,512	$3,600	$190	$14,749	$6,000	$16,607

[1] Includes establishments distributed as follows: California, 2; Indiana, 2; New Hampshire, 2; Pennsylvania, 1; Vermont, 1.

TABLE 19.—MUSICAL INSTRUMENTS, PIANO AND ORGAN MATERIALS—DETAILED SUMMARY, BY STATES: 1905—Continued.

	United States.	Connecticut.	Illinois.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	All other states.
Value of products, including amount received for custom work and repairing	$13,128,315	$2,397,822	$998,239	$2,165,393	$142,626	$288,959	$5,226,947	$1,412,839	$495,490
Power:									
Number of establishments reporting	86	6	6	21	3	6	34	4	6
Total horsepower	9,553	1,441	1,443	1,500	293	413	2,637	1,171	655
Owned—									
Engines—									
Steam—									
Number	69	16	5	11	3	7	21	2	4
Horsepower	6,649	1,028	720	1,276	285	405	2,065	375	495
Gas and gasoline—									
Number	8	...	...	1	...	...	3	3	1
Horsepower	259	...	...	10	...	...	34	210	5
Water wheels—									
Number	11	5	1	2	...	...	2	...	1
Horsepower	288	130	40	47	...	...	41	...	30
Water motors—									
Number	2	1	...	1	...	...	...	...	...
Horsepower	33	23	...	10	...	...	...	...	...
Electric motors—									
Number	48	15	20	6	...	...	2	4	1
Horsepower	971	260	500	35	...	...	30	140	6
Rented—									
Electric motors—									
Number	69	...	8	2	...	...	17	31	11
Horsepower	968	...	158	6	...	...	239	446	119
Other kind, horsepower	385	...	25	116	8	8	228	...	...
Furnished to other establishments, horsepower	113	...	10	70	...	2	31	...	...

TABLE 20.—MUSICAL INSTRUMENTS AND MATERIALS,

		United States.	California.	Connecticut.	Illinois.	Indiana.
1	Number of establishments	181	3	3	28	5
2	Capital, total	$3,743,469	$9,010	$4,700	$640,549	$445,374
3	Land	$97,402	$3,000	$50	$16,250	$13,800
4	Buildings	$318,408	$1,500	$250	$43,700	$44,550
5	Machinery, tools, and implements	$693,193	$470	$1,500	$129,969	$58,609
6	Cash and sundries	$2,634,466	$4,040	$2,900	$450,630	$328,415
7	Proprietors and firm members	190	4	3	27	3
	Salaried officials, clerks, etc.:					
8	Total number	225		1	41	39
9	Total salaries	$251,766		$1,000	$51,499	$42,790
	Officers of corporations—					
10	Number	43			11	3
11	Salaries	$73,807			$18,529	$1,248
	General superintendents, managers, clerks, etc.—					
12	Total number	182		1	30	36
13	Total salaries	$177,959		$1,000	$32,970	$41,542
	Men—					
14	Number	128		1	28	14
15	Salaries	$156,167		$1,000	$31,930	$33,050
	Women—					
16	Number	54			2	22
17	Salaries	$21,792			$1,040	$8,492
	Wage-earners, including pieceworkers, and total wages:					
18	Greatest number employed at any one time during the year	2,593	5	3	596	328
19	Least number employed at any one time during the year	1,584	4	2	171	200
20	Average number	2,139	5	2	491	283
21	Total wages	$1,162,068	$2,850	$1,396	$301,604	$125,047
	Men 16 years and over—					
22	Average number	1,890	5	2	472	252
23	Wages	$1,089,944	$2,850	$1,396	$297,404	$115,710
	Women 16 years and over—					
24	Average number	191			4	31
25	Wages	$60,612			$1,314	$9,337
	Children under 16 years—					
26	Average number	58			15	
27	Wages	$11,512			$2,886	
	Average number of wage-earners, including pieceworkers, employed during each month:					
	Men 16 years and over—					
28	January	1,937	5	1	487	220
29	February	1,946	5	1	494	225
30	March	1,933	5	1	508	225
31	April	1,686	5	1	263	235
32	May	1,783	5	1	420	247
33	June	1,792	5	1	489	251
34	July	1,800	5	3	480	258
35	August	1,816	5	3	443	261
36	September	1,958	5	3	516	270
37	October	1,971	5	3	489	271
38	November	2,023	5	3	525	275
39	December	2,035	5	3	550	277
	Women 16 years and over—					
40	January	184			4	27
41	February	185			4	28
42	March	186			4	30
43	April	186			4	28
44	May	186			4	29
45	June	189			4	31
46	July	188			4	31
47	August	188			4	29
48	September	196			4	33
49	October	199			4	34
50	November	204			4	36
51	December	201			4	36
	Children under 16 years—					
52	January	51			17	
53	February	60			17	
54	March	61			19	
55	April	56			14	
56	May	55			15	
57	June	55			15	
58	July	54			13	
59	August	56			13	
60	September	63			16	
61	October	61			14	
62	November	63			15	
63	December	61			12	
64	Miscellaneous expenses, total	$426,823	$689	$266	$56,634	$85,795
65	Rent of works	$74,903	$354	$146	$20,289	$420
66	Taxes	$12,554	$77	$5	$2,874	$2,170
67	Rent of offices, interest, insurance, and all other sundry expenses not hitherto included.	$338,324	$258	$115	$33,356	$83,110
68	Contract work	$1,042			$115	$95
69	Materials used, aggregate cost	$1,129,939	$2,170	$1,825	$206,948	$87,656
70	Principal materials, total cost	$795,116	$1,499	$1,764	$185,688	$68,922
71	Purchased in raw state	$8,405			$2,000	$640
72	Purchased in partially manufactured form	$786,711	$1,499	$1,764	$183,688	$68,282
73	Fuel	$22,801		$21	$6,069	$3,787
74	Rent of power and heat	$18,907		$40	$2,929	$180
75	Mill supplies	$8,019			$857	$1,923
76	All other materials	$275,309	$621		$9,276	$12,830
77	Freight	$9,787	$50		$2,129	$14

[1] Includes establishments distributed as follows: Colorado, 2; Georgia, 1; Iowa, 2; Kentucky, 1; Louisiana, 1; Nebraska, 1; Oregon, 1.

NOT SPECIFIED—DETAILED SUMMARY, BY STATES: 1905.

Maryland.	Massachusetts.	Michigan.	Minnesota.	Missouri.	New Jersey.	New York.	Ohio.	Pennsylvania.	Washington.	Wisconsin.	All other states.[1]	
3	22	7	4	5	7	56	7	16	3	3	9	1
$9,375	$143,280	$77,794	$5,100	$23,334	$892,134	$1,224,538	$44,861	$180,783	$1,450	$5,430	$35,757	2
....	$928	$3,100	....	$3,875	$29,234	$13,065	....	$8,500	....	$500	$5,100	3
....	$3,075	$6,435	....	$8,575	$144,819	$25,800	$75	$23,200	....	$270	$16,159	4
$2,050	$40,712	$12,224	$1,750	$3,584	$148,459	$231,997	$16,248	$35,031	$600	$3,100	$6,890	5
$7,325	$98,565	$56,035	$3,350	$7,300	$569,622	$953,676	$28,538	$114,052	$850	$1,560	$7,608	6
4	21	9	4	3	7	62	4	23	3	3	10	7
....	7	14	1	2	55	49	4	10	....	....	2	8
....	$9,696	$10,432	$250	$1,050	$62,330	$60,559	$3,911	$7,609	....	....	$640	9
....	5	2	....	....	6	13	2	1	....	....	....	10
....	$8,500	$2,400	....	....	$13,000	$25,230	$2,400	$2,500	....	....	....	11
....	2	12	1	2	49	36	2	9	....	....	2	12
....	$1,196	$8,032	$250	$1,050	$49,330	$35,329	$1,511	$5,109	....	....	$640	13
....	....	7	1	1	39	30	1	5	....	....	1	14
....	....	$6,294	$250	$900	$45,246	$32,637	$1,140	$3,600	....	....	$120	15
....	2	5	....	1	10	6	1	4	....	....	1	16
....	$1,196	$1,738	....	$150	$4,084	$2,692	$371	$1,509	....	....	$520	17
3	157	135	8	27	623	545	21	131	1	2	8	18
2	120	76	1	24	382	380	16	107	1	2	6	19
2	136	109	4	25	465	468	19	120	1	2	7	20
$1,320	$77,512	$49,075	$2,300	$14,338	$251,385	$250,908	$10,659	$65,206	$1,000	$1,440	$6,028	21
2	120	105	4	25	327	432	17	117	1	2	7	22
$1,320	$72,711	$47,975	$2,300	$14,338	$211,827	$238,636	$10,295	$64,714	$1,000	$1,440	$6,028	23
....	15	4	....	....	109	26	2	....	....	....	....	24
....	$4,593	$1,100	....	....	$34,168	$9,736	$364	....	....	....	....	25
....	1	....	....	....	29	10	....	3	....	....	....	26
....	$208	....	....	....	$5,390	$2,536	....	$492	....	....	....	27
2	129	106	7	23	378	434	18	117	1	2	7	28
2	129	102	6	24	375	438	18	117	1	2	7	29
2	124	106	6	25	341	445	18	117	1	2	7	30
2	115	102	4	25	355	435	17	117	1	2	7	31
2	112	104	1	25	297	425	17	117	1	2	7	32
2	112	95	1	25	241	426	17	117	1	2	7	33
2	113	83	1	25	278	409	17	117	1	2	6	34
2	114	89	1	25	313	417	16	117	1	2	7	35
2	113	102	2	25	335	432	17	117	1	2	7	36
2	122	127	4	26	341	435	18	118	1	2	7	37
2	130	123	7	26	343	443	15	116	1	2	7	38
2	127	121	8	26	327	445	16	117	1	2	8	39
....	17	4	....	....	109	21	2	....	....	....	....	40
....	17	4	....	....	108	22	2	....	....	....	....	41
....	15	4	....	....	109	22	2	....	....	....	....	42
....	14	4	....	....	110	24	2	....	....	....	....	43
....	13	4	....	....	109	25	2	....	....	....	....	44
....	13	4	....	....	110	25	2	....	....	....	....	45
....	13	4	....	....	108	26	2	....	....	....	....	46
....	13	4	....	....	109	27	2	....	....	....	....	47
....	13	4	....	....	110	30	2	....	....	....	....	48
....	16	4	....	....	109	30	2	....	....	....	....	49
....	18	4	....	....	110	30	2	....	....	....	....	50
....	18	4	....	....	107	30	2	....	....	....	....	51
....	1	....	....	....	20	10	....	3	....	....	....	52
....	1	....	....	....	27	10	....	5	....	....	....	53
....	1	....	....	....	28	10	....	3	....	....	....	54
....	1	....	....	....	29	10	....	2	....	....	....	55
....	1	....	....	....	29	8	....	2	....	....	....	56
....	1	....	....	....	28	8	....	3	....	....	....	57
....	1	....	....	....	27	10	....	3	....	....	....	58
....	1	....	....	....	29	10	....	3	....	....	....	59
....	1	....	....	....	32	11	....	3	....	....	....	60
....	1	....	....	....	32	11	....	3	....	....	....	61
....	1	....	....	....	33	11	....	3	....	....	....	62
....	1	....	....	....	34	11	....	3	....	....	....	63
$860	$21,843	$11,459	$733	$3,908	$89,618	$109,133	$11,059	$29,045	$577	$755	$4,449	64
$450	$8,438	$1,768	$417	$1,104	$1,056	$29,487	$2,177	$6,325	$424	$340	$1,708	65
....	$486	$759	$16	$98	$3,884	$1,243	$103	$398	$23	$55	$363	66
$410	$12,592	$8,932	$300	$2,706	$84,678	$77,898	$8,779	$22,322	$130	$360	$2,378	67
....	$327	....	....	....	....	$505	....	....	....	....	....	68
$930	$93,276	$35,097	$881	$13,082	$317,852	$303,115	$12,818	$43,497	$383	$1,276	$9,133	69
$619	$78,481	$26,244	$545	$11,950	$119,481	$241,698	$9,360	$40,313	$225	$700	$7,621	70
$1	$2,976	....	....	....	$50	$2,388	$300	....	$50	....	....	71
$618	$75,505	$26,244	$545	$11,950	$119,431	$239,310	$9,066	$40,313	$175	$700	$7,621	72
$51	$2,320	$920	$15	$349	$4,858	$2,221	$390	$1,651	$38	$16	$95	73
$75	$1,375	$1,257	$106	$60	$2,720	$8,706	$280	$990	....	$60	$129	74
$5	$277	$526	....	$110	$2,340	$1,643	$54	$281	....	....	$3	75
$155	$10,667	$4,968	$215	$524	$186,553	$45,012	$1,500	$183	$120	$500	$1,285	76
$25	$156	$1,182	....	$89	$1,900	$2,935	$1,228	$79	....	....	....	77

TABLE 20.—MUSICAL INSTRUMENTS AND MATERIALS, NOT

		United States.	California.	Connecticut.	Illinois.	Indiana.
78	Value of products, including amount received for custom work and repairing	$3,481,710	$8,145	$6,250	$674,370	$351,832
	Power:					
79	Number of establishments reporting	92		2	18	4
80	Total horsepower	1,631		3	255	125
	Owned—					
	Engines—					
	Steam—					
81	Number	24			1	2
82	Horsepower	766			150	65
	Gas and gasoline—					
83	Number	15			5	2
84	Horsepower	109			28	12
	Water wheels—					
85	Number	5				1
86	Horsepower	128				38
	Electric motors—					
87	Number	2				
88	Horsepower	28				
89	Other power, horsepower	2				
	Rented—					
	Electric motors—					
90	Number	61		2	11	1
91	Horsepower	336		3	55	10
92	Other kind, horsepower	262			22	

SPECIFIED—DETAILED SUMMARY, BY STATES: 1905—Continued.

Maryland.	Massachusetts.	Michigan.	Minnesota.	Missouri.	New Jersey.	New York.	Ohio.	Pennsylvania.	Washington.	Wisconsin.	All other states.	
$7,110	$259,445	$123,912	$9,125	$47,744	$862,886	$888,423	$30,049	$173,215	$4,247	$6,200	$28,757	78
1	10	4	2	2	5	27	3	10	...	2	2	79
2	197	70	11	7	373	430	75	61	...	2	20	80
...	2	1	...	1	8	5	1	3	...	...	...	81
...	60	35	...	5	305	78	35	33	...	...	...	82
...	...	...	...	...	...	5	1	1	...	...	1	83
...	...	...	...	...	...	34	20	10	...	...	5	84
...	4	...	...	...	...	...	...	...	...	...	...	85
...	90	...	...	...	...	...	...	...	...	...	...	86
...	...	...	...	...	1	...	1	...	...	...	...	87
...	...	...	...	...	25	...	3	...	...	...	...	88
...	...	...	...	...	...	2	...	...	...	...	...	89
1	9	8	2	1	2	14	2	5	...	2	1	90
2	16	35	11	2	43	109	17	16	...	2	15	91
...	31	...	...	...	...	207	...	2	...	...	...	92

PHONOGRAPHS AND GRAPHOPHONES.

Statistics concerning the manufacture of phonographs, graphophones, and supplies were presented in 1900 in connection with the special report on electrical apparatus and supplies,[1] inasmuch as this apparatus was invented and largely perfected by electricians, or those particularly interested in electricity. The only portion of the instrument, however, that is ever electrical in operation is the motor, which is sometimes arranged for attachment to the incandescent light wire or has a storage battery attachment, the current thus obtained furnishing the power.

For the reason, therefore, that this class of instruments may not properly be considered as electrical apparatus and as it is now considerably used in reproducing music and its introduction to the public is largely through the medium of music dealers, the statistics are presented with the report on the manufacture of musical instruments and materials. The figures given are not included with the combined statistics on musical instrument manufacture, but are presented in separate form and include not only the manufacture of the finished instrument but also phonograph and graphophone supplies and disk and cylinder records, when the same were manufactured by establishments classified under this head.

Table 21 is a comparative summary of statistics for the United States, showing the per cent of increase during the five-year period, 1900 and 1905.

TABLE 21.—*Phonographs and graphophones—comparative summary, with per cent of increase: 1905 and 1900.*

	1905	1900	Per cent of increase.
Number of establishments	14	11	27.3
Capital	$8,740,618	$3,348,282	161.0
Salaried officials, clerks, etc., number	537	144	272.9
Salaries	$666,489	$179,145	272.0
Wage-earners, average number	3,397	1,267	168.1
Total wages	$1,683,903	$608,490	176.7
Men 16 years and over	3,025	1,114	171.5
Wages	$1,564,625	$565,076	176.9
Women 16 years and over	364	146	149.3
Wages	$117,859	$42,914	174.6
Children under 16 years	8	7	14.3
Wages	$1,419	$500	183.8
Miscellaneous expenses	$1,653,762	$215,401	667.8
Cost of materials used	$4,161,136	$827,529	402.8
Value of products	$10,237,075	$2,246,274	355.7

There was an increase of but 3 establishments in the five years intervening between the two censuses, and, as these 3 establishments reported a very small product, the large increase in production has occurred without any corresponding increase in the number of establishments reporting. This concentration of manufacture in a few large companies is due to the possession of patents which enables them to retain the rights to sole production.

Table 21 shows that in 1900 the capital invested was 49.1 per cent larger than the value of products reported, while in 1905 the value of products was considerably larger, being 17.1 per cent more than the capital. This results naturally from the fact that at the last census the industry was in its infancy, and costly experiments were constantly being made which required the expenditure of large sums of money with, in some instances, comparatively little return. Experiments are still being made and expensive laboratories are maintained in the principal factories, where new materials are tested and other improvements are designed and worked out by experts; but in the main the production of phonographs and graphophones is past the experimental stage and their commercial position is assured. Thus at the census of 1905 the productive power of the capital invested was utilized much more completely than in 1900, and the alteration in the relation of capital to products at the two periods resulted.

The item of miscellaneous expense is apparently a very important factor in the cost of production of phonographs and graphophones. At the census of 1905 the amount expended for this item nearly equaled the expenditure for labor. This is due to the cost of extensive advertising and the large amounts expended to secure records of famous bands and professional soloists, items which are included in the total of miscellaneous expense.

The principal centers of the industry are Camden and Orange, N. J.; Bridgeport, Conn.; Toledo, Ohio; and New York city.

Table 22 is a summary of products of establishments manufacturing phonographs, graphophones, disk or cylinder records, and phonograph and graphophone supplies, as reported at the censuses of 1900 and 1905, showing the per cent each item is of the total for each census and also the per cent of increase during the five-year period.

TABLE 22.—*Phonographs and graphophones—products, by kind and value, with per cent of total and per cent of increase: 1905 and 1900.*

KIND.	1905		1900		Per cent of increase.
	Value.	Per cent of total.	Value.	Per cent of total.	
Total	$10,237,075	100.0	$2,246,274	100.0	355.7
Phonographs and graphophones	2,966,343	29.0	1,240,503	55.2	139.1
Disk and cylinder records	4,678,547	45.7	539,370	24.0	767.4
All other products	2,592,185	25.3	466,401	20.8	455.8

The total value of phonographs and graphophones manufactured in 1905 was but 29 per cent of the total product reported for the industry at that census, while the value of disk and cylinder records manufactured represented 45.7 per cent of the same total. In 1900 the proportions were reversed, the value of finished instruments manufactured amounting to 55.2 per cent of the total, and the value reported for

[1] Twelfth Census, Manufactures, Part IV, page 181.

disk and cylinder records to but 24 per cent of the total. This change in the relative importance of the two branches of the industry was not due to any falling off in the production of phonographs and graphophones, which increased largely during the five years, but to the far greater increase in the production of disk and cylinder records. As the machines themselves become more widely distributed, the manufacture of disk and cylinder records is sure to continue to increase at the same extraordinary rate. Every phonograph and graphophone sold creates a demand for records that results in sales which ordinarily far exceed in value the initial cost of the machine itself.

The value reported for this industry includes in some instances a product which can not be classed under either the finished instrument or disk and cylinder records. For instance, a large establishment in Philadelphia reports the exclusive manufacture of talking machine supplies, the value of which is included in Table 22 under the head of "all other products," and items of this nature are probably duplicated to a certain extent in the values reported for phonographs and graphophones by establishments manufacturing the finished product. In these latter establishments, under the heading materials used, there is reported a large expenditure for materials such as horns, cylinder cases, etc., which are reported as finished products of plants producing such supplies, and thus their values are included twice in the aggregate for the industry. It is impossible to measure the extent of this duplication, but its presence should be noted when the value reported for the industry is under consideration.

In addition to phonograph and graphophone supplies there is also included in "all other products" a number of miscellaneous articles not related to the industry—for instance, billiard balls and game markers, composition novelties, electrical specialties, numbering machines, etc.—reported by establishments whose principal product is phonographs, graphophones, records, and supplies. This value, however, is of little consequence in comparison with the grand total.

The history of the phonograph and graphophone can be found in the special report on electrical apparatus and supplies,[1] and therefore minute details will not be given in this report. Briefly stated, the principal features of the instrument are the motor, the recording and reproducing mechanism, and the record, which is flat or cylindrical according to the type of machine.

Electricity is sometimes used as motive power, especially for office dictation instruments, but the large majority of phonographs and graphophones manufactured are operated by clockwork with a tandem spring wind. The motor is arranged to turn the mandrel holding the record, and there is a delicately adjusted "governor" arranged to regulate the speed, thus retarding or accelerating the action as required.

In making a record the sound waves received in the horn of the instrument and transmitted through the sound passage, agitate the sensitive mica or glass diaphragm, which is about one one-hundred and fiftieth of an inch in thickness and from an inch and one-fourth to 2 inches in diameter. A small cutting chisel or point is attached to the diaphragm for the purpose of recording these vibrations on a blank wax record. This original or master record is then electrotyped for permanent use and duplicate records are made from an exact gold-plated copper mold negative.

The reproduction of sound from records is practically a reversal of the process of making. The reproducer point for use on cylinder records is a sapphire ball, and the sound markings are in the form of engravings about one one-thousandth of an inch in depth; whereas in a disk machine a metal reproduction needle is used and the markings are delicate zigzag lines about 100 to the inch. The stylus, resting on a revolving cylinder record, is moved rapidly up and down, agitating a horizontal diaphragm, while the needle of a disk machine is moved from left to right and vice versa, agitating a diaphragm attached to the needle obliquely with the record. This vibration produces the sound passage—sound waves which are practically identical with those originally communicated to the master record. The size and construction of the horn are important to successful results, inasmuch as it prevents the sound waves from becoming scattered. In commercial use, in teaching languages, and in all instances where there is but one listener, tubes are used in place of the horn.

Table 23 is a detailed summary for this industry at the census of 1905.

[1]Twelfth Census, Manufactures, Part IV, page 181.

TABLE 23.—PHONOGRAPHS AND GRAPHOPHONES—DETAILED SUMMARY, BY STATES: 1905.

	United States.	New Jersey.	All other states.[1]
Number of establishments	14	4	10
Capital, total	$8,740,618	$3,574,316	$5,166,302
Land	$260,000	$130,000	$130,000
Buildings	$563,779	$345,264	$218,515
Machinery, tools, and implements	$1,361,545	$755,784	$605,761
Cash and sundries	$6,555,294	$2,343,268	$4,212,026
Proprietors and firm members	6	....	6
Salaried officials, clerks, etc.:			
Total number	537	283	254
Total salaries	$666,489	$318,924	$347,565
Officers of corporations—			
Number	32	13	19
Salaries	$218,329	$88,818	$129,511
General superintendents, managers, clerks, etc.—			
Total number	505	270	235
Total salaries	$448,160	$230,106	$218,054
Men—			
Number	427	231	196
Salaries	$411,216	$212,308	$198,908
Women—			
Number	78	39	39
Salaries	$36,944	$17,798	$19,146
Wage-earners, including pieceworkers, and total wages:			
Greatest number employed at any one time during the year	4,189	2,204	1,985
Least number employed at any one time during the year	2,547	1,601	946
Average number	3,397	1,967	1,430
Total wages	$1,683,903	$959,104	$724,799
Men 16 years and over—			
Average number	3,025	1,710	1,315
Wages	$1,564,625	$876,185	$688,440
Women 16 years and over—			
Average number	364	251	113
Wages	$117,859	$82,050	$35,809
Children under 16 years—			
Average number	8	6	2
Wages	$1,410	$869	$550
Average number of wage-earners, including pieceworkers, employed during each month:			
Men 16 years and over—			
January	3,180	1,754	1,426
February	3,354	1,737	1,617
March	3,258	1,618	1,640
April	3,151	1,658	1,493
May	2,782	1,526	1,256
June	2,617	1,622	995
July	2,617	1,654	963
August	2,746	1,721	1,025
September	2,997	1,782	1,215
October	3,208	1,829	1,379
November	3,229	1,824	1,405
December	3,161	1,795	1,366
Women 16 years and over—			
January	375	263	112
February	441	269	172
March	421	244	177
April	365	240	125
May	331	240	91
June	302	235	67
July	302	238	64
Average number of wage-earners, including pieceworkers, employed during each month—Continued.			
Women 16 years and over—Continued.			
August	308	244	64
September	343	255	88
October	413	258	155
November	412	262	150
December	355	264	91
Children under 16 years—			
January	9	7	2
February	10	8	2
March	9	7	2
April	9	7	2
May	8	6	2
June	7	5	2
July	8	6	2
August	7	5	2
September	7	5	2
October	7	5	2
November	8	6	2
December	7	5	2
Miscellaneous expenses, total	$1,653,762	$1,302,425	$351,337
Rent of works	$23,089	$8,892	$14,197
Taxes	$7,948	$3,578	$4,370
Rent of offices, interest, insurance, and all other sundry expenses not hitherto included	$1,618,485	$1,289,365	$329,120
Contract work	$4,240	$590	$3,650
Materials used, aggregate cost	$4,161,136	$2,370,202	$1,790,934
Principal materials, total cost	$2,795,443	$1,169,735	$1,625,708
Purchased in raw state	$2,965	$2,965	....
Purchased in partially manufactured form	$2,792,478	$1,166,770	$1,625,708
Fuel	$29,520	$16,461	$13,059
Rent of power and heat	$22,341	$16,411	$5,930
Mill supplies	$61,433	$34,316	$27,117
All other materials	$1,142,379	$1,045,560	$96,819
Freight	$110,020	$87,719	$22,301
Value of products, including amount received for custom work and repairing	$10,237,075	$5,931,835	$4,305,240
Power:			
Number of establishments reporting	13	4	9
Total horsepower	2,812	1,782	1,030
Owned—			
Engines—			
Steam—			
Number	9	7	2
Horsepower	1,905	1,075	830
Gas and gasoline—			
Number	2	....	2
Horsepower	9	....	9
Electric motors—			
Number	14	8	6
Horsepower	290	200	90
Other power, horsepower	2	....	2
Rented—			
Electric motors—			
Number	12	6	6
Horsepower	181	107	74
Other kind, horsepower	425	400	25
Furnished to other establishments, horsepower	10	10	....

[1] Includes establishments distributed as follows: Connecticut, 4; Illinois, 1; New York, 2; Ohio, 1; Pennsylvania, 2.

AUTOMOBILES

AUTOMOBILES.

By George E. Oller.

In five years the manufacture of automobiles in the United States has grown from an industry so unimportant that it was not reported separately at the census of 1900 to one with products valued at $26,645,064 at the census of 1905, which covered the calendar year 1904. This remarkable growth is not, like that of the bicycle, based on a fad, and so liable to as sudden a decline. Unlike the bicycle, the automobile is not essentially a new vehicle, but merely a carriage or truck with a new means of propulsion, possessing many advantages over a vehicle drawn by horses. As a means of amusement its popularity may fluctuate or decline, but its practical value has been so thoroughly demonstrated that its use will doubtless become more general each succeeding year, until it is displaced by some vehicle as much its superior as the automobile is the superior of the horse and wagon.

In this report the industry is first taken up statistically, and most of this statistical discussion has to do only with the figures for establishments manufacturing automobiles as a principal product. At the end of this presentation there are briefly taken up, in the order named, automobiles as a minor product; the closely allied industries, "automobile bodies and parts" and "rubber and elastic goods;" and exports and imports of automobiles. A detailed summary of the industry closes the report. Under the historical and descriptive section which follows the statistical discussion the development of the modern automobile, motors, frame, wheels, and body are taken up in the order named.

At the census of 1905, for the first time, the manufacture of automobiles was returned as a separate industry. At preceding censuses the statistics for the industry were included under those for carriages and wagons. However, the figures for 1900 of establishments engaged exclusively in the manufacture of automobiles, or with a preponderating automobile product, have been separated from the reports for the carriage and wagon industry, and are presented in Tables 1 and 2 for purposes of comparison.

Table 1 is a comparative summary of the statistics of the industry for 1900 and 1905.

Table 1.—*Comparative summary, with per cent of increase: 1905 and 1900.*

	CENSUS.		Per cent of increase.
	1905[1]	1900	
Number of establishments	121	57	112.3
Capital	$20,555,247	$5,768,857	256.3
Salaried officials, clerks, etc	954	268	256.0
Salaries	$1,076,425	$294,770	265.2
Wage-earners, average number	10,239	2,241	356.9
Total wages	$6,178,950	$1,320,658	367.9
Men 16 years and over	10,196	2,231	357.0
Wages	$6,167,345	$1,317,715	368.0
Women 16 years and over	11	4	175.0
Wages	$3,689	$977	262.7
Children under 16 years	32	6	433.3
Wages	$7,916	$1,966	302.6
Miscellaneous expenses	$3,946,369	$281,129	1,303.8
Cost of materials used	$11,658,138	$1,804,287	546.1
Value of products	$26,645,064	$4,748,011	461.2

[1] Exclusive of the statistics of establishments engaged primarily in the manufacture of other products and which manufactured automobiles to the value of $879,205.

At the census of 1905 compared with that of 1900 the number of establishments increased 64; the capital, $14,786,390; the number of salaried officials, 686; the average number of wage-earners, 7,998; the cost of materials, $9,853,851; and the total value of products, $21,897,053.

The relatively small increase in number of establishments is due to the fact that the majority reported in 1900 were engaged largely in experimental work, with little capital invested, and employing few workmen. Growth has been along the line of extending the capacity of the old plants, or abandoning them for new and much larger ones, rather than in increasing the number of establishments.

Table 2 shows the items of miscellaneous expenses for 1900 and 1905.

Table 2.—*Miscellaneous expenses: 1905 and 1900.*

	1905	1900
Total	$3,946,369	$281,129
Rent of works	88,497	40,133
Taxes	77,625	10,228
Sundries and rent of offices	2,745,601	226,548
Contract work	1,034,646	4,220

Although the extension of the industry has largely added to the amount expended for contract work, the largest part of the increase in miscellaneous expenses is due to the cost of advertising, outside office expenses, etc.

The relatively small increase in rent of works is due to the fact that many companies are now housed in new, commodious quarters of their own, whereas in 1900 they occupied small rented quarters.

Table 3 is a comparative summary of the statistics for the manufacture of automobiles, by states, for 1900 and 1905.

TABLE 3.—COMPARATIVE SUMMARY, BY STATES: 1905 AND 1900.

STATE.	Census.	Number of establishments.	Capital.	Salaried officials, clerks, etc.: Number.	Salaried officials, clerks, etc.: Salaries.	Wage-earners and wages: Total: Average number.	Total: Wages.	Men 16 years and over: Average number.	Men 16 years and over: Wages.	Women 16 years and over: Average number.	Women 16 years and over: Wages.	Children under 16 years: Average number.	Children under 16 years: Wages.
United States	1905	121	$20,555,247	954	$1,076,425	10,239	$6,178,950	10,196	$6,167,345	11	$3,689	32	$7,916
	1900	57	5,768,857	268	294,770	2,241	1,320,658	2,231	1,317,715	4	977	6	1,966
California [1]	1905	6	48,802	3	4,800	14	10,124	14	10,124	...	...	...	...
Connecticut [2]	1905	7	3,712,922	62	86,372	1,065	783,993	1,057	781,604	...	...	8	2,389
Illinois	1905	8	378,536	15	26,180	146	100,433	146	100,433	...	...	...	...
	1900	4	974,894	36	27,523	303	217,603	299	215,949	...	...	4	1,654
Indiana [2]	1905	8	1,140,509	94	74,293	789	482,198	784	480,456	3	1,326	2	416
Maryland [3]	1900	3	81,600	8	7,900	26	16,325	26	16,325	...	...	...	...
Massachusetts	1905	11	1,623,857	98	115,832	952	596,277	944	594,082	1	300	7	1,895
	1900	12	475,512	18	24,157	303	188,098	303	188,098	...	...	...	...
Michigan [1]	1905	22	3,765,240	151	188,452	2,123	970,895	2,122	970,770	1	125	...	...
New Jersey	1905	5	310,261	22	13,662	60	40,296	59	40,248	...	...	1	48
	1900	4	762,500	35	53,808	201	143,840	201	143,840	...	...	...	...
New York	1905	21	3,172,531	200	202,869	1,624	1,095,470	1,618	1,094,120	1	288	5	1,062
	1900	15	638,553	56	56,632	288	166,051	283	164,882	3	857	2	312
Ohio	1905	14	3,544,162	172	218,950	2,277	1,368,810	2,272	1,367,160	5	1,650	...	...
	1900	3	68,500	7	5,405	86	51,826	86	51,826	...	...	...	...
Pennsylvania	1905	6	1,452,963	65	78,681	566	352,482	566	352,482	...	...	...	...
	1900	8	297,100	16	17,629	60	43,247	60	43,247	...	...	...	...
Wisconsin [2]	1905	6	1,240,006	59	54,180	520	299,624	511	297,518	...	...	9	2,106
All other states	[4] 1905	7	165,458	13	12,154	103	78,348	103	78,348	...	...	...	...
	[5] 1900	8	2,470,198	92	101,716	974	493,668	973	493,548	1	120	...	...

STATE.	Census.	Miscellaneous expenses.	Cost of materials used.	Products: Aggregate value.	Automobiles: Total: Number.	Total: Value.	Gasoline: Number.	Gasoline: Value.	Electric: Number.	Electric: Value.	Steam: Number.	Steam: Value.	All other products: Value.	Amount received for custom work and repairing.
United States	1905	$3,946,369	$11,658,138	$26,645,064	21,692	$23,751,234	18,699	$19,566,941	1,425	$2,496,255	1,568	$1,688,038	$2,042,777	$851,053
	1900	281,129	1,894,287	4,748,011	3,723	4,548,108	(6)	(6)	(6)	(6)	(6)	(6)	126,079	73,824
California [1]	1905	10,139	12,863	36,380	12	13,606	12	13,606	...	...	...	...	1,761	21,013
Connecticut [2]	1905	466,851	1,163,072	2,644,334	832	1,958,682	386	1,125,863	319	747,420	127	85,399	331,253	354,399
Illinois	1905	61,721	104,390	327,710	205	262,691	66	56,800	139	205,891	...	...	23,290	41,729
	1900	55,627	291,653	747,777	660	747,777	...	...	...	...	...	...	...	...
Indiana [2]	1905	230,226	811,823	1,595,302	1,020	1,428,463	595	1,034,519	424	391,444	1	2,500	114,963	51,876
Maryland [3]	1900	3,345	30,882	64,700	25	55,500	...	...	...	...	...	...	2,700	6,500
Massachusetts	1905	228,504	1,047,488	2,160,455	2,365	2,052,943	1,765	1,662,943	...	...	600	390,000	78,907	28,605
	1900	47,094	306,645	769,397	1,132	757,242	...	...	...	...	...	...	12,150	5
Michigan [1]	1905	1,423,167	2,872,655	6,876,708	9,125	6,552,804	9,114	6,537,404	11	15,400	...	...	276,680	47,224
New Jersey	1905	40,459	43,905	118,753	51	71,400	6	12,500	15	25,900	30	33,000	36,050	11,303
	1900	36,860	175,508	478,680	213	423,550	...	...	...	...	...	...	5,980	49,150
New York	1905	565,776	1,764,567	3,791,956	1,808	3,071,093	1,496	2,169,093	307	892,000	5	10,000	494,608	226,255
	1900	19,710	172,973	455,911	521	374,947	...	...	...	...	...	...	66,644	14,320
Ohio	1905	677,374	2,298,651	5,788,563	2,808	5,197,360	1,811	3,853,621	200	196,000	797	1,147,739	554,642	36,561
	1900	13,918	60,344	145,000	132	145,000	...	...	...	...	...	...	...	...
Pennsylvania	1905	61,795	601,430	1,225,678	963	1,134,776	955	1,116,176	8	18,600	...	...	83,183	7,719
	1900	32,707	31,089	98,884	65	66,400	...	...	...	...	...	...	29,484	3,000
Wisconsin [2]	1905	163,995	845,348	1,875,259	2,390	1,856,694	2,388	1,853,094	2	3,600	...	...	16,080	2,485
All other states	[4] 1905	16,362	91,946	203,966	113	150,722	105	131,322	...	...	8	19,400	31,360	21,884
	[5] 1900	71,868	735,193	1,987,662	975	1,977,692	...	...	...	...	...	...	9,121	849

[1] No establishments reported in 1900.
[2] Included in "all other states" in 1900.
[3] No establishments reported in 1905.
[4] Includes establishments distributed as follows: Kansas, 1; Maine, 1; Minnesota, 1; Missouri, 1; New Hampshire, 1; Rhode Island, 2.
[5] Includes establishments distributed as follows: Connecticut, 2; Indiana, 1; Maine, 2; Missouri, 1; New Hampshire, 1; Wisconsin, 1.
[6] Not reported separately.

Table 3 shows that the manufacture of automobiles was carried on in 13 states in 1900, and in 17 in 1905. At the census of 1905 Michigan, with 22 establishments, ranked first. New York stood second, with 21, and Ohio third, with 14. Massachusetts, with 11 establishments; Illinois and Indiana, with 8 each; Connecticut, with 7; California, Pennsylvania, and Wisconsin, with 6 each; and New Jersey, with 5, followed in the order named.

Michigan, from which state no establishments were reported in 1900, held first rank in capital invested in 1905, the amount being $3,765,240. Connecticut, with $3,712,922, dropped from first place in 1900 to second in 1905. Ohio, with an increase of $3,475,662, more than fiftyfold, advanced from eighth rank to third; Massachusetts, with an increase of $1,148,345, from fifth to fourth; and Pennsylvania, with an increase of $1,155,863, nearly fourfold, from sixth to fifth. Wisconsin, with $1,240,006, and Indiana, with $1,140,509, both of which reported but 1 establishment in 1900, ranked sixth and seventh, respectively, in 1905. With the enormous general increase in the industry, it is surprising to note the following decreases: Illinois fell from second to eighth place, reporting a decrease of $596,358, or 61.2 per cent; and New Jersey, from third to ninth place, with a decrease of $452,239, or 59.3 per cent. Maryland reported $81,600 capital in 1900 and none at all in 1905. In 1900 Connecticut was the only state that reported a total capital in excess of $1,000,000, while there were 8 states in this class in 1905.

From Table 3 it is evident that the average capital per establishment increased materially between 1900 and 1905. For the entire country the advance was from $101,208 in 1900 to $169,878 in 1905, an increase of $68,670, or 67.9 per cent.

The number of wage-earners increased from 2,241 in 1900 to 10,239 in 1905. At the census of 1900 Connecticut ranked first both in number of wage-earners and total wages paid. In number of wage-earners Illinois and Massachusetts followed, each having 303. In wages paid Illinois stood second, with $217,603, and Massachusetts third, with $188,098. New York stood fourth both in number of wage-earners and in wages paid, and New Jersey fifth. These 5 states reported a total of 1,990 wage-earners, receiving $1,168,331 in wages, 88.8 and 88.5 per cent, respectively, of the totals for the country.

In number of wage-earners in 1905 Ohio stood first, with 2,277, an increase of 2,191. Michigan followed, with 2,123. New York, with 1,624, an increase of 1,336, advanced from fourth to third in rank. Connecticut, with 1,065, fell from first to fourth place. Massachusetts, though reporting an increase of 649, fell from second to fifth place. Indiana, Pennsylvania, and Wisconsin followed in the order named. In amount of wages paid in 1905 the states ranked in the same order with a single exception, New York exchanging places with Michigan.

The inconsiderable number of women and children employed is noteworthy. This is due to the fact that the labor requires physical strength and a high degree of mechanical skill. In 1900 only 4 women were employed in the entire United States, 3 of whom were reported by New York. In 1905 the number had increased to only 11. In 1900 only 6 children were employed, and in 1905 but 32.

From Table 3 it will be observed that the relation of the cost of materials to the value of product is practically constant, at least to the extent that the states occupy the same rank, whether arranged according to the cost of materials or according to value of product. This is true for both 1900 and 1905. At the census of 1905 Michigan had advanced to first rank in these two respects. Ohio had risen from sixth to second place, with an increase of $2,238,307 in cost of materials, and an increase of $5,643,563 in value of products. New York advanced from fifth to third place, with an increase of $1,591,594 in cost of materials and $3,336,045 in value of products. Connecticut fell from first to fourth place, though showing an increase of $464,800 in cost of materials and $752,492 in value of products; and Massachusetts from second to fifth, though showing an increase of $740,843 in cost of materials and $1,391,058 in value of products. Wisconsin occupied sixth place in 1905 and Indiana seventh.

In an industry characterized by such marked increases, the decreases reported in nearly every item for the 3 states, Illinois, Maryland, and New Jersey, are notable. The largely experimental stage of the industry and local conditions, such as the removal of factories, are responsible for the decreases.

In 1900 "all other products" included for the most part horse-drawn vehicles manufactured in connection with automobiles, while at the census of 1905 the item represented entirely gas engines, batteries, parts, and finishings, manufactured in excess of the number required for the automobiles turned out. Comparison is therefore impracticable. It is of interest, however, to note the gradual change in certain establishments to meet the new conditions. The change in the character of the "all other products" indicates the abandonment in certain plants of the manufacture of horse-drawn vehicles in favor of the automobile. This item for 1905 shows the extent to which the manufacture of parts overreached the production of the finished automobile.

The amount received for custom work and repairing increased from $73,824 in 1900 to $851,053 at the census of 1905. These amounts represent repair work almost exclusively, and show the extent to which the manufactories are called upon to do this class of work, which is largely on vehicles of their own make. This does not represent the full extent of the repairing, however, as much of this class of work is done at the local garage in which the machine is housed.

At the census of 1900 only the total number and value of automobiles were reported, regardless of the kind of power used. For the entire United States there were reported 3,723, valued at $4,548,108, an average value of $1,222. Of the various states, Massachusetts produced the greatest number of vehicles, the average value being $669. Connecticut ranked second in the number turned out, the average value being $2,114. Illinois ranked third, with an average value of $1,133; New York, fourth, with an average value of $720; and New Jersey, fifth, with an average value of $1,988.

At the census of 1905 21,692 automobiles were manufactured, valued at $23,751,234, having an average value of $1,095. Of this number, 18,699, or 86.2 per cent, were propelled by gasoline; 1,425, or 6.6 per cent, by electricity; and 1,568, or 7.2 per cent, by steam. The average prices per vehicle were $1,046 for the gasoline, $1,752 for the electric, and $1,077 for the steam. Michigan held to first rank in respect to the number turned out. Only one-tenth of 1 per cent were electric and the remainder gasoline. The total average price was $718. Ohio advanced from sixth place in 1900 to second in 1905, with an average value of $1,851 at the later census. Of this state's output, 64.5 per cent were gasoline; 7.1 per cent electric; and 28.4 per cent steam. Wisconsin ranked third with 2,390 vehicles, only 2 of which were electric and the rest gasoline. The average value was only $777, owing to the fact that they were mostly runabouts. Massachusetts, first in 1900 in the number of machines turned out, dropped to fourth place in 1905. Of the total, 25.4 per cent were steam and the remainder gasoline. The total average value was $868. New York fell from fourth to fifth place. Of the 1,808 vehicles made in the year covered by the census, 82.7 per cent were gasoline; 17 per cent electric; and only three-tenths of 1 per cent steam. However, on account of the large average value of all machines, $1,699, New York ranked third in value of product. These 5 states taking precedence as to the number of automobiles manufactured, reported in 1905 a total of 18,496 vehicles, or 85.3 per cent of the total for the country, having a value of $18,730,894, or 78.9 per cent of the total value of all machines manufactured in the United States.

Table 4 shows the chief classes of automobiles manufactured, with their number and value, and distribution, by kind of power used.

TABLE 4.—NUMBER AND VALUE OF AUTOMOBILES, BY CLASS AND KIND OF POWER USED: 1905.

CLASS.	TOTAL.		GASOLINE.		ELECTRIC.		STEAM.	
	Number.	Value.	Number.	Value.	Number.	Value.	Number.	Value.
Aggregate	21,692	$23,751,234	18,699	$19,566,941	1,425	$2,496,255	1,568	$1,688,038
Touring car[1]	7,220	11,781,521	6,444	10,576,023	39	55,038	737	1,150,460
Runabout[1]	12,131	8,831,504	10,999	7,976,821	455	453,304	677	401,379
Stanhope	520	614,104	206	298,550	209	255,217	105	60,337
Delivery, heavy	160	491,490	55	50,390	105	441,100		
Delivery, light	251	455,457	140	215,897	109	235,560	2	4,000
Surrey	221	229,872	131	108,810	45	57,200	45	63,862
Victoria	66	77,740			66	77,740		
Phaeton	49	69,450	48	68,250	1	1,200		
Doctor's wagon or car	54	47,140	1	500	53	46,640		
Station wagon or car	13	25,800			13	25,800		
All other varieties	1,007	1,127,156	675	271,700	330	847,456	2	8,000

[1] Does not include 729 runabouts, valued at $438,596, and 210 touring cars, valued at $204,934, manufactured as a minor product in establishments principally engaged in other lines of manufacture. In addition 199 automobiles, valued at $235,675, manufactured in carriage and wagon factories, are not included in this table, because the classes and power were not reported.

Table 4 shows that 12,131, or 55.9 per cent, of the total number of automobiles manufactured in the United States were runabouts. Of these, 90.7 per cent were gasoline; 3.7 per cent electric; and 5.6 per cent, steam. Less in number, though greater in aggregate value, were the touring cars, constituting 33.3 per cent of the total vehicles turned out. Of this class, 89.3 per cent were propelled by gasoline, 10.2 per cent by steam, and only five-tenths of 1 per cent by electricity. Stanhopes were fourth in point of number, of which 39.6 per cent were gasoline, 40.2 per cent electric, and 20.2 per cent steam. Light and heavy delivery wagons ranked next, of which 47.4 per cent were gasoline, 52.1 per cent electric, and five-tenths of 1 per cent steam. The figures for delivery wagons indicate that electricity is the preferred motive power for the heaviest vehicles.

Under "other varieties" are classed broughams, landaulets, omnibuses, sight-seeing coaches, buckboards, etc.

Michigan produced 6,432 runabouts, having an average value of $631. These runabouts constituted 70.5 per cent of all automobiles manufactured in the state and 53 per cent of the total runabouts manufactured in the United States. All but 11 were propelled by gasoline. Michigan also ranked first in touring cars, reporting 2,561, or 35.5 per cent, of all of this class of automobiles manufactured in the country. Their average value was $938.

Ohio produced 186 runabouts, valued at an average of $670; 2,521 touring cars, valued at an average of $1,971; and 100 electric stanhopes, valued at an average of $1,000. This state turned out 34.9 per cent of all the touring cars made in the country. Michigan and Ohio together turned out 70.4 per cent of all such vehicles manufactured in the United States.

Of the 2,390 vehicles made in Wisconsin, 2,358 were runabouts, averaging $775 in value. Among the automobiles manufactured in Massachusetts there were 1,153 runabouts, valued at $708 apiece; 361 touring cars, valued at $1,918 apiece; 105 surreys, valued at $1,046 apiece; and 73 light delivery wagons, valued at $2,255 apiece. The greater number of machines manufactured in New York consisted of runabouts, having an average value of $1,075. The 397 touring cars turned out had an average value of $2,509.

Table 5 gives the average value of the different classes and kinds of automobiles manufactured.

TABLE 5.—*Average value of automobiles, by class and kind of power used: 1905.*

CLASS.	All kinds of power.	Gasoline.	Electric.	Steam.
Aggregate	$1,095	$1,046	$1,752	$1,077
Touring car	1,632	1,641	1,411	1,561
Runabout	728	725	996	593
Stanhope	1,181	1,449	1,221	575
Delivery, heavy	3,072	916	4,201	....
Delivery, light	1,815	1,542	2,161	2,000
Surrey	1,040	831	1,271	1,419
Victoria	1,178	....	1,178	....
Phaeton	1,417	1,422	1,200	....
Doctor's wagon or car	873	500	880	....
Station wagon or car	1,215	....	1,215	....
All other varieties	1,119	403	2,568	4,000

A noticeable feature of Table 5 is the variation indicated in the average values of the same class of machine when equipped with different kinds of propelling power. Where the power is different in vehicles of the same class, the structure is entirely changed.

The average values given are based on the prices at the factory and in no case represent the average selling prices to the consumer. In the 5 leading states the average value of runabouts varied as follows: Michigan, $631; Ohio, $670; Wisconsin, $775; Massachusetts, $708; and New York, $1,075. The average value of touring cars varied still more: Michigan, $938; Ohio, $1,971; Massachusetts, $1,918; and New York, $2,509.

In order to show the remarkable changes in the relative positions of the leading states in this industry, Table 6 is presented, showing their rank with respect to the principal items of inquiry for 1900 and 1905.

The states selected for this table are the 7 leading states in value of products in 1905. The same rank in any item of inquiry was retained at the two censuses in only five cases. Michigan made the most marked advance, from no standing at all in the industry in 1900 to first in most respects at the census of 1905. Connecticut, first in most respects in 1900, dropped from one to three points in all items of inquiry. Ohio advanced from two to five points in every item. New York retained about the same relative position at both censuses, having varied none at all in respect to two of the six items and not more than two points in any of the others. In the amount of capital the rank of Massachusetts remained unchanged, but this state fell from two to three points in each of the other items. Indiana advanced from one to four points in every item. In the number of establishments the rank of Wisconsin remained the same, but this state advanced from two to five points in each of the other items.

TABLE 6.—RANK OF LEADING STATES WITH RESPECT TO PRINCIPAL ITEMS OF INQUIRY: 1905 AND 1900.

STATE.	NUMBER OF ESTABLISHMENTS.		CAPITAL.		WAGE-EARNERS AND WAGES.				COST OF MATERIALS USED.		VALUE OF PRODUCTS.	
					Average number.		Wages.					
	1905	1900	1905	1900	1905	1900	1905	1900	1905	1900	1905	1900
Michigan	1	(1)	1	(1)	2	(1)	3	(1)	1	(1)	1	(1)
Ohio	3	5	3	8	1	5	1	6	2	6	2	6
New York	2	1	4	4	3	3	2	4	3	5	3	5
Connecticut	6	6	2	1	4	1	4	1	4	1	4	1
Massachusetts	4	2	5	5	5	2	5	3	5	2	5	2
Wisconsin	7	7	7	9	8	10	8	11	6	11	6	11
Indiana	5	7	8	11	6	7	6	10	7	9	7	9

[1] No establishments reported in 1900.

Table 7 presents statistics of the manufacture of automobiles at the census of 1905 in cities having in 1900 a population of over 20,000.

TABLE 7.—SUMMARY FOR CITIES HAVING A POPULATION IN 1900 OF AT LEAST 20,000: 1905.

CITY.	Number of establishments.	Capital.	SALARIED OFFICIALS, CLERKS, ETC.		WAGE-EARNERS AND WAGES.		Miscellaneous expenses.	Cost of materials used.	Value of products.
			Number.	Salaries.	Average number.	Wages.			
Total	86	$16,340,573	739	$859,302	8,081	$4,961,205	$3,389,442	$9,044,119	$21,075,073
Buffalo, N. Y.	5	790,853	53	70,859	625	389,505	179,562	579,604	1,385,509
Chicago, Ill.	7	376,886	15	26,180	145	99,433	61,591	103,740	324,710
Cleveland, Ohio	7	2,653,837	127	175,749	1,505	868,399	589,262	1,880,108	4,256,979
Detroit, Mich.	12	2,982,949	106	132,006	1,564	733,012	1,287,160	2,199,277	5,382,212
Indianapolis, Ind.	4	810,160	62	56,177	447	277,844	134,920	553,973	797,652
Kalamazoo, Mich.	3	96,471	9	7,828	48	28,019	10,874	29,564	72,959
New York, N. Y.	6	1,357,064	54	63,086	430	418,581	242,339	672,080	1,186,452
Reading, Pa.	3	367,694	19	11,968	164	91,428	19,948	132,617	269,464
All other cities [1]	39	6,904,659	294	315,449	3,153	2,054,984	863,786	2,893,156	7,399,136

[1] Includes establishments distributed as follows: Albany, N. Y., 1; Boston, Mass., 1; Bridgeport, Conn., 1; Cambridge, Mass., 1; Grand Rapids, Mich., 1; Hartford, Conn., 1; Hoboken, N. J., 1; Holyoke, Mass., 1; Jackson, Mich., 1; Los Angeles, Cal., 1; Milwaukee, Wis., 2; Minneapolis, Minn., 1; Newark, N. J., 1; New Britain, Conn., 1; New Haven, Conn., 1; Oshkosh, Wis., 1; Passaic, N. J., 1; Philadelphia, Pa., 1; Pittsburg, Pa., 1; Poughkeepsie, N. Y., 1; Providence, R. I., 2; Racine, Wis., 1; Rochester, N. Y., 1; St. Louis, Mo., 1; San Francisco, Cal., 2; San Jose, Cal., 2; Springfield, Mass., 1; Springfield, Ohio, 1; Syracuse, N. Y., 1; Taunton, Mass., 1; Toledo, Ohio, 2; Topeka, Kans., 1; Utica, N. Y., 1; Waltham, Mass., 1.

Of the total number of establishments in the United States Table 7 shows that 86, or 71.1 per cent, were located in cities of over 20,000 population. Of the totals for the country the capital invested in these establishments was 79.5 per cent; the number of salaried officials, etc., 77.5 per cent; the salaries paid, 79.8 per cent; the number of wage-earners, 78.9 per cent; the wages paid, 80.3 per cent; miscellaneous expenses, 85.9 per cent; cost of materials used, 77.6 per cent; and the value of products, 79.1 per cent. The average capital, cost of materials, and value of products, for the establishments located in the cities included in this table was $190,007, $105,164, and $245,059, respectively, as compared with $120,419, $74,686, and $159,143 for all automobile works located in the smaller cities, villages, and rural districts.

The prominence which Michigan holds in this industry is due, in large measure, to the establishments located in Detroit. The capital invested in this city alone was 14.5 per cent of the total for the United States; and the value of products 20.2 per cent of the total. The average capital invested per establishment in Detroit was $248,579, and the average value of products $448,518, compared with $379,120 and $608,140, the respective averages for establishments located in Cleveland, the second city in rank as to value of products. These two cities together were credited with more than one-third the total value of products for the entire country.

Contrasted with the compactness of the industry shown in the four leading centers—Detroit, Cleveland, Buffalo, and New York—is its wide dispersion among the 34 cities included in "all other cities." These scattered plants were located in 13 different states, as follows: Six plants in 6 different cities of Massachusetts; 5 in a like number of cities of New York; 5 in 3 cities of California; 4 in 4 cities of Connecticut; 4 in 3 cities of Wisconsin; 3 in 3 cities of New Jersey; 3 in 2 cities of Ohio; 2 in 2 cities in each of the states of Michigan and Pennsylvania; 2 in 1 city of Rhode Island; and 1 in each of the states of Kansas, Minnesota, and Missouri.

Table 8 is a comparative summary of the motive power used in 1900 and 1905.

TABLE 8.—*Power—comparative summary: 1905 and 1900.*

	1905	1900
Number of establishments reporting	113	51
Total horsepower	10,484	3,601
Owned:		
Engines—		
Steam—		
Number	53	33
Horsepower	5,565	2,610
Gas or gasoline—		
Number	59	13
Horsepower	1,149	130
Water wheels—		
Number	1	2
Horsepower	40	75
Electric motors—		
Number	96	32
Horsepower	2,860	437
Rented:		
Electric motors—		
Number	64	13
Horsepower	792	164
Other kind, horsepower	78	185
Furnished to other establishments, horsepower	25	7

A noteworthy fact shown by Table 8 is the marked increase in the average power used per establishment in 1905 over 1900. The 113 plants reporting in 1905 used an average of 92.8 horsepower per establishment, an increase of 22.2 horsepower over the average for 1900. In addition to the increased horsepower used, there was scarcely an establishment which had been in existence for three or four years that had not been enlarged.

AUTOMOBILES AS A MINOR PRODUCT.

The foregoing statistics pertain entirely to establishments engaged primarily in the production of automobiles, and therefore do not include 47 establishments engaged primarily in the manufacture of other products, but which during the census year 1905 turned out 1,138 automobiles, valued at $879,205. This amount has been included in the value of products of the several industries to which these plants belong. In 24 establishments classified under "carriages and wagons," 199 automobiles, valued at $235,675, were produced. In the industry "bicycles and tricycles" 6 establishments turned out 470 automobiles, valued at $314,554. Of these, 360 were runabouts and 110 touring cars. In "foundry and machine shop products" 13 establishments turned out 228 automobiles, valued at $190,700 and made up of 192 runabouts and 36 touring cars. Four establishments, 2 classified as "shipbuilding, wooden, including boat building," 1 as "sewing machines and attachments," and 1 as "carriage and wagon materials," reported 241 automobiles, valued at $138,276, manufactured as a minor product. Of these machines, 177 were runabouts and 64 touring cars. All these automobiles were propelled by gasoline, with the possible exception of those manufactured in carriage and wagon factories, for which the power was not reported.

ALLIED INDUSTRIES.

Automobile bodies and parts.—In considering the increase of the industry, it must be borne in mind that the entire work of manufacturing was not performed at the automobile factory. Certain parts were manufactured in establishments making a specialty of the component parts of the automobile, such as bodies, wheels, motors, lamps, and various articles of hardware. While some of the larger plants turn out all the parts, the smaller establishments, and by far the greater number, do not, but purchase more or less material in fully or partially manufactured form. In fact, there is a strong tendency in this direction, especially in the separate manufacture of the body of the automobile, as distinguished from the chassis or running gear. The Census classification for such establishments is "automobile bodies and parts." Although they enter into the statistics of the automobile industry proper only to the extent that their products constitute a portion of the cost of materials and miscellaneous expenses, they are really an integral part of that industry. In 1900 there was no separate classification of "automobile bodies and parts," therefore the general statistics for this industry are available only for the census of 1905.

A combination of the statistics for automobiles given in Table 1, and the figures given above for automobile bodies and parts, is exhibited in Table 9.

TABLE 9.—*Summary—automobiles and automobile bodies and parts: 1905.*

	Total.	Automobiles.	Automobile bodies and parts.
Number of establishments	178	121	57
Capital	$23,083,860	$20,555,247	$2,528,613
Salaried officials, clerks, etc	1,181	954	227
Salaries	$1,257,259	$1,076,425	$180,834
Average number of wage-earners	12,049	10,239	1,810
Total wages	$7,158,958	$6,178,950	$980,008
Miscellaneous expenses	$4,266,154	$3,946,369	$319,785
Cost of materials used	$13,151,365	$11,658,138	$1,493,227
Value of products	$30,033,536	$26,645,064	$3,388,472

Rubber and elastic goods.—Another industry which enters largely into automobile construction is the manufacture of rubber and elastic goods. A leading product of this industry is rubber tires, which form a very necessary element in automobile construction. The magnitude of the "rubber and elastic goods" industry in the United States, as well as its growth since 1900, is shown in Table 10.

TABLE 10.—*Rubber and elastic goods—comparative summary: 1905 and 1900.*

	1905	1900
Number of establishments	224	261
Capital invested	$46,297,537	$39,302,353
Average number of wage-earners	21,184	20,404
Total wages	$9,412,368	$8,081,803
Miscellaneous expenses	$6,516,272	$2,805,200
Cost of materials used	$38,912,226	$33,482,314
Value of products	$62,995,909	$52,621,830

Table 10 shows that during the five-year period there was an increase of $10,374,079 in the value of products of the rubber industry. A large part of this increase was caused not only by the enormous quantity of rubber used in the equipment of automobiles, but in the manufacture of various articles made necessary by their extensive use. Of the total increase, $8,633,499, or 83.2 per cent, was reported by the single state of Ohio. Some establishments there located have doubled their product between 1900 and 1905, which is largely, and in some cases entirely, through the increasing demand for automobile tires.

IMPORTS AND EXPORTS.

Table 11 shows the value of exports of automobiles and automobile parts from the United States to foreign countries for each year since they have been separately reported.

TABLE 11.—*Value of exports of automobiles and automobile parts, for years ending June 30: 1902 to 1905.*[1]

EXPORTED TO—	1905	1904	1903	1902
Aggregate	$2,481,243	$1,895,605	$1,207,065	$948,528
Europe	1,428,411	1,020,681	853,437	796,108
Austria-Hungary	26,051	3,500	1,850	13,106
Belgium	38,220	22,971	3,670	7,797
Denmark	8,922	11,549	6,431	9,905
France	252,742	92,576	98,029	59,051
Germany	154,141	97,303	30,798	24,491
Greece	520	....	....	....
Italy	159,396	10,567	8,200	2,200
Netherlands	14,690	11,909	10,164	5,285
Norway	9,245	10,794	2,500	....
Portugal	3,784	1,904	12,904	....
Roumania	4,973	240	....	....
Russia on Baltic and White seas	59,243	64,981	813	1,023
Russia on Black sea	13,308	9,861	875	....
Spain	15,184	17,820	1,506	....
Sweden and Norway	....	....	....	1,697
Sweden	54,640	9,625	1,226	....
Switzerland	5,951	5,440	3,660	....
United Kingdom	607,401	649,641	670,811	671,553
North America	682,609	498,799	180,487	77,801
Bermuda	....	775	....	1,500
Dominion of Canada	441,425	330,952	136,586	37,439
Nova Scotia, New Brunswick, etc	18,647	16,359	2,916	1,500
Quebec, Ontario, Manitoba, etc	408,544	308,720	130,515	31,111
British Columbia	14,234	5,873	3,155	4,828
Newfoundland	7,300	997	2,025	....
Central America	1,810	38	21	....
Guatemala	600	....	21	....
Nicaragua	125	38	....	....
Panama	1,020	....	....	....
Salvador	65	....	....	....
Mexico	119,986	113,280	24,762	27,710
West Indies	112,088	52,757	17,093	11,152
British	14,982	5,758	4,948	....
Cuba	96,538	46,999	11,345	11,152
Dutch	50	....	....	....
French	88	....	800	....
Haiti	30	....	....	....
Santo Domingo	400	....	....	....
South America	81,368	35,106	24,557	15,353
Argentina	18,350	12,997	6,588	10,203
Brazil	4,010	2,346	6,900	2,150
Chile	5,659	1,693	....	....
Colombia	983	954	148	....
Ecuador	653	10,442	10,921	....
Guiana:				
British	450	....	....	....
Dutch	....	14	....	....
Peru	50,597	4,031	....	3,000
Venezuela	666	2,629	....	....
Asia	120,264	112,946	38,113	22,832
Chinese Empire	11,091	12,389	5,200	6,645
East Indies:				
British India	56,790	70,479	....	....
Straits Settlements	5,931	2,648	15,032	4,299
Other British	9,383	1,440	....	....
Dutch	20,169	2,335	2,544	1,200
Hongkong	815	780	1,600	1,175
Japan	13,438	22,875	13,737	9,513
Siam	1,782	....	....	....
Turkey in Asia	865	....	....	....
Oceania	101,464	168,382	51,163	23,797
British Australasia	98,562	164,130	48,078	9,581
French Oceania	1,200	....	....	....
Philippine Islands	1,702	4,252	3,085	14,216
Africa	67,127	59,691	59,308	12,637
British Africa—South	54,511	57,202	59,048	12,637
Canary Islands	....	....	260	....
French Africa	1,040	....	....	....
Portuguese Africa	679	654	....	....
Turkey in Africa—Egypt	10,897	1,835	....	....

[1] "Commerce and Navigation of the United States," Bureau of Statistics, Department of Commerce and Labor.

Table 11 shows the growing favor with which American-made automobiles are being received in foreign countries. The figures are also ample evidence that American manufacturers are fully alive to the advantage of extending their trade abroad. The number of cars exported is not available.

Europe has afforded the best market, though its percentage of the total purchases appears to be decreasing. During the years 1902 to 1905 this percentage was 83.9, 70.7, 53.8, and 57.6, respectively. However, the value of the exports to this grand division almost doubled in the three years. North America, whose purchases increased from $77,801 in 1902 to $682,609 in 1905, nearly eightfold, ranked second as a market for this class of American manufactures; and was followed by Asia, which showed an increase from $22,832 in 1902 to $120,264 in 1905, more than fourfold. In the three years Oceania increased its purchases from $23,797 to $101,464, or 326.4 per cent; South America, from $15,353 to $81,368, or 430 per cent; and Africa, from $12,637 to $67,127, or 431.2 per cent.

The great number of countries into which the American-made machine finds its way, some themselves foremost in the automobile industry, and some among the most remote in the world, will be a source of surprise to many readers.

Of the European countries, by far the greatest exportation has been to the United Kingdom, although during the three years there has been a small decrease of $64,152, or 9.6 per cent. Of the North American countries, the greatest exportation was to the Dominion of Canada, the purchases of which showed a gain of $403,986, or over tenfold, during the three years. Argentina and Peru in South America; British South Africa; and British India, Japan, and the Chinese Empire in Asia proved to be the best markets in their respective grand divisions.

Table 12, compiled from the Annual Reports of the Bureau of Statistics, Department of Commerce and Labor, shows the value of imports of automobiles and automobile parts for the fiscal years ending June 30, 1901 to 1905, together with the number, total value, and average value of the automobiles.

TABLE 12.—*Automobiles and automobile parts imported and entered for consumption during the fiscal years ending June 30: 1901 to 1905.*

YEAR.	Aggregate value.	AUTOMOBILES.			Automobile parts, value.
		Number.	Total value.	Average value.	
1901	$47,471	26	$43,126	$1,658.59	$4,345
1902	550,199	224	530,876	2,369.98	19,323
1903	1,009,001	317	963,998	3,041.00	45,003
1904	1,446,303	423	1,294,160	3,059.48	152,143
1905	2,433,507	653	2,297,104	3,517.77	136,403

Prior to the beginning of the fiscal year 1901 imports of automobiles were not enumerated separately. Since that time there has been a remarkable increase. This constant gain is due largely to the fact that the majority of the automobiles imported are heavy, high-power touring cars, with multiple cylinder motors, in the construction of which foreign makers have gained preeminence. American designers have heretofore directed their efforts mainly toward the production of a light car equipped with horizontal motors, and in this type they have attained a higher efficiency than foreign makers. The work of the American and of the foreign manufacturers has thus been largely along different lines. However, the great advance being made by Americans in the manufacture of the touring car along the lines laid down by foreign makers indicates that conditions will assume a different aspect in the near future.

Not only the number and value of imports of automobiles have increased rapidly from year to year, but also the average value per machine has advanced steadily from $1,658.59 in 1901 to $3,517.77 in 1905, an increase of $1,859.18, or 112.1 per cent. This increase is not due to an advance in the price of imported vehicles, but to the importation of a higher grade of machines.

STATISTICAL SUMMARY.

Detailed statistics for the industry, as reported at the census of 1905, are shown in Table 13. This table presents totals for each of the 11 states which have three establishments or more engaged in manufacturing automobiles as a principal product, and combined totals for the 6 states having each less than 3 establishments. The components of the capital are shown, viz, amount invested in land; buildings; machinery, tools, and implements; and cash on hand and sundries. The salaried employees are classified into officers of corporations, and general superintendents, managers, clerks, etc., and wage-earners—men, women, and children—with the different amounts paid each class. The average number of men wage-earners employed during each month of the year is also given. Miscellaneous expenses, the cost of materials used, the value of products, and the kind and amount of power used are shown in detail.

HISTORICAL AND DESCRIPTIVE.

The modern automobile.—The early experimenters in motor vehicles were hampered by the lack of engines which used a fuel less heavy and bulky than coal. Light vehicle motors were made possible by the successful production of liquid or volatile fuels and the invention and perfection of the gas engine. The motive power in these gas or gasoline engines is furnished by a succession of explosions which take place within the cylinder itself, thereby doing away with the cumbersome boiler and furnace.

In 1886 it fell to the lot of two Germans, Gottlieb Daimler and Carl Benz, working independently, to apply the gas engine to road vehicles successfully. This revolutionized motor vehicle construction and occasioned its first great impetus. Daimler, who was manager of the Otto Gas Engine Works at Deutz, fitted his small air-cooled motor to a bicycle by placing it vertically between the front and rear wheels, the rear wheel being driven by means of a belt. In 1889 he constructed a two-cylinder engine, which attracted the attention of Messrs. Panhard and Levassor, of Paris, who acquired the necessary rights and immediately began the construction of the essentially modern motor car, the first of which was brought out in 1891.

Carl Benz first applied his single horizontal cylinder, water-jacketed engine to a three-wheel carriage. It was placed over the rear axle and drove a vertical crank shaft, thus giving the fly wheel a horizontal position. This arrangement insured stability in the steering of the car. The crank shaft was connected by bevel gearing to a short horizontal shaft, which was in turn coupled to a countershaft by a belt. The ends of this countershaft were connected to the road wheels by means of chains. Benz's engine was first worked on the two-stroke cycle, but in the subsequent development of the machine, in which he was assisted by Roger, of Paris, the Otto four-stroke cycle was used.

However, it must be remembered that during this earliest period in the evolution of the modern automobile the steam engine was advancing in efficiency and light construction to a degree equal to or greater than the gasoline engine. In Europe the most notable achievements along this line were those of Leon Serpollet, a Frenchman, who applied to road vehicles his instantaneous or "flash" generator, invented in 1889. The principle of this great invention consists in generating steam instantaneously by pumping water through flattened tubes of a very narrow section kept at a red heat by the furnace. The fuel used is vaporized oil.

The earliest attempts by American inventors to build horseless carriages were confined to steam motors. The omnibus built in 1878 by a Mr. Fawcett, of Pittsburg, employed a Brayton motor of unknown design. During the eighties a Mr. Copeland brought out a bicycle equipped with a steam motor, followed by two tricycles similarly equipped, which were the predecessors of the light steam vehicles. However, Copeland had to abandon his experiments through lack of capital.

The distinction of early experiments in this line is also claimed by a citizen of the state of Michigan in the person of Mr. R. E. Olds, who in 1886 began the construction of a horseless carriage. This vehicle, which was not completed until the following year, 1887, was first fitted with a steam engine which was geared to the rear axle. The boiler was of the porcupine type and gasoline was used as the fuel. Later, this machine was remodeled, using a flash boiler, that is, the steam was generated only as required by the engines. In 1893 Mr. Olds began building gasoline motors for horseless carriages which, since their perfection in 1895, have proved practical and successful.

In 1886 Charles E. Duryea decided that the gasoline engine was best fitted to propel the horseless carriage. It was, however, not until 1892 that assisted by his brother, J. F. Duryea, he completed his first automobile. This machine proved to be decidedly underpowered and built of too light materials. Their next car, finished in 1893, embodied all the essential features of the modern automobile and was a success. The Duryea Motor Wagon Company was organized, and the 13 automobiles finished in the summer of 1896 were the first manufactured for sale in the United States. The price of these vehicles, $1,500, was considered very high for an untried substitute for the horse and carriage and prevented the immediate acceptance of the gasoline automobile in America. A large majority of the plants reported for the industry at the census of 1900 commenced operation in 1899, the date of the substantial beginning of the automobile movement in America.

Steam motors.—The principal parts of the steam motor are the boiler and engine. Two types of tubular boilers are used, the water tube and fire tube, according to whether the tubes are to contain fire or water. The Serpollet boiler, used almost universally in European steam vehicles, is of the water-tube variety, while American builders use the fire-tube type to a great extent. The common boiler used in American steam machines is a cylindrical upright steel shell, through which pass vertical copper or steel fire tubes, from 300 to 350 in number.

The invention of the instantaneous generator, known by the name of the inventor, Leon Serpollet, in 1889, gave the first real impulse to modern steam carriage building. It consisted of a coil of 1½-inch lap-welded steel tubing flattened, in the earliest type, until the bore was of almost capillary width, but later to a width of about one-eighth of an inch. The coil was surrounded by a cast-iron covering to protect the steel from corrosion by heat. The water, upon being injected into the heated tube, was vaporized almost instantly. Two coils connected in series were later used, and finally a train of coils and bent tubing.

The engine used with the Serpollet boiler has four single-acting cylinders arranged in pairs. They may be set either obliquely, so as to make an angle of 45 degrees with each other at the crank shaft, or horizontally on opposite sides of the crank shaft. A countershaft is used, parallel to the rear axle, connected with the crank shaft by chain, and to the driving axle by gearing.

The engine most commonly used on the lighter vehicles by American manufacturers is double-cylindered, double acting, and set vertically. The diameter of the cylinder varies from 2½ to 3 inches, and the stroke from 3 to 3½ inches. The power is transmitted usually direct from the engine shaft to the rear driving axle by chain, but in a few cases the countershaft is used. The fuel used is some form of mineral oil, usually gasoline, or alcohol, which is vaporized by the use of special burners. Compressed air, supplied by either a hand pump or a power pump operated by the moving parts of the engine, affords a pressure for feeding the oil to the burners. Automatic feed pumps, operated by the engine, supply water to the boilers.

Petrol motors.—In 1882 M. Beau de Rochas, a French engineer, patented an internal-combustion engine. The principles of this invention have ever since afforded the basis for designers of this class of engine. The simplest form consists of a single cylinder closed at the top and open at the bottom, within which moves a closely fitting piston, connected by a swinging rod to the crank shaft. A mixture of air and the vaporized spirit is introduced into the cylinder when the piston is at the top, forming a cushion between the fixed top of the cylinder and the movable piston. The mixture is then ignited, causing an explosion. The piston, which is fitted gas tight, is the only thing that can give way, and is driven to the bottom of the cylinder, where its further downward movement is arrested by the crank. The impulse of this explosive stroke is stored in a fly wheel attached to the crank shaft, which is carried round again, driving the piston up.

The mechanism described is the two-stroke cycle, sometimes called the "two-cycle engine." The chief claim for this type of engine is its undoubted simplicity. The absence of valves, gears, cams, and springs makes it cheap to manufacture and repair. Although theoretically it would appear to be adapted to the automobile, since the gain in power over a four-cycle engine of the same size exceeds 60 per cent, it has thus far proved unavailable.

The four-cycle engine, more commonly called the "Otto cycle," from Dr. N. A. Otto, the first to make practical use of it, is now almost universally used for the automobile. In this engine there is only one explosion to four strokes of the piston. These are termed, respectively, the suction stroke, to draw into the cylinder the mixture of air and vaporized spirit; the compression stroke; the explosion stroke, following the ignition of the vapor; and the exhaust stroke, to drive out the gases of combustion. It is estimated that an engine of this character is capable of 1,200 to 1,500 revolutions per minute, while a two-cycle engine of the same power can make no more than 300 to 350 revolutions. The description given is of a single-cylinder engine. Automobiles are variously equipped with one, two, four, six, and eight cylinder motors. Three-cylinder motors have also been tried but to a very limited extent.

The other main parts of the gasoline motor are the carburetor or vaporizer, in which the liquid hydrocarbon is transformed into vapor, and the ignition apparatus, which produces the spark or hot surface essential to explosion. There are two general types of carburetors—surface carburetors that operate by evaporation, and float-feed carburetors or sprayers. At the present time the surface carburetor is little used, except for motor cycles. There are also several methods of ignition, among which may be mentioned the gas jet and hot tube of the Otto engines, the hot head of the Hornsby-Akroyd motor, the hot wall of the Diesel motor, and the electric spark. The Daimler type of carriage motor still retains the hot-tube ignition, while most other types use the electric spark.

On account of the great heat developed in the cylinder of a gasoline motor some means of cooling sufficiently to avert premature explosion and permit of proper lubrication must be employed. The two systems in general use are the air cooling, limited to engines of small dimensions, and the water cooling.

The early motors were practically all air cooled. American inventors first designed successful air cooling systems. The most successful means at present employed to air-cool cylinders is a rotary fan on the main shaft which creates a forced draft through an air jacket surrounding the cylinder, to the outside surface of which fins or flanges are attached, or a large number of brass pins are secured in holes on the outside of the cylinder's wall. The water cooling system, however, by which a constant circulation of water around the cylinder is maintained through the use of a water jacket, is far more generally used.

Like the steam motor, the gasoline motor transmits its power to a crank shaft from which it is conveyed to the driving shaft by a chain or gearing. The motor is generally started by rotating the crank shaft by a lever attached to one end, although several methods are in use by which the engine is automatically started.

In the United States gasoline has been used almost exclusively for automobile internal-combustion motors, although benzine and alcohol are most used in Germany. A law removing the internal revenue tax on denatured alcohol may open the door for a great advance in the automobile industry in the United States by substituting alcohol for gasoline. The importance of this measure may be realized when it is known that the supply of gasoline is limited, as petroleum yields only 2 per cent of gasoline; whereas the sources from which alcohol can be produced are inexhaustible. Alcohol is better and safer than gasoline and also free from unpleasant odors. A recent experiment with a six-cylinder car demonstrated that with the same amounts of gasoline and alcohol, the former developed 52 horsepower, and the latter 60.

Electric motors.—The electric motor for use on the automobile is in a less advanced state of development than either the steam or gasoline motor. The only practical supply of power is by means of heavy storage batteries carried on the car itself. The full capacity of the average storage battery will not carry an automobile more than 40 or 50 miles. If the electricity gives out at any place other than an electric charging station, the machine is helpless. Electrical engineers are working toward a more satisfactory storage battery, which when perfected will undoubtedly make the electric automobile the ideal type, as the mechanism is the simplest and least liable to get out of order. The most notable extension of the use of electric automobiles has been in the industrial field. During the past five years large numbers of electric drays, trucks, delivery wagons, etc., have been built.

The storage battery for supplying the current, the motor for transforming this current into mechanical power, and the controller for regulating the speed of the motor constitute the principal equipment of the electric automobile. The current passes from the storage battery into the motor or reversed dynamo, which drives the rear wheels through proper gearing. When two motors are used no transmission shaft or gearing is necessary. A number of fairly successful vehicles have been introduced in which a hydrocarbon engine drives a dynamo-electric generator which in turn furnishes current to the storage batteries and motor; in some instances the dynamo, being reversible, is also made to play the part of a motor.

Frame, wheels, and body.—In making the frame the ends sought by the automobile manufacturer are lightness and strength. Steel tubing was formerly considered almost essential to secure this desired combination, but experience has proven that the reduction in weight is more than offset by the greater complexity of structure, the present tendency being toward the use of pressed steel.

The wheels of self-propelled vehicles must possess great strength and elasticity. The automobile requires a wheel about eighteen times as strong as the ordinary horse-drawn vehicle, since it carries a load over twice as heavy at a speed over three times as great. Wire wheels, which sustain a heavier load than wooden wheels in proportion to their weight, were first used, but they will not stand so great a side thrust and have therefore been practically superseded by the modern type of artillery wheel. Strength is gained by using a wheel of much smaller diameter than those used on horse-drawn vehicles. Heavy tires are necessary to secure efficient traction and the elasticity needed to counteract the vibration caused by the machinery and the irregular roadways.

The present automobile body is a development of the ordinary carriage body. In the pioneer days of the horseless carriage, makers naturally adopted buggy and carriage bodies, as their attention was devoted almost exclusively to the operation of the engine. As the machinery began to work more satisfactorily it was realized that the carriage body was in the way, and the designer was called upon for a body more suitable for an automobile. As the carriage builder was experienced in body making and best equipped for it, the body is now commonly manufactured in a separate establishment from the running gear. The development of the body has kept pace with that of the running gear. American designers have improved upon their French models until now the best American automobile bodies are unexcelled. The separate manufacture of body and running gear has led to the common custom of purchasing the chassis from the automobile maker and the body from some firm engaged in that particular branch of manufacture.

In the manufacture of automobile bodies hickory and cypress are used to some extent, but ash from Michigan, Wisconsin, Indiana, and Ohio, and poplar from Indian Territory and Georgia find most favor. The ash is used for the frame and the poplar for the panels and the top.

The horsepower of the motors used for commercial and pleasure purposes ranges from about 5 to 100. The remarkable progress made by the automobile as a purely speed machine has been furthered by the various tests of speed and endurance arranged largely as a means of recreation. The racing car, with over 100 horsepower crowded into a vehicle weighing 2,000 pounds, has attained a speed of more than 2 miles a minute on specially prepared and peculiarly suitable roads. Even up steep grades nearly 80 miles an hour has been made. In speed the touring car holds a position next to the racing car, as 60 miles an hour can be covered with ease.

Though not yet perfected, the automobile has become at least reliable. Models and parts are being standardized, thus rendering it possible to replace broken or worn out parts without delay. In the United States many express and transfer companies, department stores, and fire departments have abandoned the horse-drawn vehicle for the automobile. In New Mexico it has supplanted the stage coach between Roswell and Torrance, a distance of 101 miles. It has worked a revolution in Nevada, where the means of local transportation have heretofore been confined to the mule. Liverymen acknowledge the passing of the horse by operating automobiles in connection with their stables. In many of the larger cities the automobile has been introduced for public transportation. Although it is as yet unsuited for general transportation in the field, yet the utility and advisability of the self-propelled vehicle for military purposes have been amply demonstrated. In Germany armored automobiles are being constructed for use in the army.

In the United States the use of automobiles will be limited only by their cost and the condition of the highways. The cost is gradually becoming less and the automobile itself is already felt as a factor in the movement for good roads.[1]

[1] In the preparation of the foregoing historical and descriptive sketch the following authorities have been consulted: The Complete Motorist, Young; The Book of the Automobile, Sloss; Self-Propelled Vehicles, Homans; Petrol Motors and Motor Cars, White; Modern Steam Road Wagons, Norris; various publications of The Motor Way; article "Automobiles" in International Encyclopedia.

TABLE 13.—AUTOMOBILES—DETAILED

		United States.	California.	Connecticut.
1	Number of establishments	121	6	7
	Capital:			
2	Total	$20,555,247	$48,802	$3,712,922
3	Land	$951,910	$500	$138,324
4	Buildings	$2,720,760	$800	$770,987
5	Machinery, tools, and implements	$4,290,831	$28,800	$851,477
6	Cash and sundries	$12,591,746	$18,702	$1,952,134
7	Proprietors and firm members	53	4	4
	Salaried officials, clerks, etc.:			
8	Total number	954	3	62
9	Total salaries	$1,076,425	$4,800	$86,372
	Officers of corporations—			
10	Number	114	...	9
11	Salaries	$286,557	...	$34,500
	General superintendents, managers, clerks, etc.—			
12	Total number	840	3	53
13	Total salaries	$789,868	$4,800	$51,872
	Men—			
14	Number	661	3	42
15	Salaries	$703,441	$4,800	$46,560
	Women—			
16	Number	179	...	11
17	Salaries	$86,427	...	$5,312
	Wage-earners, including pieceworkers, and total wages:			
18	Greatest number employed at any one time during the year	14,585	24	1,475
19	Least number employed at any one time during the year	6,333	13	808
20	Average number	10,239	14	1,065
21	Total wages	$6,178,950	$10,124	$783,993
	Men 16 years and over—			
22	Average number	10,196	14	1,057
23	Wages	$6,167,345	$10,124	$781,604
	Women 16 years and over—			
24	Average number	11	...	...
25	Wages	$3,689	...	...
	Children under 16 years—			
26	Average number	32	...	8
27	Wages	$7,916	...	$2,389
	Average number of wage-earners, including pieceworkers, employed during each month:[2]			
	Men 16 years and over—			
28	January	9,133	20	902
29	February	9,973	18	963
30	March	11,272	14	1,081
31	April	12,405	13	1,237
32	May	12,531	13	1,258
33	June	12,562	12	1,342
34	July	10,770	15	1,255
35	August	8,881	13	1,029
36	September	8,155	13	671
37	October	8,254	12	706
38	November	8,776	12	1,074
39	December	9,640	13	1,166
	Miscellaneous expenses:			
40	Total	$3,946,369	$10,139	$466,851
41	Rent of works	$88,497	$3,420	$1,945
42	Taxes	$77,625	$257	$11,843
43	Rent of offices, interest, insurance, and all other sundry expenses not hitherto included	$2,745,601	$6,462	$453,063
44	Contract work	$1,034,646	...	...
	Materials used:			
45	Total cost	$11,658,138	$12,863	$1,163,072
46	Principal materials	$9,507,503	$10,104	$600,184
47	Fuel	$180,092	$199	$28,328
48	Rent of power and heat	$35,387	$550	$640
49	Mill supplies	$133,589	$85	$8,734
50	All other materials	$1,609,806	$1,900	$498,279
51	Freight	$191,761	$25	$26,907
	Products:			
52	Aggregate value	$26,645,064	$36,380	$2,644,334
	Automobiles—			
53	Total number	21,692	12	832
54	Total value	$23,751,234	$13,606	$1,958,682
	Touring—			
55	Number	7,220	1	292
56	Value	$11,781,521	$1,800	$1,008,383
	Runabout—			
57	Number	12,131	6	209
58	Value	$8,831,504	$5,156	$283,800
	Stanhope—			
59	Number	520	...	106
60	Value	$614,104	...	$61,637
	Delivery, heavy—			
61	Number	160	1	23
62	Value	$491,490	$3,000	$91,000
	Delivery, light—			
63	Number	251	3	...
64	Value	$455,457	$3,150	...
	Surrey—			
65	Number	221	...	38
66	Value	$229,872	...	$45,462
	Victoria—			
67	Number	66	...	...
68	Value	$77,740	...	...
	Phaeton—			
69	Number	49	...	...
70	Value	$69,450	...	...
	Doctor's wagon or car—			
71	Number	54	1	...
72	Value	$47,140	$500	...

[1] Includes establishments distributed as follows: Kansas, 1; Maine, 1; Minnesota, 1; Missouri, 1; New Hampshire, 1; Rhode Island, 2.

SUMMARY, BY STATES: 1905.

Illinois.	Indiana.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	Pennsylvania.	Wisconsin.	All other states.[1]	
8	8	11	22	5	21	14	6	6	7	1
$378,536	$1,140,509	$1,623,857	$3,765,240	$310,261	$3,172,531	$3,544,162	$1,452,963	$1,240,006	$165,458	2
$2,500	$67,500	$73,141	$173,977	....	$275,018	$83,050	$65,600	$67,300	$5,000	3
$3,000	$167,871	$199,048	$361,634	....	$369,275	$518,952	$231,129	$86,644	$11,420	4
$209,654	$309,125	$352,773	$544,560	$51,874	$791,534	$751,304	$194,204	$161,727	$43,799	5
$163,382	$596,013	$998,895	$2,685,069	$258,387	$1,736,704	$2,190,856	$962,030	$924,335	$105,239	6
4	4	4	9	1	7	3	....	8	5	7
15	94	98	151	22	200	172	65	59	13	8
$26,180	$74,293	$115,832	$188,452	$13,662	$202,869	$218,950	$78,681	$54,180	$12,154	9
8	5	16	15	2	24	23	6	2	4	10
$18,500	$12,300	$40,384	$31,020	$2,000	$62,559	$52,505	$20,789	$6,000	$6,000	11
7	89	82	136	20	176	149	59	57	9	12
$7,680	$61,993	$75,448	$157,432	$11,662	$140,310	$166,445	$57,892	$48,180	$6,154	13
6	68	61	96	19	138	120	53	49	6	14
$7,200	$53,721	$64,887	$133,914	$11,246	$124,338	$151,877	$56,128	$44,124	$4,646	15
1	21	21	40	1	38	29	6	8	3	16
$480	$8,272	$10,561	$23,518	$416	$15,972	$14,568	$1,764	$4,056	$1,508	17
172	973	1,448	3,064	115	2,468	3,215	717	799	115	18
123	511	495	1,474	57	721	1,436	377	224	94	19
146	789	952	2,123	60	1,624	2,277	566	520	103	20
$100,433	$482,198	$596,277	$970,895	$40,296	$1,095,470	$1,368,810	$352,482	$299,624	$78,348	21
146	784	944	2,122	59	1,618	2,272	566	511	103	22
$100,433	$480,456	$594,082	$970,770	$40,248	$1,094,120	$1,367,160	$352,482	$297,518	$78,348	23
....	3	1	1	....	1	5	....	....	....	24
....	$1,326	$300	$125	....	$288	$1,650	....	....	....	25
....	2	7	....	1	5	....	....	9	....	26
....	$416	$1,895	....	$48	$1,062	....	....	$2,106	....	27
142	750	854	1,726	39	1,457	2,215	435	493	100	28
143	818	1,042	1,921	41	1,378	2,517	446	584	102	29
145	864	1,269	2,215	42	1,657	2,704	534	646	101	30
152	869	1,357	2,661	47	1,831	2,838	602	696	102	31
154	881	1,187	2,870	49	1,667	2,968	628	754	102	32
154	895	1,073	2,948	48	1,780	2,771	666	770	103	33
160	858	967	2,264	69	1,311	2,385	668	711	107	34
159	701	802	1,846	85	1,376	1,786	602	374	108	35
140	642	705	1,737	68	1,446	1,794	547	289	103	36
139	616	646	1,720	71	1,676	1,840	502	228	98	37
135	694	667	1,749	76	1,820	1,641	544	259	105	38
129	820	759	1,807	73	2,017	1,805	618	328	105	39
$61,721	$230,226	$228,504	$1,423,167	$40,459	$565,776	$677,374	$61,795	$163,995	$16,362	40
$8,701	$3,592	$6,397	$12,805	$3,776	$36,838	$4,281	$2,118	$580	$4,044	41
$1,297	$5,547	$9,591	$9,365	$950	$7,793	$20,034	$1,160	$9,192	$596	42
$51,723	$221,087	$212,016	$370,035	$35,733	$520,895	$652,637	$58,517	$154,223	$9,210	43
....	....	$500	$1,030,962	....	$250	$422	....	....	$2,512	44
$104,300	$811,823	$1,047,488	$2,872,655	$43,905	$1,764,567	$2,298,651	$601,430	$845,348	$91,946	45
$95,335	$625,262	$865,370	$2,586,305	$29,931	$1,459,265	$1,985,047	$383,346	$796,681	$70,583	46
$1,535	$18,523	$20,573	$21,177	$3,074	$27,892	$42,815	$7,732	$6,447	$1,797	47
$3,380	$1,157	$3,420	$3,330	$1,462	$14,486	$3,648	$2,924	....	$390	48
$135	$20,276	$11,988	$30,517	$612	$5,293	$46,766	$7,624	$945	$614	49
$3,620	$128,535	$126,871	$163,814	$8,299	$250,831	$195,761	$187,314	$27,400	$17,182	50
$385	$18,070	$19,266	$67,422	$527	$6,800	$24,614	$12,490	$13,875	$1,380	51
$327,710	$1,595,302	$2,160,455	$6,876,708	$118,753	$3,791,956	$5,788,563	$1,225,678	$1,875,259	$203,966	52
205	1,020	2,365	9,125	51	1,808	2,808	963	2,390	113	53
$262,691	$1,428,463	$2,052,943	$6,552,804	$71,400	$3,071,093	$5,197,360	$1,134,776	$1,856,694	$150,722	54
52	387	361	2,561	3	397	2,521	576	20	49	55
$75,838	$736,869	$692,439	$2,402,125	$8,000	$995,982	$4,967,731	$798,972	$20,000	$73,382	56
54	230	1,153	6,432	32	1,082	186	330	2,358	59	57
$35,800	$173,084	$816,844	$4,057,439	$34,500	$1,163,554	$124,629	$247,204	$1,826,294	$63,200	58
46	231	....	....	....	36	100	1	....	....	59
$69,097	$326,370	....	....	....	$55,500	$100,000	$1,500	....	....	60
....	....	....	51	1	81	1	....	2	....	61
....	....	....	$36,390	$3,000	$349,500	$5,000	....	$3,600	....	62
....	18	73	51	15	77	....	1	10	3	63
....	$20,160	$164,600	$35,250	$25,900	$191,457	....	$2,000	$6,800	$6,140	64
....	24	105	30	....	22	....	2	....	....	65
....	$28,800	$109,860	$21,600	....	$20,600	....	$3,550	....	....	66
....	64	....	....	....	2	....	....	....	....	67
....	$74,240	....	....	....	$3,500	....	....	....	....	68
1	....	....	....	....	....	....	48	....	....	69
$1,200	....	....	....	....	....	....	$68,250	....	....	70
....	53	....	....	....	....	....	....	....	....	71
....	$46,640	....	....	....	....	....	....	....	....	72

[1] The average number of women 16 years and over and children under 16 years, employed during each month, are not included in the table, because of the small number reported.

TABLE 13.—AUTOMOBILES—DETAILED

		United States.	California.	Connecticut.
	Products—Continued.			
	Automobiles—Continued.			
	Station wagon or car—			
73	Number	13	...	...
74	Value	$25,800	...	...
	Other varieties—			
75	Number	1,007	...	164
76	Value	$1,127,156	...	$468,400
77	All other products, including parts	$2,042,777	$1,761	$331,253
78	Amount received for custom work and repairing	$851,053	$21,013	$354,399
	Motive power:			
79	Total number of machines	21,692	12	832
80	Gasoline, number	18,699	12	386
81	Electric, number	1,425	...	319
82	Steam, number	1,568	...	127
	Power:			
83	Number of establishments reporting	113	5	6
84	Total horsepower	10,484	32	1,822
	Owned—			
	Engines—			
	Steam—			
85	Number	53	...	7
86	Horsepower	5,565	...	1,245
	Gas or gasoline—			
87	Number	59	2	1
88	Horsepower	1,149	18	3
	Water wheels—			
89	Number	1	...	...
90	Horsepower	40	...	...
	Electric motors—			
91	Number	96	...	17
92	Horsepower	2,860	...	539
	Rented—			
	Electric motors—			
93	Number	64	3	1
94	Horsepower	792	14	15
95	Other kind, horsepower	78	...	20
96	Furnished to other establishments, horsepower	25	...	...

SUMMARY, BY STATES: 1905—Continued.

Illinois.	Indiana.	Massachusetts.	Michigan.	New Jersey.	New York.	Ohio.	Pennsylvania.	Wisconsin.	All other states.	
...	11	...	...	...	2	...	...	...	...	73
...	$19,800	...	...	...	$6,000	...	...	...	...	74
52	2	673	...	...	109	...	5	...	2	75
$80,756	$2,500	$269,200	...	...	$285,000	...	$13,300	...	$8,000	76
$23,290	$114,963	$78,907	$276,680	$36,050	$494,608	$554,642	$83,183	$16,080	$31,360	77
$41,729	$51,876	$28,605	$47,224	$11,303	$226,255	$36,561	$7,719	$2,485	$21,884	78
205	1,020	2,365	9,125	51	1,808	2,808	963	2,390	113	79
66	595	1,765	9,114	6	1,496	1,811	955	2,388	105	80
139	424	...	11	15	307	200	8	2	...	81
...	1	600	...	30	5	797	...	...	8	82
7	7	10	22	5	20	14	6	6	5	83
114	1,050	616	1,511	232	1,228	2,550	568	645	116	84
...	4	6	7	4	7	11	5	2	...	85
...	525	437	758	165	575	1,040	320	500	...	86
4	6	3	15	2	9	4	3	7	3	87
36	137	41	390	14	113	86	103	145	63	88
...	...	...	...	...	...	...	...	...	1	89
...	...	...	...	...	...	...	...	...	40	90
3	23	1	8	...	17	21	6	...	...	91
23	378	10	206	...	192	1,307	145	...	...	92
5	1	13	10	8	15	7	...	...	1	93
55	10	122	90	53	343	80	...	...	10	94
...	...	6	7	...	5	37	...	...	3	95
...	...	5	...	...	...	...	...	...	20	96

BICYCLES AND TRICYCLES

BICYCLES AND TRICYCLES.

By Robert H. Merriam.

The statistics for the 101 establishments that were engaged primarily in manufacturing bicycles and tricycles at the census of 1905, and those for similar establishments for the censuses of 1890 and 1900, are summarized in Table 1.

Table 1.—*Comparative summary, with per cent of increase and decrease: 1890 to 1905.*

	CENSUS.			Per cent of decrease, 1900 to 1905.	Per cent of increase, 1890 to 1900.
	1905[1]	1900	1890		
Number of establishments	101	312	27	67.6	1,055.6
Capital	$5,883,458	$29,783,659	$2,058,072	80.2	1,347.2
Salaried officials, clerks, etc., number	361	2,034	[2] 128	82.3	1,489.1
Salaries	$350,798	$1,753,235	[2] $123,714	80.0	1,317.2
Wage-earners, average number	3,319	17,525	1,797	81.1	875.2
Total wages	$1,971,403	$8,189,817	$982,014	75.9	734.0
Men 16 years and over	3,298	16,700	1,747	80.3	855.9
Wages	$1,964,940	$7,952,257	$971,539	75.3	718.5
Women 16 years and over	7	517	15	98.6	3,346.7
Wages	$3,481	$175,028	$3,729	98.0	4,593.7
Children under 16 years	14	308	35	95.5	780.0
Wages	$2,982	$62,532	$6,746	95.2	826.9
Miscellaneous expenses	$574,655	$2,252,604	$242,018	74.5	830.8
Cost of materials used	$2,628,146	$16,792,051	$718,848	84.3	2,236.0
Value of products	$5,153,240	$31,915,908	$2,568,326	83.9	1,142.7

[1] Exclusive of the statistics of 13 establishments making bicycles and tricycles, and bicycle parts, but engaged primarily in the manufacture of other products. The value of bicycles and tricycles, and bicycle parts made in such establishments was $575,959.

[2] Includes proprietors and firm members with their salaries; number only reported in 1900 and 1905, but not included in this table.

The most noticeable feature in this industry, as shown by the figures in Table 1, is its rapid growth and decline within fifteen years. The establishments engaged primarily in manufacturing bicycles and tricycles numbered only 27 in 1890, while in 1900 they numbered 312, and at the present census only 101. The decrease is also noticeable in the average number of wage-earners employed, and in the value of the products. The average number of wage-earners decreased from 17,525 in 1900 to 3,319 in 1905, which was only 1,522 more than were employed in 1890, and the value of products decreased from $31,915,908 in 1900 to $5,153,240 in 1905.

Prior to the decade ending in 1880, the manufacture of bicycles was intermittent, and it was not until 1890 that the industry was of sufficient importance in the United States to be reported separately. Up to that time the statistics relating to this industry were included in those for carriages and wagons. During the decade ending in 1900 the progress made was most remarkable, the climax being reached about the middle of that period.

With the general adoption of the pneumatic tire and society's approval of cycling, came the prosperous days of 1894 to 1896. People went cycle mad; the bicycle industry appeared to be an Eldorado, and there was a rush to engage in it. Then followed the decline in popularity, with the resultant dull times and failures among the manufacturers. By 1898, however, the industry was being conducted upon sound economic principles.

When the demand for bicycles decreased some manufacturers turned to the automobile, and many establishments that made only bicycles in 1900 are now devoted primarily to the manufacture of automobiles, while others make them to a greater or less degree in connection with the manufacture of bicycles. As far as reported to this Bureau, the value of automobiles and automobile parts reported at the census of 1905 by establishments devoted primarily to the manufacture of bicycles and tricycles was $345,179.

Production.—Table 2 is a detailed statement, for the United States, of the number and value of the different kinds of products made in all establishments making bicycles and tricycles and bicycle parts during the census years 1900 and 1905.

Table 2.—*Number and value of different kinds of products, including those produced as secondary products: 1905 and 1900.*

	1905			1900		
	Number.	Value.	Average value.	Number.	Value.	Average value.
Total	256,986	$5,729,199	......	1,208,960	$33,469,085	......
Bicycles	252,923	4,109,429	$16.25	1,182,850	23,689,437	$20.03
Individual— Chainless	4,077	142,136	34.86	42,929	1,957,329	45.59
Chain	246,304	3,594,504	14.59	1,136,122	21,488,589	18.91
Tandem	106	4,283	66.02	3,640	210,569	57.85
Motor	2,436	368,506	154.25	159	32,950	207.23
Tricycles	4,063	33,560	8.26	26,110	71,985	2.76
Custom work and repairing	....	296,344	......	....	(1)	......
All other products	....	[2] 1,289,866	......	....	9,707,663	......

[1] This item, reported under the classification "bicycle and tricycle repairing," amounted to $13,766,033.

[2] Includes value of automobiles and automobile and bicycle parts, etc.

In addition to the 101 establishments shown in Table 1, there were 13 factories engaged primarily in some other branch of manufacture, which made, during the census year 1905, 25,319 bicycles and tricycles, valued at $551,794; manufactured bicycle parts to the value of $16,540; and did custom and repair work to the value of $7,625. The figures for these 13 establishments are included in Table 2.

The 101 establishments engaged primarily in the manufacture of cycles made 231,667 bicycles and tricycles, valued at $3,591,195; bicycle parts, valued at $933,147; and did custom and repair work to the amount of $288,719. The total value of all products, as shown in Table 2, is $5,729,199. In the item "all other products" is included $345,179, the value of automobiles and automobile parts manufactured by bicycle and tricycle establishments, while the value of chains, spokes, handle bars, saddles, rims, and other parts manufactured make up the greater part of the remaining $944,687.

At the census of 1900 the total number of bicycles reported was 1,182,850, while in 1905 only 252,923 were reported, a decrease of 929,927. It is probable this decrease was much larger than is shown in Table 2, for the reason that in 1900 there were 6,328 establishments classified as bicycle and tricycle repair shops, which undoubtedly manufactured a considerable number of bicycles. As detailed reports were not received from these repair establishments, an estimate of the number of wheels they made would be of little value. The gross value of the product of these shops in 1900, however, was $13,766,033.

The average value of a chain bicycle was $14.59 in 1905 as compared with $18.91 in 1900. This is for a "stripped" wheel at the factory, as the majority of the manufacturers reported stripped and not completely equipped wheels. This explanation also applies to chainless wheels, whose average value at the factory in 1905 was $34.86, while in 1900 it was $45.59. The decrease in price per wheel between the two census periods is but a continuation of the downward trend which first began in 1894, when the price of a complete wheel fell from $150 to $125. In the following year another $25 was deducted, and in spite of the prosperous season of 1895-96 the price continued to fall until it reached the present level of from $35 to $50 for a chain bicycle.

The only kind of machine referred to in Table 2, which shows an increase over 1900, is the motor cycle. In 1900 there were reported 159 motor cycles, valued at $32,950, while at the present census 2,436 are reported, valued at $368,506. The motor cycle had received scant attention during the low ebb in cycling, owing to the general attention being directed toward low-priced machines and the apparently large profits to be made in manufacturing automobiles. Slowly, however, the motor cycle won its way toward recognition, and, one after another, the bicycle establishments took up its manufacture. At the present census 28 establishments are making motor cycles.

Most of the tricycles reported were children's toys, which accounts for the low price.

Table 3 is a comparative summary, by states, of the bicycle and tricycle industry for the censuses of 1890, 1900, and 1905, the table also shows the increases and decreases.

TABLE 3.—*Comparative summary—active establishments, by states, with increase and decrease: 1890 to 1905.*[1]

STATE.	CENSUS.			Decrease, 1900 to 1905.	Increase, 1890 to 1900.
	1905	1900	1890		
United States	101	312	27	211	285
California	4	4			4
Colorado	2	1		[2]1	1
Connecticut	2	24	2	22	22
Illinois	13	60	5	47	55
Indiana	2	19	1	17	18
Iowa		1		1	1
Kentucky		1		1	1
Maine		1		1	1
Maryland	1	1			1
Massachusetts	8	25	7	17	18
Michigan	4	11	1	7	10
Minnesota	8	4		[2]4	4
Missouri	2			[2]2	
Nevada		1		1	1
New Hampshire		1		1	1
New Jersey	3	7	1	4	6
New York	32	66	4	34	62
North Carolina	1			[2]1	
Ohio	3	34	2	31	32
Oregon			1		[3]1
Pennsylvania	12	24	3	12	21
Rhode Island	1	4		3	4
Wisconsin	3	23		20	23

[1] Does not include establishments producing bicycles and tricycles as secondary products.
[2] Increase.
[3] Decrease.

In but 4 states did the industry show an increase in 1905 over 1900, and in 2 of these—Missouri and North Carolina—no establishments were reported in 1900, while in 1905 there were only 2 and 1, respectively. The other states showing an increase were Colorado and Minnesota, in which there were no bicycle and tricycle factories in 1890. California and Maryland had the same number of factories in 1905 as in 1900. Iowa, Kentucky, Maine, Nevada, and New Hampshire each having 1 establishment in 1900 had no plants in 1905. The remaining states which reported establishments in 1900 show a large decrease at the present census. This is particularly noticeable in Connecticut, Illinois, Indiana, Massachusetts, New York, Ohio, Pennsylvania, and Wisconsin.

In 1890 there were only 27 establishments reported which were distributed among 10 states; in 1900, 312 establishments were reported from 20 states, and in 1905 there were 101 factories reported from 17 states. Connecticut, Illinois, Indiana, Massachusetts, Michigan, New Jersey, New York, Ohio, and Pennsylvania have reported active establishments in this industry ever since it was first reported separately. Oregon is the only state named in the table which has reported no active establishments since 1890.

Of the 101 establishments reported at the present census 40 reported in 1900, while 61 are either new concerns started since 1900, or, in some cases, possibly reorganizations, under different names, of firms active in 1900. As far as ascertained 236 of the bicycle and tricycle plants which reported at the census of 1900 have since then gone out of business, while 36 have retained their names, although they have changed from the manufacture of bicycles and tricycles to some other industry.

Table 4 is a comparative summary, by states, of the figures reported by manufacturers engaged primarily in the production of bicycles and tricycles in 1900 and 1905.

TABLE 4.—COMPARATIVE SUMMARY, BY STATES: 1905 AND 1900.

STATE.	Year.	Number of establishments.	Capital.	SALARIED OFFICIALS, CLERKS, ETC.		WAGE-EARNERS AND WAGES.		Miscellaneous expenses.	Cost of materials used.	Value of products.
				Number.	Salaries.	Average number.	Wages.			
United States	1905	101	$5,883,458	361	$350,798	3,319	$1,971,403	$574,655	$2,628,146	$5,153,240
	1900	312	29,783,659	2,034	1,753,235	17,525	8,189,817	2,252,604	16,792,051	31,915,908
California	1905	4	13,531	2	1,300	10	6,010	3,029	15,708	29,652
	1900	4	19,254	…	…	19	11,080	3,144	25,470	47,670
Connecticut [1]	1900	24	4,215,309	263	251,091	2,159	1,150,736	323,629	1,720,249	3,672,225
Illinois	1905	13	1,029,875	82	82,304	969	593,902	76,915	512,753	1,161,481
	1900	60	7,694,658	642	522,477	4,388	2,144,897	630,442	4,836,585	8,960,421
Indiana [1]	1900	19	2,061,560	123	96,996	1,481	613,840	121,260	1,221,786	2,115,901
Massachusetts	1905	8	689,567	47	45,026	344	180,384	110,908	289,107	582,047
	1900	25	2,646,498	139	117,242	1,581	815,028	125,076	1,307,900	2,715,310
Michigan	1905	4	238,330	19	13,225	79	47,763	24,567	95,709	208,384
	1900	11	757,021	53	39,643	311	141,629	59,485	345,725	627,658
Minnesota	1905	8	18,235	2	1,060	11	6,088	3,354	14,407	34,016
	1900	4	38,205	2	2,220	47	8,440	4,673	30,997	66,505
New Jersey	1905	3	11,300	2	1,404	2	1,060	1,458	4,539	12,162
	1900	7	204,465	24	23,457	183	71,343	19,548	147,317	295,226
New York	1905	32	657,529	28	25,974	410	205,645	83,268	347,165	758,789
	1900	66	3,326,943	267	216,120	2,103	988,052	366,501	1,856,065	3,842,020
Ohio	1905	3	1,132,225	61	62,296	446	292,780	158,556	456,656	1,040,982
	1900	34	4,074,576	209	197,406	2,380	1,017,061	247,332	2,251,358	4,059,980
Pennsylvania	1905	12	209,909	6	3,940	94	51,762	30,670	130,181	250,348
	1900	24	1,550,957	110	91,681	947	431,369	128,931	1,065,461	1,855,043
Rhode Island [1]	1900	4	24,300	6	3,600	17	6,100	1,309	23,195	43,382
Wisconsin	1905	3	31,212	3	2,388	12	6,925	10,892	18,781	44,456
	1900	23	2,337,975	160	134,007	1,572	625,149	170,266	1,536,592	2,795,236
All other states	[2] 1905	11	1,851,745	109	111,881	942	578,784	71,038	743,140	1,030,923
	[3] 1900	7	831,848	36	57,195	357	165,083	51,008	423,551	779,331

[1] Included in "all other states" in 1905.
[2] Includes establishments distributed as follows: Colorado, 2; Connecticut, 2; Indiana, 2; Maryland, 1; Missouri, 2; North Carolina, 1; Rhode Island, 1.
[3] Includes establishments distributed as follows: Colorado, 1; Iowa, 1; Kentucky, 1; Maine, 1; Maryland, 1; Nevada, 1; New Hampshire, 1.

The most noticeable feature in Table 4 is the decrease in Connecticut, Illinois, Indiana, Massachusetts, New York, Ohio, Pennsylvania, and Wisconsin, that for the last-named state being most prominent. In 1900 each of these states produced bicycles and tricycles valued at over $1,000,000, while in 1905 the product of but 2, Illinois and Ohio, was valued at $1,000,000 or over.

Exports.—The value of bicycles and tricycles and parts thereof exported from the United States each year from 1896 to 1905, inclusive, is shown in Table 5.

TABLE 5.—*Value of exports of bicycles and tricycles, and parts thereof: 1896 to 1905.*[1]

FISCAL YEAR.	Exports.	FISCAL YEAR.	Exports.
1896	$1,898,012	1901	$2,515,804
1897	7,005,323	1902	2,627,572
1898	6,846,529	1903	2,132,629
1899	5,753,880	1904	1,965,026
1900	3,553,149	1905	1,378,428

[1] "Commerce and Navigation of the United States," Bureau of Statistics, Department of Commerce and Labor.

The high tide of bicycle export from the United States was reached in 1897, when the American wheel commanded a market not only in nonmanufacturing countries, but also in the United Kingdom and throughout continental Europe. Excepting a slight increase in 1902 over the previous year, the decline in the export trade has kept pace with the decline in the popularity of the bicycle.

Historical and descriptive.—The history of the bicycle was discussed in the Report on Manufactures, Twelfth Census, Part IV. The history of the manufacture of motor cycles was not dwelt upon at that time but is here introduced.

The first power-driven bicycle produced in the United States was a steam "boneshaker," made and used in 1868 by W. W. Austin, of Winthrop, Mass.[1] This machine, which weighed 90 pounds, is said to have run about 2,000 miles. The engine and boiler were attached to the frame just back of the rider.[2]

[1] The Bicycling World, Vol. XLIII, No. 15, Jan. 10, 1901, page 370.
[2] The Bicycling World, Vol. XLII, No. 7, Nov. 15, 1900, page 141.

During 1884–85 the better known "Copeland steam bicycle" was devised by W. E. and L. D. Copeland, of San Francisco, Cal. The wheel used was of the regular "Star" pattern, and the engine and boiler were planned so as to occupy very little space outside the lines of the machine. The engine proper weighed 1 pound and 12 ounces, including the driving pulley, and the speed was 7 revolutions to 1 of the bicycle. The engine was capable of making 1,000 revolutions per minute. Enough water could be taken into the boiler to last an hour, and the power of the engine was sufficient to drive the 51-inch wheel about 12 miles on a floor, or about 1 mile in eight minutes on the road.[1]

So far as known nothing else in the form of a motor cycle was attempted in this country during the succeeding ten years. During the year 1894–95, when the safety bicycle and pneumatic tires were firmly established, E. J. Pennington, of Cleveland, Ohio, formed the Motor Cycle Company, and advertised extensively both a single and tandem power-driven machine. Kerosene was the fuel used, and it was claimed that 1 gallon would serve for 200 miles. Explosions which drove the machine were caused by electric ignition, the mere pressure of an electric button on the handle bar being sufficient to start or stop the machine and also to regulate the speed. While the contrivance was most ingenious, it was in advance of the times, the public not then being interested in power-driven cycles.[1]

In 1884 Gottlieb Daimler, of Deutz, Germany, produced and patented a small gas engine designed to run at very high speed, so high that the heat generated by it was enough to ignite the charges of gas furnishing the propelling power. This engine Mr. Daimler, in 1886, fitted to a bicycle by placing it vertically between the front and rear wheels, the rear wheel being driven from the engine by means of a belt. Gas was supplied from a carburetor in which an explosive vapor was produced by causing air to enter the liquid from below. This engine proved so satisfactory that Daimler continued work on it, and in 1889 constructed a two-cylinder engine, the piston rods of which were coupled to a single crank.[2]

From 1900 to the present time increased attention has been given to motor cycles, with the result that to-day there are many types upon the market, the majority, if not all, being propelled by a gasoline motor.

Under the report on automobiles in this volume the gasoline motor has been so generally covered that it was not considered necessary to give this subject any further attention in this article.

The detailed statistics for the bicycle and tricycle industry in establishments devoted primarily to their manufacture are presented in Table 6, which gives separate totals for each state in which there are three or more establishments, and groups the statistics for other states so as not to disclose the operations of individual establishments.

[1] The Bicycling World, Vol. XLI, No. 6, May 10, 1900, page 157.

[2] The Complete Motorist, page 28.

TABLE 6.—BICYCLES AND TRICYCLES—

		United States.	California.	Illinois.
1	Number of establishments	101	4	13
	Capital:			
2	Total	$5,883,458	$13,531	$1,029,875
3	Land	$282,740	....	$47,036
4	Buildings	$1,115,039	....	$142,840
5	Machinery, tools, and implements	$2,360,698	$2,317	$432,196
6	Cash and sundries	$2,124,981	$11,214	$407,803
7	Proprietors and firm members	81	3	6
	Salaried officials, clerks, etc.:			
8	Total number	361	2	82
9	Total salaries	$350,798	$1,300	$82,304
	Officers of corporations—			
10	Number	31	1	5
11	Salaries	$76,216	$700	$7,780
	General superintendents, managers, clerks, etc.—			
12	Total number	330	1	77
13	Total salaries	$274,582	$600	$74,524
	Men—			
14	Number	275	1	69
15	Salaries	$251,717	$600	$71,874
	Women—			
16	Number	55	....	8
17	Salaries	$22,865	....	$2,650
	Wage-earners, including pieceworkers, and total wages:			
18	Greatest number employed at any one time during the year	4,893	12	1,624
19	Least number employed at any one time during the year	1,740	8	371
20	Average number	3,319	10	969
21	Total wages	$1,971,403	$6,010	$593,902
	Men 16 years and over—			
22	Average number	3,298	10	968
23	Wages	$1,964,940	$6,010	$593,641
	Women 16 years and over—			
24	Average number	7	....	1
25	Wages	$3,481	....	$261
	Children under 16 years—			
26	Average number	14	....	....
27	Wages	$2,982	....	....
	Average number of wage-earners, including pieceworkers, employed during each month:[2]			
	Men 16 years and over—			
28	January	4,075	11	1,457
29	February	4,260	11	1,547
30	March	4,205	12	1,498
31	April	3,719	12	915
32	May	3,676	12	868
33	June	3,322	11	797
34	July	2,550	9	566
35	August	2,149	8	557
36	September	2,309	8	651
37	October	2,578	8	742
38	November	3,047	9	875
39	December	3,686	9	1,143
	Miscellaneous expenses:			
40	Total	$574,655	$3,029	$76,915
41	Rent of works	$58,453	$1,665	$31,050
42	Taxes	$29,963	$56	$5,357
43	Rent of offices, interest, insurance, and all other sundry expenses not hitherto included	$408,044	$1,308	$40,508
44	Contract work	$78,195	....	....
	Materials used:			
45	Total cost	$2,628,146	$15,708	$512,753
46	Principal materials	$2,039,566	$14,350	$378,158
47	Fuel	$85,791	$122	$21,318
48	Rent of power and heat	$19,712	$186	$400
49	Mill supplies	$42,884	$100	$11,700
50	All other materials	$404,327	$800	$96,212
51	Freight	$35,866	$150	$4,965
	Products:			
52	Aggregate value	$5,153,240	$29,652	$1,161,481
	Bicycles—			
53	Total number	227,504	996	80,231
54	Total value	$3,557,635	$17,125	$907,010
	Individual—			
	Chainless—			
55	Number	3,675	....	1,244
56	Value	$118,016	....	$37,470
	Chain—			
57	Number	221,428	990	78,730
58	Value	$3,081,206	$15,925	$825,012
	Tandem—			
59	Number	106	....	22
60	Value	$4,283	....	$900
	Motor—			
61	Number	2,295	6	235
62	Value	$354,130	$1,200	$43,628
	Tricycles—			
63	Number	4,063	30	....
64	Value	$33,560	$3,000	....
65	All other products	$1,273,326	$1,284	$234,523
66	Amount received for custom work and repairing	$288,719	$8,243	$19,948

[1] Includes establishments distributed as follows: Colorado, 2; Connecticut, 2; Indiana, 2; Maryland, 1; Missouri, 2; North Carolina, 1; Rhode Island, 1.

DETAILED SUMMARY, BY STATES: 1905.

Massachusetts.	Michigan.	Minnesota.	New Jersey.	New York.	Ohio.	Pennsylvania.	Wisconsin.	All other states.[1]	
8	4	8	3	32	3	12	3	11	1
$689,567	$238,330	$18,235	$11,300	$657,529	$1,132,225	$209,909	$31,212	$1,851,745	2
$4,400	$2,500	$1,900	...	$25,250	$30,529	$27,100	...	$144,025	3
$106,247	$20,189	$2,400	...	$81,459	$199,130	$28,701	$2,225	$522,848	4
$344,710	$48,334	$5,700	$2,800	$277,114	$395,056	$46,121	$10,775	$795,575	5
$234,210	$158,307	$8,235	$8,500	$273,706	$507,510	$107,987	$18,212	$389,297	6
6	2	7	2	28	...	15	4	8	7
47	19	2	2	28	61	6	3	109	8
$45,026	$13,225	$1,060	$1,404	$25,974	$62,296	$3,940	$2,388	$111,881	9
...	2	...	1	8	7	...	2	5	10
...	$5,000	...	$780	$8,400	$13,800	...	$1,920	$37,836	11
47	17	2	1	20	54	6	1	104	12
$45,026	$8,225	$1,060	$624	$17,574	$48,496	$3,940	$468	$74,045	13
36	12	2	1	13	40	4	...	97	14
$39,568	$6,320	$1,060	$624	$14,062	$42,644	$3,280	...	$71,685	15
11	5	...	...	7	14	2	1	7	16
$5,458	$1,905	...	...	$3,512	$5,852	$660	$468	$2,360	17
492	118	18	3	620	555	157	19	1,275	18
213	23	9	3	192	295	61	8	557	19
344	79	11	2	410	446	94	12	942	20
$180,384	$47,763	$6,088	$1,060	$205,945	$292,780	$51,762	$6,925	$578,784	21
335	79	11	2	407	446	90	12	938	22
$178,030	$47,763	$6,088	$1,060	$205,113	$292,780	$51,060	$6,925	$576,470	23
3	...	...	...	...	...	...	...	3	24
$1,088	...	...	...	...	...	...	...	$2,132	25
6	...	...	...	3	...	4	...	1	26
$1,266	...	...	...	$832	...	$702	...	$182	27
437	111	7	2	475	474	78	8	1,015	28
450	110	8	2	524	500	81	9	1,018	29
401	97	16	2	547	486	87	10	1,049	30
357	80	15	2	534	503	102	13	1,186	31
324	76	14	2	461	552	103	17	1,247	32
277	71	14	2	353	523	102	19	1,153	33
244	29	13	2	355	379	93	18	842	34
257	21	12	2	284	314	81	16	597	35
237	55	11	2	266	349	72	12	646	36
238	89	11	2	312	346	75	10	745	37
320	103	6	2	343	444	98	6	841	38
478	106	5	2	430	482	108	6	917	39
$110,908	$24,567	$3,354	$1,458	$83,268	$158,556	$30,670	$10,892	$71,038	40
$2,220	$740	$1,768	$570	$10,604	$720	$3,740	$844	$4,532	41
$3,064	$918	$150	$8	$2,644	$3,078	$544	$76	$14,068	42
$35,584	$22,609	$1,311	$880	$69,287	$154,758	$26,386	$2,975	$52,438	43
$70,040	$300	$125	...	$733	...	...	$6,997	...	44
$289,107	$95,709	$14,407	$4,539	$347,165	$456,656	$130,181	$18,781	$743,140	45
$238,189	$83,915	$13,071	$3,020	$287,932	$326,582	$124,418	$17,734	$552,197	46
$13,262	$3,243	$210	$55	$7,393	$17,073	$2,714	$532	$19,869	47
$520	$12	$336	...	$6,059	$10,647	$503	$20	$1,029	48
$5,808	$1,487	$25	$4	$3,795	$3,384	$195	$425	$15,961	49
$28,407	$5,852	$765	$1,450	$38,170	$92,286	$500	...	$139,885	50
$2,921	$1,200	...	$10	$3,816	$6,684	$1,851	$70	$14,199	51
$582,047	$208,384	$34,016	$12,162	$758,789	$1,040,982	$250,348	$44,456	$1,030,923	52
13,456	8,225	297	398	29,089	36,138	5,769	575	52,330	53
$537,403	$186,200	$16,737	$5,591	$367,094	$671,330	$127,195	$36,930	$685,020	54
495	...	...	...	200	...	10	...	1,726	55
$18,850	...	...	...	$7,000	...	$500	...	$54,196	56
11,782	8,225	228	398	28,723	35,985	5,680	395	50,292	57
$333,736	$186,200	$8,892	$5,591	$338,379	$654,792	$115,525	$9,930	$587,224	58
83	...	...	...	1	...	...	...	...	59
$3,333	...	...	...	$50	...	...	...	...	60
1,096	...	69	...	165	153	79	180	312	61
$181,484	...	$7,845	...	$21,665	$16,538	$11,170	$27,000	$43,600	62
...	2	...	...	...	3,038	993	...	...	63
...	$350	...	...	...	$26,493	$3,717	...	...	64
$42,084	$7,000	$600	$1,350	$345,677	$319,335	$95,726	$850	$224,897	65
$2,560	$14,834	$16,679	$5,221	$46,018	$23,824	$23,710	$6,676	$121,006	66

[1] The average number of women 16 years and over and children under 16 years, employed during each month, are not included in the table because of the small number reported.

TABLE 6.—BICYCLES AND TRICYCLES—

		United States.	California.	Illinois.
	Power:			
67	Number of establishments reporting	80	3	10
68	Total horsepower	7,131	8	2,939
	Owned—			
	Engines—			
	Steam—			
69	Number	49		20
70	Horsepower	4,906		2,208
	Gas or gasoline—			
71	Number	34	1	4
72	Horsepower	231	4	16
	Water wheels—			
73	Number	2		
74	Horsepower	35		
	Electric motors—			
75	Number	50		23
76	Horsepower	1,401		705
	Rented—			
	Electric motors—			
77	Number	42	2	1
78	Horsepower	336	4	10
79	Other kind, horsepower	222		
80	Furnished to other establishments, horsepower	2		2

DETAILED SUMMARY, BY STATES: 1905—Continued.

Massachusetts.	Michigan.	Minnesota.	New Jersey.	New York.	Ohio.	Pennsylvania.	Wisconsin.	All other states.	
8	4	5	1	23	3	10	3	10	67
1,130	232	11	4	612	655	128	32	1,380	68
7	3	...	1	4	2	3	...	9	69
613	225	...	4	362	229	55	...	1,210	70
3	1	1	...	6	4	3	3	8	71
14	3	3	...	19	105	16	32	19	72
...	...	...	...	2	...	...	...	...	73
...	...	...	...	35	...	...	...	...	74
9	1	...	...	...	10	...	...	7	75
485	1	...	...	...	108	...	...	102	76
2	1	4	...	10	13	2	...	7	77
8	3	8	...	38	213	3	...	49	78
10	...	...	...	158	...	54	...	...	79
...	...	...	...	...	...	...	...	...	80