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THE SAFETY MOVEMENT IN THE IRON AND STEEL INDUSTRY 1907 TO 1917

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THE SAFETY MOVEMENT IN THE IRON AND STEEL INDUSTRY, 1907 TO 1917.

INTRODUCTORY NOTE.

In 1913 the Bureau of Labor Statistics published the results of a study of accidents in the iron and steel industry, covering the period 1907 to 1910.[1] The report now offered constitutes a much more comprehensive study of the same subject, based upon a very much larger amount of material and strengthened by the accumulated knowledge of recent years in the field of accident prevention.

The report is divided into two distinct parts:

Part I constitutes a brief review of the course of accidents from 1907 to 1917, with special reference to the effects of the War upon accident occurrence. Owing to the extreme difficulty of obtaining entirely up-to-date accident statistics the information for the latter part of the period under review is not complete upon all points, but it is sufficient to give a fairly accurate idea of the trend of accidents during a period of extraordinary interest.

Part II contains a series of studies upon various phases of the accident problem in the iron and steel industry. The primary object in view was, in every case, to find out where accidents occur, how serious they are, why they occur, and by what means they may be prevented. The material available for this part covers practically the entire industry from 1910 to 1914. For the earlier years, 1907 to 1909, approximately 10 per cent of the industry is included.

[1] Report on Conditions of Employment in the Iron and Steel Industry in the United States. Vol. IV, Accidents and Accident Prevention. (S. Doc. 110, 62d Cong., 1st sess.)

PART I.—A REVIEW OF THE SAFETY MOVEMENT, WITH SPECIAL REFERENCE TO THE WAR.

PART I.—A REVIEW OF THE SAFETY MOVEMENT, WITH SPECIAL REFERENCE TO THE WAR.

The period covered by this report—i. e., 1907 to 1917—embraces practically the entire history of the safety movement, not only in the manufacture of iron and steel but in the whole field of American industry. Prior to that time efforts toward accident prevention had been made, but they were isolated, were individual in character, and were not productive of any general results.

At that time, indeed (say 1907 and the immediately preceding years), there existed in American industry generally a frightful disregard of human life. Accident occurrence had reached a condition not paralleled perhaps at any other time or place. Two factors contributed to such a condition: First, there was an unprecedented degree of business activity; and, second, there was a larger proportion of inexperienced immigrant labor than at any time before or since. The combination of these circumstances, with the absence of any organized safety effort as the term is understood to-day, produced accident rates of a degree of frequency and severity not fully reflected in the available records. The records which it is possible to secure for the early years of the period are those of the better plants. The conditions in the worse establishments were not made a matter of record.

Among the industries which had sinned most, and which most needed to awake to the importance of accident prevention, the iron and steel industry stood out prominently. It was not only one of the great basic industries, but its intrinsic hazards were of a more pronounced character than those of the majority of industrial employments. And because of this, because the industry was spectacularly hazardous, the safety movement, when it finally began, had room for equally spectacular accomplishments.

The awakening came slowly. But gradually there was a stirring of dry bones within the industry. The accident prevention idea began to spread. Many plants instituted accident compensation schemes. Outside of industry there arose a strong propaganda for the enactment of compensation laws by the States. The effect of this combination of earnest study of the accident problem within industry and the outside movement for compensation legislation was to lay the foundation for the very remarkable progress in accident reduction which will be demonstrated in the course of this review.

The progress, however, has not been uniform throughout the industry. Some plants were early in beginning their campaigns; others were late in beginning. Even now there are some which have failed to profit at all fully from the accumulating knowledge of recent years. But, broadly speaking, the iron and steel industry as a whole experienced a steady decline in accident rates from 1906 or 1907 onward for a period of almost 10 years.

Then, into the natural and orderly progress in matters of safety, there intruded the enormous dislocation of the great war. Its first effect upon American industry generally was one of great depression. Employment in the iron and steel industry declined to a point nearly or quite as low as that reached in 1908. This decline continued until about the middle of 1915. Then began an upward movement in activity and in employment which was entirely without precedent. And not only was it more rapid than any previous movement of its kind, but it was modified very materially by entirely new labor conditions. Instead of an influx of labor from European countries such as had hitherto accompanied every revival of industrial activity, there was an actual emigration. The demand for labor led to the introduction of entirely new labor elements and to a movement of labor from place to place and from employer to employer such as had never before occurred.

All these factors combined to test the adequacy of accident prevention effort in the iron and steel industry as no previous experience had tested it. Both the strength and weakness of the movement were now displayed.

On the whole, it may be said that the test was well met. In some branches of the industry accident rates kept declining in spite of the new pressure. In others, however, there was a condition bordering on demoralization. Accident rates went up rapidly. But in very few of the better organized plants did the new rates rise as high as they had been in the next preceding period of industrial activity, and by the middle or latter part of 1916 the situation almost everywhere was well in hand. Accident rates began to drop in spite of the fact that employment went on increasing.

The safety movement in the iron and steel industry may thus be said to have passed with credit its most serious test. But there must be no resting on the oars. Accident rates are still high, and, if necessary, the safety movement must revise its foundation principles in order to meet new demands. There seems to be no good reason why the downward movement should not continue indefinitely. Indeed, as is pointed out in a later chapter,[1] there must be no compromise on any lesser goal than the elimination of all serious accidents. It is a goal which perhaps may never quite be reached, but

[1] Ch. VIII.

nevertheless the possibility of reaching it exists and must be steadily kept in mind.

SAFETY EXPERIENCE OF A LARGE STEEL PLANT.

The movement outlined is well illustrated by Table 1.

TABLE 1.—ACCIDENT EXPERIENCE OF A LARGE STEEL PLANT, 1905 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).
1905	6,406	300	34.5
1906	7,494	214	54.3
1907	7,585	189	38.1
1908	4,575	150	29.9
1909	6,215	174	23.7
1910	7,642	134	19.9
1911	5,774	112	18.6
1912	7,396	153	14.3
1913	7,562	115	21.3
1914	4,741	74	12.2
1915	5,599	48	20.6
1916	9,634	96	13.4
1917	10,862	85	12.9

This table shows the course of accident rates in a large steel plant from 1905 to 1917. The experience of this plant is of particular interest, since complete accident records were available for it as early as 1905 and as late as 1917. There is a pronounced, although not entirely regular, decline in both the frequency and severity of accidents during the course of the period.

SAFETY EXPERIENCE OF A GROUP OF PLANTS, 1907 TO 1917.

The experience of the plant cited above is not entirely typical of the industry, as safety activities in it were developed unusually early and have been applied with more than usual thoroughness. But, on the whole, its experience is not very dissimilar from the majority of other plants. This is brought out in Table 2, which gives the accident rates for a large group of plants from 1907 to 1917. As the plants included constitute about 25 per cent of the entire iron and steel industry of the country, deductions may be made as fairly representative of the industry.

The table gives both accident frequency rates and accident severity rates. The accident frequency rates are expressed in terms of so many cases of accident per 1000 300-day workers, and entirely disregard the character of the resulting injury; all accidents are counted as of equal value. The severity rate takes into account the resulting seriousness of the accident; accidents are expressed in terms of the number of workdays lost (according to a scale later explained) and the average number of days lost per worker is used as the unit of measurement. The severity rate is thus a much truer measure of accident hazard than is the frequency rate.[1]

[1] For a full discussion of severity rating see Chapter I, Part II.

TABLE 2.—ACCIDENT RATES IN THE IRON AND STEEL INDUSTRY, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	27,632	2.2	3.8	236.3	242.4	19.9	4.0	3.2	27.1
1910	79,486	1.2	5.2	177.7	184.1	11.0	3.9	2.2	17.1
1911	80,029	.9	5.3	167.6	173.8	7.8	3.8	1.9	13.5
1912	93,666	.9	5.1	186.3	192.3	8.2	3.4	2.2	13.8
1913	91,107	1.1	4.5	150.3	155.9	10.3	2.9	1.9	15.1
1914	77,474	.8	3.4	108.5	112.7	6.9	2.5	1.5	10.9
1915	79,065	.7	4.2	106.5	111.4	6.4	2.6	1.3	10.3
1916	108,994	.7	4.9	95.1	100.8	6.3	3.1	1.3	10.7
1917	86,847	.8	3.2	77.0	81.0	7.0	2.0	1.2	10.2

Examination of Table 2 shows the same steady, although irregular, decline in accident rates during the course of the period covered as was noted in the case of the plant earlier referred to. The frequency rate declined from 242.4 cases per 1,000 300-day workers in 1907 to 81.0 cases in 1916, a decrease of 67 per cent. Between the same years the severity rate declined from 27.1 days lost per 300-day worker to 10.2 days, a decrease of 62 per cent. The high points of accident severity occurred in the years 1907 (27.1 days), 1910 (17.1 days), 1913 (15.1 days), and 1916 (10.7 days).

RESULTS OF THE SAFETY MOVEMENT IN VARIOUS DEPARTMENTS.

In tracing more in detail the accident history of the iron and steel industry, it is necessary to consider separately the more important departments. The steel industry is made up of several divisions or departments—blast furnaces, Bessemer, rolling mills, etc., each with its distinctive activities and its distinctive hazards. Safety work has been developed somewhat differently, and has met with differing degrees of success, in the different departments. To combine them all into one unit is very often to balance the good experience of one department with the bad experience of another. Or again, in such a combination one or more large departments may, by the fact of size, dominate the showing of the industry as a whole. This latter condition actually occurs in the table just presented, as will appear in the following presentation of accident rates by individual departments. Here, as in the preceding table, all accident rates are expressed in two forms: Frequency rates, i. e., the number of accident cases per 1,000 300-day workers; and severity rates, that is, the average number of working days lost per 300-day worker.

BLAST FURNACES.

On the whole, the blast furnace department exceeds all other departments in the severity of its accidents. This is due, in considerable measure, to the hazard of asphyxiating gas.

Table 3 shows in detail the course of accidents in the blast furnace department from 1907 to 1917.

TABLE 3.—ACCIDENT RATES IN BLAST FURNACES, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	961	5.8	7.0	291.2	304.0	51.7	6.9	5.5	64.1
1910	3,891	2.8	3.1	243.1	249.0	25.4	2.3	2.8	30.5
1911	3,921	1.8	4.6	201.9	208.2	16.1	8.0	2.3	26.4
1912	5,034	3.0	6.0	233.2	242.2	26.8	6.4	2.8	36.0
1913	5,641	2.7	4.8	166.1	173.6	24.0	5.1	2.3	31.4
1914	4,797	2.3	5.0	104.6	111.9	20.6	3.8	1.7	26.1
1915	4,835	2.5	3.9	97.0	103.4	22.3	2.7	1.3	26.3
1916	6,694	1.3	6.0	95.5	102.8	12.1	4.9	1.5	18.5
1917	5,194	3.5	2.9	70.0	76.4	31.4	1.9	1.1	34.4

The decline in the accident rates between 1907 and 1916 is very striking. Thus, total frequency rates declined from 304.0 to 102.8 cases, a decrease of 66 per cent; and severity rates declined from 64.1 to 18.5 days, a decrease of 71 per cent. In 1917 the frequency rate continued to decline, but the severity rate showed a marked increase, due to the occurrence of several fatal accidents.

The high years, as regards severity rates, are 1907 (64.1 days), 1910 (30.5 days), 1912 (36.0 days), and 1917 (34.4 days). These do not exactly coincide with the high years for the industry as a whole.

BESSEMER AND OPEN HEARTH STEEL WORKS.

The Bessemer and open hearth steel works are so different in their operations that they should be studied separately. But, with the present group of material, it was impossible to make a satisfactory separation, and therefore the experiences of these two departments are presented in combined form in Table 4.

TABLE 4.—ACCIDENT RATES IN STEEL WORKS, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	1,176	3.4	6.0	276.4	285.7	30.6	13.7	5.5	49.8
1910	4,246	4.2	6.1	223.0	233.4	38.2	6.5	3.2	47.9
1911	4,293	1.6	5.4	174.1	181.0	14.7	4.4	2.3	21.4
1912	5,546	2.2	7.2	229.2	238.5	19.5	4.7	3.1	27.3
1913	5,207	1.5	6.2	179.2	186.9	13.8	3.7	3.1	20.6
1914	3,073	2.3	3.9	131.5	137.7	20.5	3.3	2.1	25.9
1915	4,713	1.3	8.1	100.6	109.9	11.5	4.6	1.6	17.7
1916	6,556	1.5	7.5	107.2	116.2	13.7	6.3	1.8	21.8
1917	6,347	1.6	3.6	71.0	76.2	14.2	1.9	1.4	17.5

The high years, as regards severity rates, run as follows: 1907 (49.8 days), 1910 (47.9 days), 1912 (27.3 days), 1914 (25.9 days), 1916 (21.8 days). Attention has been called to the fact that the year 1913 does not correspond exactly to the period of highest industrial stress but that a year including portions of 1912 and 1913 is the high year. As a result the high rate in that period sometimes appears in one calendar year and sometimes in the other.

The descending series is therefore in essential accord with that of the entire industry. One exception of a character likely to occur from time to time may be noted. The year 1914, though one of low activity, has a high severity rate, 25.9 days. This is due to unusual fatality in that year such as may happen in a highly hazardous department under the most favorable circumstances.

SHEET MILLS.

It would add greatly to the interest of this presentation of data for the sheet mills if the characteristic occupation, the hot-mill crew, could be isolated for separate study. At present such isolation is impossible, and the mills have to be accepted as units.

Table 5 shows the accident rates in sheet mills from 1907 to 1917. It will be noted that the rates for 1907 are lower than those for 1910. This is exceptional, and may be due to the rather small size of the group in 1907.

TABLE 5.—ACCIDENT RATES IN SHEET MILLS, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,211	0.9	3.6	129.8	134.3	8.1	3.8	1.2	13.1
1910	15,485	1.5	2.5	199.7	203.6	13.4	1.7	1.7	16.8
1911	14,461	.4	3.0	195.6	199.0	3.1	2.5	1.8	7.4
1912	19,129	.6	2.9	225.8	229.3	5.2	1.8	2.3	9.3
1913	15,780	.9	1.6	176.1	178.5	8.0	.7	2.0	10.7
1914	12,963	.2	2.4	143.9	146.4	1.4	1.5	1.7	4.6
1915	16,266	.4	1.4	116.9	118.7	3.9	.6	1.5	6.0
1916	21,640	.5	2.4	111.7	114.5	4.2	1.0	1.6	6.8
1917	23,916	.4	1.4	100.3	102.1	3.4	1.0	1.5	5.9

TUBE MILLS.

Table 6 shows the accident rates for tube mills from 1907 to 1917. These mills show a constant increase in employment from 1910 to 1913; employment then drops off in 1914, to rise again through 1915 to its maximum in 1917.

TABLE 6.—ACCIDENT RATES IN TUBE MILLS, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,007	0.5	2.1	286.4	289.0	4.5	1.5	4.6	10.6
1910	6,038	.2	1.5	161.2	162.8	1.5	.3	1.7	3.5
1911	7,678	.1	4.6	145.9	150.6	1.2	2.7	1.5	5.4
1912	8,694	.7	3.8	150.2	154.7	6.2	1.9	1.8	9.9
1913	9,619	.6	4.2	79.0	83.8	5.6	2.0	1.2	8.8
1914	6,459	.6	2.8	30.0	33.5	5.6	1.5	.9	8.0
1915	7,109	.3	3.0	25.6	28.8	2.5	1.5	.6	4.6
1916	11,355	.2	2.3	37.4	39.9	1.6	.8	.8	3.2
1917	11,657	.7	2.2	27.9	30.8	6.2	1.1	.5	7.8

A most significant fact about this table is that between 1910 and 1912 severity rates were going up rapidly while frequency rates were declining. Evidently the manufacturers of tubes were misled for a time by their success in reducing frequency rates and did not pay sufficient attention to the more serious kinds of accidents. Later, realizing the true conditions, a somewhat different kind of safety campaign was carried on, and thereafter both frequency and severity rates steadily declined to 1916.

In 1917 the severity rate again rises, but does not reach the level of the previous peak. This rise was due to a high fatality rate. It has not been possible to make any inquiry regarding the factors which may have been responsible for this increase.

UNCLASSIFIED ROLLING MILLS.

The accident rates for this group of mills could not be obtained as early as 1907. Those for 1910 to 1917 are presented in table 7. Here the decline in rates is somewhat more vacillating than in many other departments, but there is the same evidence of steady progress extending into the war period.

TABLE 7.—ACCIDENT RATES IN UNCLASSIFIED ROLLING MILLS, 1910 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	5,615	2.1	7.7	267.7	277.5	19.2	4.9	3.2	27.3
1911	8,205	1.5	6.2	156.3	163.9	13.2	4.5	2.2	19.9
1912	10,448	.8	4.7	189.5	195.0	6.9	3.4	2.5	12.8
1913	10,673	.9	5.1	138.6	144.6	8.4	2.8	2.1	13.3
1914	5,992	.7	4.8	92.4	98.0	6.0	3.2	1.3	10.5
1915	9,111	1.2	5.2	95.9	102.3	10.9	3.5	.8	15.2
1916	13,027	.4	5.8	86.9	90.1	3.5	3.8	1.4	8.7
1917	11,505	.8	4.1	58.4	63.3	7.0	2.6	.9	10.5

WIRE DRAWING DEPARTMENT.

In the wire drawing department, as in the unclassified rolling mills, no satisfactory record is available of accident rates for the year 1907, but it is known that the rates at that time were materially higher than in any of the years from 1910 to 1917. Table 8 gives the rates for the latter period.

TABLE 8.—ACCIDENT RATES IN WIRE DRAWING, 1910 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	8,374	0.5	7.9	239.2	247.6	4.3	5.9	2.2	12.4
1911	8,186	.2	8.9	205.4	214.5	2.2	5.9	2.0	10.1
1912	8,278	.2	8.9	243.1	252.2	2.2	6.6	2.3	11.1
1913	7,604	.5	5.8	239.7	246.1	4.7	3.6	2.3	10.6
1914	6,306	.2	5.6	168.3	174.0	1.4	4.3	1.8	7.5
1915	7,859	.1	8.0	230.8	239.0	1.1	6.0	2.3	9.4
1916	9,552	.4	10.9	184.7	196.0	3.8	7.4	1.9	13.1
1917	9,528	.2	5.1	121.3	126.6	.9	2.9	1.6	5.4

Inspection of the table will at once disclose that this department was not able to prevent a considerable increase of its severity rate in the year 1916 when the war stress reached its maximum, but in 1917 the severity rate shows a very sharp decline. The increase in 1916 was probably due to the fact that the rate of expansion was very rapid in this department and that the pressure for product was very great. This would in two ways tend to advance the rates: (1) A relatively larger number of inexperienced men would be introduced into the working force; (2) the speed of production would undoubtedly be sufficiently increased to add some impetus to the tendency.

Also it may well have been the case that the decline in frequency which occurred in 1916 diverted attention from the increasing severity of the accidents that did occur.

FABRICATING SHOPS.

The accident rates in the fabricating shops, as presented in the next table, show that these shops have very markedly improved their condition over what it was in 1907, but that there has been no improvement in recent years. In fact, with the increased stress of the war period, the accident rates rise to a higher level in 1916 than in any year since 1907.

TABLE 9.—ACCIDENT RATES IN FABRICATING SHOPS, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,081	2.9	5.8	274.4	283.1	25.9	6.9	2.5	35.3
1910	3,936	1.0	3.8	185.8	190.6	9.2	1.7	1.8	12.7
1911	4,007	.3	7.0	164.7	172.0	2.2	3.5	2.0	7.7
1912	5,023	1.0	6.4	190.3	197.7	9.0	3.2	2.6	14.8
1913	5,313	.9	6.6	187.5	195.0	8.5	5.6	2.3	16.4
1914	3,811	.8	3.4	111.8	116.0	7.1	1.9	1.5	10.5
1915	2,994	1.0	4.3	122.2	127.6	9.0	1.9	2.1	13.0
1916	4,465	1.6	5.4	140.0	146.9	14.1	1.7	2.6	18.4
1917	5,020	.8	5.2	105.7	110.7	7.2	3.8	1.6	12.6

MECHANICAL DEPARTMENT.

The accident rates in the mechanical department from 1907 to 1917 are as follows:

TABLE 10.—ACCIDENT RATES IN MECHANICAL DEPARTMENT, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,542	0.8	1.6	249.7	252.1	7.1	1.3	3.5	11.9
1910	7,871	.9	4.1	145.9	150.8	8.0	2.9	1.4	12.3
1911	6,712	.7	5.2	130.8	136.8	6.7	3.3	1.5	11.5
1912	7,122	.7	5.3	143.6	149.7	6.3	4.0	1.7	12.0
1913	7,474	.9	4.4	131.3	136.6	8.4	3.5	1.7	13.6
1914	5,125	.6	3.7	99.5	103.8	5.3	2.6	1.2	9.1
1915	5,693	.2	4.7	84.8	89.8	1.6	2.8	1.1	5.5
1916	9,185	1.0	5.4	75.5	81.9	8.8	4.2	1.0	14.0
1917	8,892	.1	4.2	57.9	60.2	1.0	2.3	.8	4.1

This department exhibits the most striking opposition between frequency rates and severity rates that has anywhere come under notice. Thus the ascending series of severity rates for the high years beginning with 1907 is as follows: 11.9 days, 12.3 days, 13.6 days, 14.0 days; and the corresponding descending series of frequency rates is 252.1, 150.8, 136.6, and 81.9. While the frequency rate declines 68 per cent the severity rate actually rises 18 per cent.

There can be no doubt that those responsible for conditions in these departments were in a measure misled by the declining frequency rate and did not give adequate attention to those causes which give rise to more serious injury. In the years prior to 1917 not only was there no reduction in serious injury, but serious injury was actually increasing. In 1917 there was a very important decline in the severity rate, due to a remarkably small number of fatalities.

That the war period materially influenced the severity rate of this department is very evident from the fact that 1916 shows a rate (14.0 days) more than double that (5.5 days) of 1915. In a measure this result was to be expected. In a period of such rapid expansion the amount of extraordinary repair work which the mechanics must do under unfavorable conditions increases very greatly. Overtime and night work greatly increase. All this tends strongly to the increase of serious injury.

It may be said with serious emphasis that the remedy for this condition does not lie largely with the men. It is a question of better machines. The machines in use were probably not equal to the task imposed by such a time. The evidence for this is the fact that a multitude of machines which stood up under ordinary stresses are going to the scrap heap to be replaced by others stronger, better designed, more efficient, safer.

YARD DEPARTMENT.

The internal transportation problems of an iron and steel plant afford many opportunities for severe injury. The result has been to place the yard department among the seriously hazardous departments. It may, therefore, be regarded as definitely satisfactory to find that the severity rate in the yard department in the war-year 1916 and 1917 was held down to a lower point than in any of the preceding high years.

The details by years are shown in Table 11. The year 1916 can hardly be compared with 1915, since that year is doubtless rather abnormal in its entire escape from fatal accident.

TABLE 11.—ACCIDENT RATES IN YARDS, 1907 TO 1917.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,618	1.9	3.8	194.4	200.1	17.2	5.9	3.2	26.3
1910	5,111	2.0	3.3	106.8	112.1	17.6	2.5	1.2	21.3
1911	3,726	.3	6.2	160.0	166.4	2.4	4.6	2.0	9.0
1912	4,102	1.7	7.8	201.9	211.4	15.4	5.3	2.3	23.0
1913	4,275	2.6	4.4	162.8	169.8	23.2	1.9	1.9	27.0
1914	2,900	.7	4.1	135.2	140.0	6.2	4.7	1.8	12.7
1915	3,689	....	4.9	111.7	116.6	....	4.1	1.3	5.4
1916	6,302	1.3	7.9	110.4	119.6	11.4	5.4	1.5	18.3
1917	4,738	1.7	4.6	65.6	71.9	15.2	4.2	1.0	20.4

SUMMARY OF DEPARTMENTAL EXPERIENCE.

The above survey of accident rates in the several departments of the iron and steel industry discloses:

(1) That six of the nine important departments—blast furnaces, steel works, sheet mills, tube mills, other rolling mills, and yards—

show essentially the same downward movement in both the frequency and severity of accidents since 1907. Broadly speaking, the movement is marked by four points of high industrial activity with accompanying high points or "peaks" in accident rates. The four peaks, occurring usually in 1907, 1910, 1913, and 1916, form a descending series in which, as a rule, the rate of each succeeding peak year is lower than that of the one next earlier.

(2) That three departments show in 1916 (a year of intense war activity) accident rates which exceed those of the next preceding high year, but that each of the three shows a reduction in 1917 over 1916.

(3) That the six departments in the first-mentioned group are of such size and importance that they dominate the showing of the combined departments, as brought together in Table 2, and give to it, as a whole, the same series of descending rates as that found in the six departments.

Finally, it may be noted that the accident showing of a given department at any fixed time is the resultant of three determining influences. These are: (1) The intrinsic hazard of the department. This gives, for example, a higher severity rate to blast furnaces than to tube mills. (2) Changing industrial conditions. When industry revives from a period of stagnation, there usually occurs an influx of new and inexperienced men, and from this fact rising accident rates are to be expected. (3) Efforts at accident control. Whenever increased business activity occurs, with its tendency toward increased accident rates, both instruction in safe and effective methods of work and the efforts to make working conditions safe by adequate "engineering revision" should be pushed with the utmost energy.

SPECIAL STUDY OF ACCIDENTS DURING THE WAR PERIOD.

The preceding section dealt with the general trend of accident rates in the iron and steel industry during the period 1907 to 1917. The results of a special study of accidents in the period immediately antecedent to the War and extending to the end of 1917 will now be presented.

The material available covers not less than 50 per cent of the industry and the plants are so distributed both industrially and geographically that they may be accepted as entirely representative of the industry.

The value of the material, however, is diminished by the fact that it was not in sufficiently complete shape to permit of the compilation of severity rates. This omission, however, is in part supplied by the use of fatality rates, and in any case the period covered is so important that even incomplete information is of great value.

Table 12 presents the fatality and general frequency rates for this group of plants from 1913 to 1917. The data are carried back to

1913 for the reason that a fair comparison is not possible unless periods of similar industrial stress are brought into relation. It will be noted that the rates as given in the table are shown by overlapping years ending with March, June, September, and December. This method of showing accident rates by years ending with specified months gives a more complete view of the change occurring than is possible by any presentation by individual months or by calendar years.

TABLE 12.—FREQUENCY RATES OF FATALITIES AND OF ALL ACCIDENTS IN THE IRON AND STEEL INDUSTRY, 1913 TO 1917.

Year ending with—	Number of 300-day workers.	Fatalities per 1,000 300-day workers.	Total accidents per 1,000 300-day workers.
December, 1913	153,098	1.34	181.0
March, 1914	146,522	1.29	168.4
June, 1914	137,816	1.09	154.7
September, 1914	128,023	.81	138.9
December, 1914	117,214	.70	130.4
March, 1915	111,881	.63	118.0
June, 1915	111,794	.65	114.0
September, 1915	117,933	.85	118.6
December, 1915	133,627	.86	124.5
March, 1916	148,221	.96	131.8
June, 1916	160,819	1.09	134.1
September, 1916	168,790	1.02	135.5
December, 1916	175,013	1.11	133.2
March, 1917	178,937	1.15	128.5
June, 1917	182,587	1.08	121.6
September, 1917	185,445	1.11	110.9
December, 1917	186,357	.98	103.4

On examination of the table, it will be noted that employment was declining from 1913 to the year ending with June, 1915, and that coincident with this decreasing employment went a still more rapid decline of both the fatality rate and of the total frequency rate. This is most readily observed in Charts A and B, which offer a graphic presentation of the data of this table.

When the turn in industrial activity came, about the year ending with June, 1915, fatality rates increased for a time more rapidly than employment. The general frequency rate also increased, but less rapidly than employment. Finally, at about the middle of 1916 the total rate began to decline and later the fatality rate also declined.

That this decline in accident rates began while employment was still increasing is of the utmost significance. All existing data on the subject show that accident rates always tend to rise when recovery from industrial depression calls for the introduction of new men.[1] Unless special efforts at instruction and accident prevention are undertaken at the same time, this rising accident rate is likely to continue as long as the increasing employment continues. The fact, that, in the case now under consideration, accident rates began to

[1] See Ch. VII, p. 131.

decline prior to the culmination of employment can have no other explanation than that the countervailing influences of the safety movement proved measurably successful, in spite of the unprecedented stress of war work.

ACCIDENT RATES, BY PRODUCTS.

In the above statement the plants of the iron and steel industry covered are considered as a unit. In that procedure lurks the possibility that some portion of the industry may have an entirely different experience. To meet this possibility an analysis of the general experience set forth above has been made by products and causes.

Table 13 isolates the fatality rates for the producers of certain products. Four of the six groups have almost the same course in their fatality rates as that shown by the industry as a whole. The groups thus conforming to the industry type are sheets, miscellaneous steel products A, miscellaneous steel products B, and tubes. The wire products group follows a similar course, but its high point occurs rather later than the others. The group of fabricated products maintains its rising rates longer than any other group.

TABLE 13.—FATALITY RATES IN PLANTS PRODUCING SPECIFIED PRODUCTS, 1913 TO 1917.

Year ending with—	Fatality rates per 1,000 300-day workers in plants producing—					
	Fabricated products.	Sheets.	Wire products.	Miscellaneous steel products (group A).	Miscellaneous steel products (group B).	Tubes.
December, 1913	0.62	0.70	0.86	1.84	1.50	0.58
March, 1914	.64	.78	.61	1.86	1.48	.61
June, 1914	.57	.59	.31	1.77	1.22	.50
September, 1914	.49	.44	.24	1.30	.83	.45
December, 1914	.49	.20	.04	1.21	.87	.45
March, 1915	.56	.27	.09	.89	.95	.43
June, 1915	.60	.38	.27	.67	1.34	.38
September, 1915	1.05	.43	.47	.82	1.44	.57
December, 1915	1.01	.48	.48	.88	1.42	.55
March, 1916	1.07	.58	.71	1.11	1.12	.53
June, 1916	1.09	.64	.76	1.42	1.22	.48
September, 1916	1.01	.60	.68	1.45	1.11	.35
December, 1916	1.17	.65	.83	1.63	1.19	.33
March, 1917	1.11	.60	.89	1.63	1.33	.33
June, 1917	1.29	.51	.76	1.44	1.33	.40
September, 1917	1.17	.61	.78	1.57	1.52	.36
December, 1917	1.09	.42	.64	1.35	1.44	.41

It is clear from this table that substantially similar influences were at work in all the divisions of the industry represented. This conclusion is strongly supported by consideration of Table 14 in which are given the total frequency rates for the six groups of plants, and for a considerable group of industrial railways. The sheet mills alone vary from type, these mills maintaining a declining frequency until near the end of the period.

TABLE 14.—TREND OF ACCIDENT FREQUENCY RATES, 1913 TO 1917, IN PLANTS PRODUCING SPECIFIED PRODUCTS AND ON INDUSTRIAL RAILWAYS.

Year ending with—	Plants producing specified products.							Industrial railways.
	Fabricated products.	Sheets.	Wire products.	Tubes.	Miscellaneous steel products (group A).	Miscellaneous steel products (group B).	Total.	
	Accident frequency rates (per 1,000 300-day workers).							
December, 1913	300.9	184.9	177.9	81.5	212.8	123.8	181.0	....
January, 1914	288.7	179.7	169.6	76.9	210.4	118.3	176.0	....
February, 1914	276.6	176.6	164.2	72.1	208.0	115.6	171.9	....
March, 1914	263.6	173.0	159.4	67.4	205.8	116.7	168.4	....
April, 1914	264.5	169.7	159.3	63.6	201.9	106.4	164.0	....
May, 1914	236.0	164.9	157.6	60.4	196.6	102.7	159.5	....
June, 1914	226.6	161.0	152.9	57.2	188.3	100.0	154.7	....
July, 1914	215.6	157.3	148.7	51.9	181.7	91.1	149.7	....
August, 1914	200.0	148.3	146.6	48.1	173.3	92.9	143.7	....
September, 1914	189.5	142.1	143.9	45.0	167.1	88.1	138.9	....
October, 1914	184.9	141.7	140.4	41.8	160.6	85.2	134.9	....
November, 1914	178.5	141.8	140.2	39.5	155.4	82.1	132.1	....
December, 1914	176.9	141.5	138.6	37.5	152.0	82.7	130.4	....
January, 1915	170.9	140.7	136.1	35.5	145.3	80.8	127.1	....
February, 1915	165.3	139.9	136.1	33.4	136.1	83.1	123.1	....
March, 1915	164.9	135.4	131.0	30.7	130.4	81.3	118.0	....
April, 1915	159.9	134.2	129.5	27.9	126.8	79.1	117.2	....
May, 1915	159.9	128.9	129.9	27.1	126.2	75.2	114.9	....
June, 1915	153.6	125.3	132.9	26.1	128.1	69.9	114.0	....
July, 1915	147.9	120.0	135.4	26.3	130.5	65.4	112.8	....
August, 1915	152.6	117.1	138.5	28.8	134.9	60.3	114.3	....
September, 1915	156.7	115.5	149.8	30.0	140.3	61.3	118.6	....
October, 1915	155.5	114.1	154.2	31.4	145.5	62.9	120.8	....
November, 1915	159.1	114.3	154.4	32.2	151.2	66.4	122.8	....
December, 1915	160.4	111.8	157.2	32.3	155.8	69.0	124.5	106.4
January, 1916	160.3	110.9	157.9	33.4	164.1	73.5	127.3	110.3
February, 1916	159.9	111.0	158.4	34.0	172.5	76.1	129.8	114.1
March, 1916	158.3	111.8	159.9	34.9	179.3	75.9	131.8	117.5
April, 1916	158.2	111.2	158.8	36.2	183.6	76.1	132.7	121.9
May, 1916	161.8	110.5	158.8	36.5	186.1	78.3	133.8	126.1
June, 1916	163.6	109.4	156.5	36.7	188.2	81.0	134.1	131.5
July, 1916	162.3	109.7	154.5	37.2	193.0	82.5	135.4	138.0
August, 1916	164.1	108.4	153.2	37.0	197.9	85.6	136.3	143.6
September, 1916	160.4	107.2	149.2	36.7	200.1	86.2	135.5	145.9
October, 1916	160.3	105.6	146.7	36.6	202.8	86.9	135.1	151.2
November, 1916	157.2	104.3	147.9	36.2	203.6	86.1	134.8	153.4
December, 1916	156.2	102.0	144.5	37.1	202.7	84.6	133.2	153.9
January, 1917	158.7	102.3	141.4	36.1	201.5	82.1	131.7	155.7
February, 1917	159.3	100.9	139.1	36.2	199.6	79.7	130.1	157.5
March, 1917	161.9	99.4	136.6	35.6	196.4	78.5	128.5	157.1
April, 1917	162.8	96.8	135.1	34.8	193.9	77.4	126.7	156.2
May, 1917	161.9	96.5	132.6	34.6	190.9	76.0	124.7	157.8
June, 1917	159.8	97.0	127.7	34.6	186.7	73.4	121.6	157.3
July, 1917	159.2	100.8	123.0	33.2	180.5	70.6	118.2	153.7
August, 1917	158.2	104.6	118.6	32.2	173.7	67.5	115.0	151.0
September, 1917	158.1	102.5	111.5	31.7	167.4	65.4	110.9	150.5
October, 1917	157.6	102.7	108.1	31.2	162.6	63.1	108.6	147.6
November, 1917	159.5	101.5	101.7	30.8	158.8	61.9	105.9	146.6
December, 1917	154.0	101.7	97.5	30.5	154.0	61.4	103.4	146.9
	Number of 300-day workers.							
June, 1914	8,817	16,841	25,575	19,944	41,744	18,922	137,816	....
June, 1915	6,706	15,759	22,434	13,329	35,670	13,477	111,794	[1] 12,240
June, 1916	8,276	21,906	31,377	21,031	45,673	23,000	160,819	[1] 16,690
June, 1917	10,110	25,504	32,928	24,880	49,893	27,046	182,587	[1] 17,840

[1] Year ending with December.

Chart C presents the data of this table in graphic form. Inspection of the chart will at once disclose the downward trend of employment to some point in 1915, after which time it rises to the limit of the chart. Accident frequency declines in all groups to about the same point, then rises, except in sheet mills, into 1916 and finally declines, although employment continues to rise. As before remarked, this substantial uniformity in the elements of the industry is highly significant of some underlying cause common to them all.

ACCIDENTS IN CONNECTION WITH INDUSTRIAL RAILWAYS.

The industrial railways deserve a word of special comment. These are railways which serve primarily the purposes of transportation for industrial plants and do little or nothing in the way of carrying for the general public. There has been a distinct apprehension on the part of some interested in and familiar with railways that the very great stress under which they were operating would be accompanied by seriously increasing accident rates, and there is good ground for this apprehension. Some railways have felt that they were justified by existing conditions in giving up their special efforts in the direction of safety.

This is a most shortsighted policy, especially at a time when above all others the most strenuous effort should be made. The experience of the steel mills is ample evidence that, imperfect as the efforts doubtless were, a definite increase rather than diminution of effort has saved them from what would otherwise have been inevitable, namely, an increase in accidents running above the former high mark.

The railway is a difficult proposition from the standpoint of severe injury. Some railway occupations have a hazard exceeded, if at all, only by the erection of structural steel. On this account it is of much interest to follow the experience of this group of roads as shown in Table 14. On examining the accident rates as there listed it will appear that the rise, which began no doubt about the middle of 1915, as in the other departments, was of longer continuance. The turn came in manufacturing about the middle of 1916. It did not come for nearly a year later in the railways. The high point is the year ending May, 1917. Since it was not possible to follow the railway-accident rates back to the preceding period of high industrial stress, in 1913, it can not be determined whether this high year exceeds the earlier one.

From the high point there is a definite and constant though not very considerable decline. Whether or not the safety work done on these roads is comparable with that done in the manufacturing groups it is impossible to state. It is known, however, that during the war period there has been more rather than less attention to safety matters. It may therefore be fairly concluded that railways do not form an exception. Patient effort will here as elsewhere hold in check the tendency to rising accident rates which regularly tend to accompany industrial revival.

TREND OF ACCIDENT CAUSES, 1913 TO 1917.

Table 15 gives the frequency rates for the principal groups of accident causes in the iron and steel industry from 1913 to the end of 1917.

TABLE 15.—ACCIDENT FREQUENCY RATES FOR THE PRINCIPAL CAUSE GROUPS IN THE IRON AND STEEL INDUSTRY, 1913 TO 1917.

[Frequency rate means the number of accidents per 1,000 300-day workers.]

Year ending with—	Hot substances.	Cranes and hoists.	Falls of workers.	Falling objects.	Operation of machines.	Handling objects and tools.	Flying objects.	Power vehicles.
March, 1914	16.8	10.3	14.2	34.3	12.6	55.5	11.5	6.4
April, 1914	16.3	10.2	14.2	33.1	12.4	54.2	11.1	6.4
May, 1914	15.7	9.6	14.1	31.6	12.1	52.9	10.6	6.2
June, 1914	15.0	9.4	13.7	30.6	11.7	51.5	10.1	5.9
July, 1914	14.4	9.0	13.1	28.8	11.0	48.7	9.3	5.5
August, 1914	13.6	8.7	12.8	27.1	10.8	47.2	9.0	5.4
September, 1914	12.9	8.4	12.7	25.7	10.4	46.6	8.4	5.1
October, 1914	12.5	7.9	12.6	24.9	10.1	45.6	8.1	4.7
November, 1914	12.0	7.6	12.5	24.3	10.1	44.8	8.0	4.6
December, 1914	11.8	7.6	12.5	23.7	9.9	44.5	7.8	4.6
January, 1915	11.5	7.5	11.8	23.3	9.3	43.9	7.6	4.5
February, 1915	11.2	7.3	11.1	22.2	9.0	43.2	7.2	4.6
March, 1915	10.9	6.9	11.0	21.4	8.9	42.4	7.1	4.5
April, 1915	10.5	6.7	10.7	20.7	8.3	42.3	6.8	4.5
May, 1915	10.3	6.8	10.4	20.4	8.1	41.8	6.7	4.3
June, 1915	10.2	6.6	10.4	20.8	8.2	41.6	6.5	4.3
July, 1915	10.2	6.4	10.3	20.5	7.9	41.5	6.4	4.3
August, 1915	10.5	6.5	10.4	21.2	7.8	41.9	6.4	4.3
September, 1915	10.8	6.8	10.6	22.3	8.1	43.5	6.8	4.4
October, 1915	11.0	7.0	10.7	22.4	8.0	44.7	7.1	4.6
November, 1915	11.1	7.3	10.7	23.2	8.1	45.1	7.2	4.6
December, 1915	11.5	7.4	10.8	24.1	8.2	45.6	7.4	4.8
January, 1916	11.7	7.7	11.1	24.3	8.5	45.8	7.5	4.9
February, 1916	11.9	7.7	11.1	26.3	8.6	46.7	7.4	5.1
March, 1916	12.1	7.8	11.4	26.9	8.7	46.8	7.4	5.3
April, 1916	12.4	7.8	11.2	27.1	8.8	47.1	7.4	5.3
May, 1916	12.8	7.8	11.3	27.7	8.8	47.2	7.5	5.3
June, 1916	13.1	8.0	11.2	27.6	8.7	47.1	7.9	5.2
July, 1916	13.4	8.1	11.2	27.8	8.7	47.6	7.9	5.2
August, 1916	13.6	8.4	11.2	28.0	8.7	47.7	8.0	5.3
September, 1916	13.5	8.4	11.1	27.8	8.7	47.2	7.9	5.4
October, 1916	13.6	8.4	11.3	28.0	8.7	46.5	7.8	5.4
November, 1916	13.5	8.3	11.2	27.6	8.6	46.8	7.8	5.4
December, 1916	13.6	8.4	11.2	27.1	8.6	46.1	7.7	5.1
January, 1917	13.4	8.4	11.1	26.4	8.3	45.8	7.6	5.1
February, 1917	13.4	8.5	11.1	25.7	8.3	45.1	7.7	5.0
March, 1917	13.3	8.7	11.0	25.0	8.1	44.5	7.8	4.8
April, 1917	13.0	8.7	10.9	24.8	7.9	43.7	7.8	4.7
May, 1917	12.9	8.7	10.9	24.2	7.8	42.7	7.6	4.7
June, 1917	12.4	8.6	10.8	23.5	7.6	42.0	7.1	4.6
July, 1917	11.8	8.5	10.6	22.9	7.4	41.1	6.9	4.5
August, 1917	11.6	8.2	10.1	21.9	7.2	40.3	6.7	4.3
September, 1917	11.2	8.0	10.1	21.0	6.8	38.7	6.4	4.3
October, 1917	11.1	8.0	9.9	20.5	6.6	37.8	6.3	4.3
November, 1917	10.9	8.1	9.8	20.1	6.6	36.1	6.1	4.2
December, 1917	10.5	7.8	9.7	19.4	6.3	35.3	6.2	4.3

Examination of the table shows that in each cause group there is a downward trend during the depressed year of 1914, and extending into 1915, approximately to the middle of the year. From that point there is an upward swing for about one year. The highest point reached in this upward swing is in no case as high as that reached in the year ending with March, 1914, which includes nine months of the calendar year 1913 and three months of 1914. From this point near the middle of 1916 there is a decline in all causes except one—cranes and hoists.

ILLUSTRATIVE CHARTS.

The three following charts illustrate graphically the data presented in Tables 12, 13, and 14.

Chart A shows the relation of employment to death frequency; chart B shows employment and the total accident rate; chart C gives the course of the total accident rates in the plants producing different products.

These charts are plotted by a method which projects the percentage of difference, from period to period, rather than the amount. On the ordinary chart the distance from 100 to 200 is one hundred times as great as that from 1 to 2. On a percentage chart, such as here used, the distances are identical. Stated in general terms, this means that on a chart plotted on the percentage basis a given vertical distance in any part of the chart always represents the same percentage of difference.[1]

[1] Renewed interest in this method of charting has resulted from the appearance in the publications of the American Statistical Association, June, 1917, of an article by Prof. Irving Fisher, of Yale University.

CHART A.—TREND OF EMPLOYMENT AND FATALITY RATES, YEAR ENDING WITH SPECIFIED MONTH.

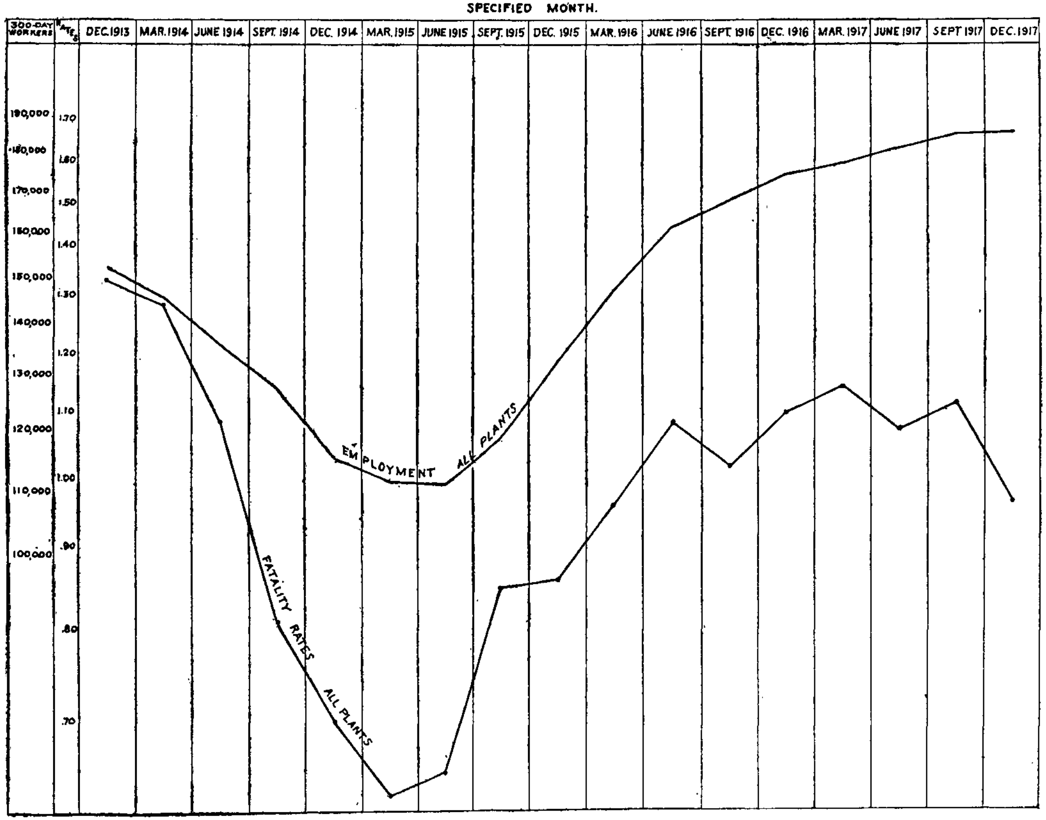


CHART B.—TREND OF EMPLOYMENT AND ACCIDENT FREQUENCY, YEAR ENDING WITH SPECIFIED MONTH.

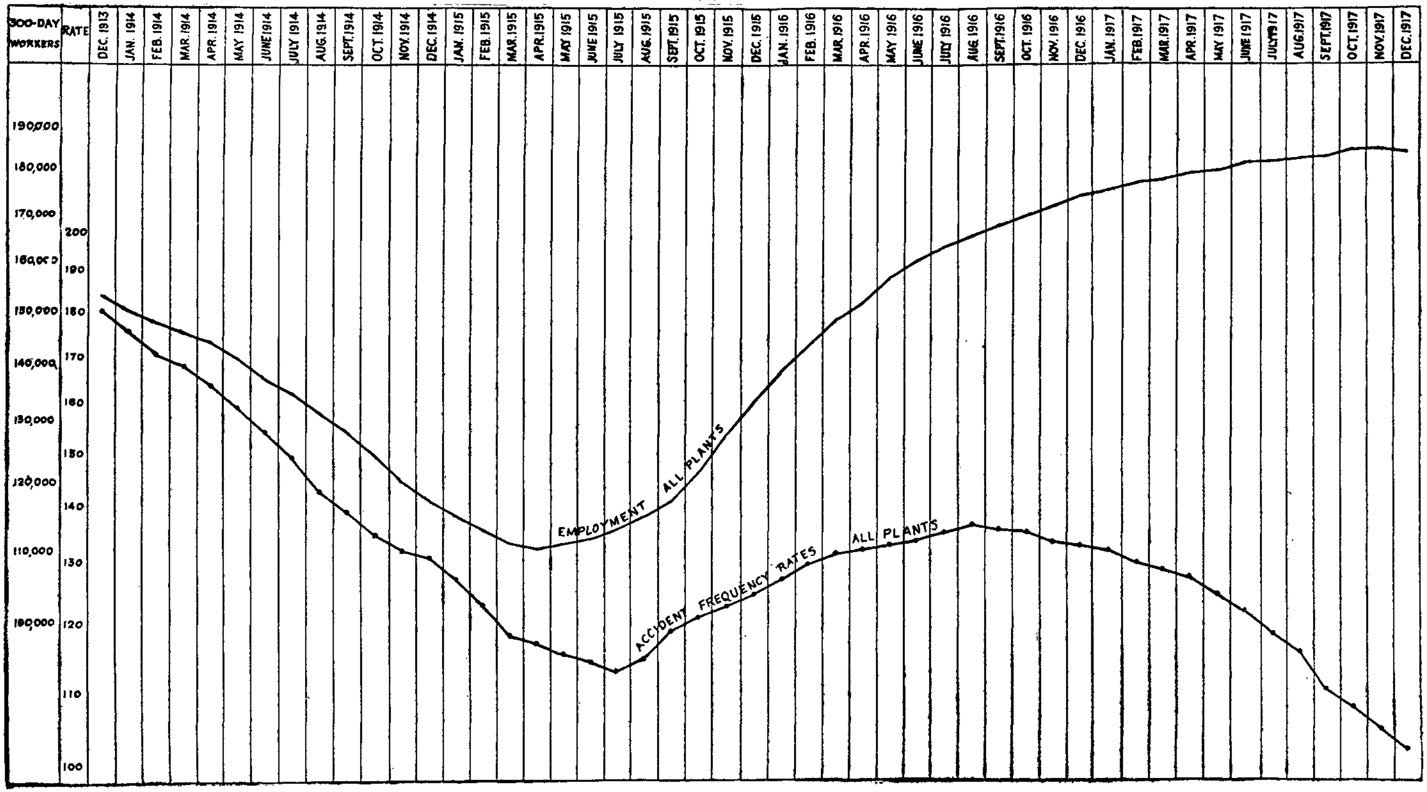
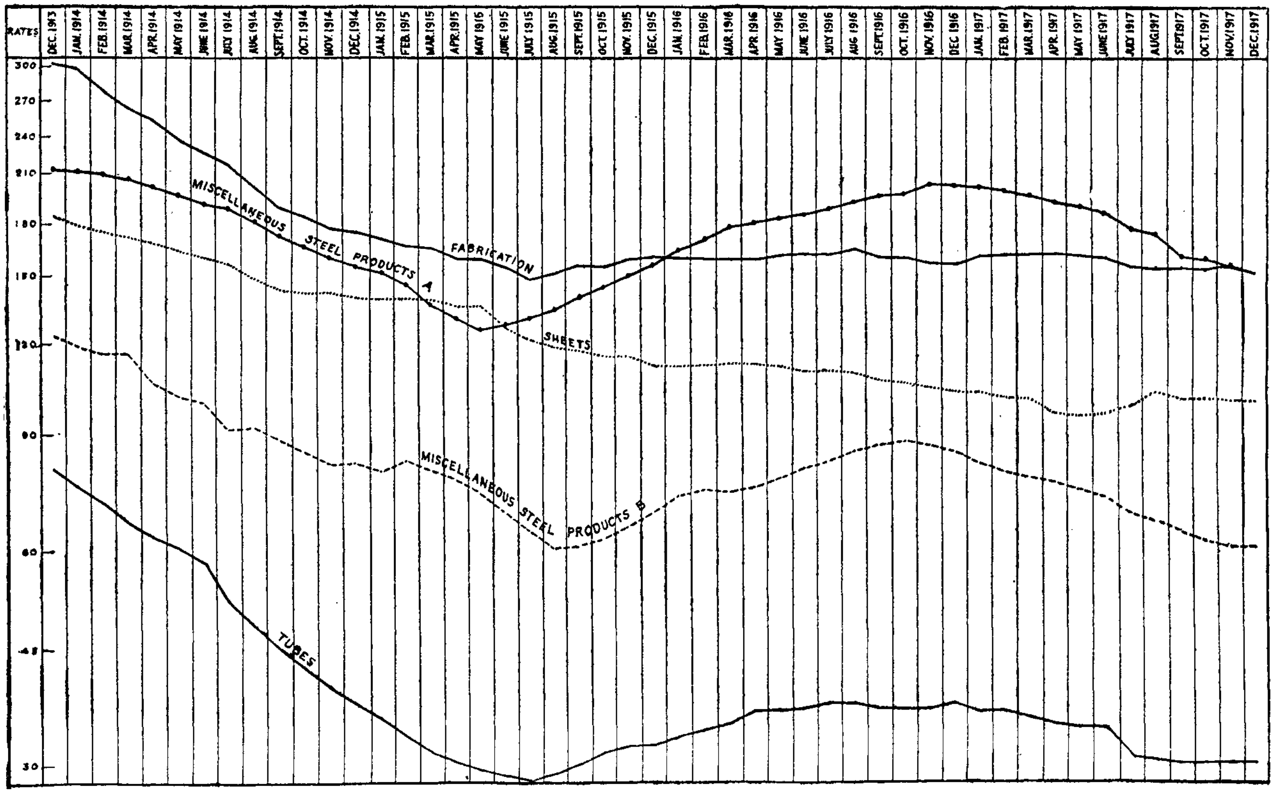


CHART C.—ACCIDENT FREQUENCY RATES FOR YEAR ENDING WITH SPECIFIED MONTH.



PART II.—CAUSES AND PREVENTION OF ACCIDENTS.

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SUMMARY.

PURPOSE OF THE INVESTIGATION.

The purpose of this investigation was to determine the frequency and severity of accidents in the iron and steel industry and particularly to study the occurrences in such ways as to point out effective safety measures. To this end the report locates, as far as possible, the accident hazards in particular departments and occupations, develops the causes for accident occurrence, and discusses methods of prevention which experience has shown to be effective.

SCOPE OF THE REPORT.

The fundamental departments of the iron and steel industry are the blast furnaces, steel works, and rolling mills. Since, however, many of the large producers include in their processes the production of more finished materials, such as wire and structural fabrications, it is desirable to include them in this review.

From 1910 to 1914 the data secured cover all the important steel plants of the country with only three exceptions.[1] In these years the number of 300-day workers included varies from 202,157 to 319,919, the total being 1,310,919. The total number of accidents considered is 232,909. The plants involved number over 400. In addition it was possible to extend the review back to 1907 for six plants having from 19,481 to 29,766 300-day workers. This latter group carries the study back to the beginning of the safety movement.

ACCIDENT SEVERITY RATES.[2]

This report continues and extends the use of "severity rates" begun in the report on machine building—Bulletin No. 216 of this bureau.

The meaning of this term may be best expressed by means of an example: Assume that a plant employing 1,000 300-day workers during the course of a year had 200 accidents, and that the total time lost by the men injured was 5,000 working days; the accident-frequency rate for the year would be 200 per 1,000 workers; the "severity" rate would be 5,000 days lost per 1,000 workers, or, more conveniently expressed, an average of 5 days per individual worker.

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[1] See p. 194.

[2] See Chap. I.

To make such computations it is necessary, of course, to express fatal and permanent injuries, as well as temporary disabilities, in terms of workdays lost. This is done by valuing a fatal injury (assuming the employees killed of an average age of 30) as equivalent to the loss of 30 years' work time—9,000 days. Lesser permanent injuries—such as loss of hand or foot—are credited with lower time losses in proportion to their probable effect upon earning capacity—2,196 days for a hand, 1,845 days for a foot, etc. This method of evaluating permanent injury in terms of time loss, although based upon somewhat rough estimates, is by no means arbitrary.

Severity rates, thus computed, constitute a very much more accurate measure of accident hazard than do the older frequency rates. A striking example may be cited: The machine-building industry, in one year, had an accident frequency rate of 118 per 1,000 300-day workers. This was, as it happened, actually higher than the accident frequency in a large steel plant in one year, the rate there being 115 cases per 1,000 workers. But even a casual acquaintance with the two industries would indicate that the steel plant represents the more hazardous employment, inasmuch as its accidents are, on the whole, of a more serious character than those occurring in machine building. This was evident when severity rates were computed according to the method described, the steel plant having a severity rate of 21.2 days lost per worker, as against only 5.6 days lost per worker in machine building. In this case the severity rate is clearly more valuable than the frequency rate in indicating the relative hazards of the two industries.

A most important application of such rates is to the study of accident causes, nature of injury, and other similar subjects.

PHYSICAL CAUSES OF ACCIDENTS.[1]

In order to deal at all adequately with his problems the safety man must have exact knowledge of the causes which bring about accidents. Without the use of some system of severity rating such as that just outlined no really satisfactory analysis is possible. It is found that in the iron and steel industry as a whole the cause groups rank as follows in the severity of the accidents attributable to them: Working machines, 1.40 days per 300-day worker; cranes and hoists, 3.30 days; hot substances, 3.27 days; falling objects, 2.23 days; falls of worker, 1.71 days; handling tools and objects, 0.92 day; power vehicles, 2.44 days; miscellaneous causes, 2.03 days.

"Working machines" have their greatest importance in tube mills (3.06 days), plate mills (2.22 days), and sheet mills (2.08 days).

"Cranes and hoists" show high rates in all departments, particularly in fabricating (9.29 days), Bessemer (4.68 days), foundries (4.84 days), and open hearths (4.47 days).

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[1] See Ch. II.

"Hot substances" are naturally the characteristic hazard of blast furnaces (11.96 days), Bessemer (11.05 days), and open hearths (5.81 days). The hazard of burns in foundries has been considered rather serious, but the severity rate (1.87 days) is much below that for cranes (4.84 days).

"Falling objects" take the greatest toll of time in the Bessemer (5.29 days), foundries (5.21 days), and mechanical departments (3.54 days).

"Falls of worker" appear prominently only in blast furnaces (6.27 days) and among mechanics (4.05 days). In both cases this is due to the necessity of climbing and working at elevations.

"Handling tools and objects" in frequency rate (35. 6 cases) ranks next to "falling objects" (36.3 cases), but in severity rate "falling objects" (2.23 days) exceeds "handling" (0.92 day) very decidedly. This relative unimportance of "handling" is found to exist in all departments. "Power vehicles" give rise to enough serious injury to demand careful attention in each department. The departments of conspicuous hazard are yard department (9.73 days), blast furnaces (4.20 days), open hearths (3.83 days), and Bessemer converters (3.04 days).

"Miscellaneous causes" have a striking severity rate only in blast furnaces. This is entirely due to the results of the presence in them of asphyxiating gas. The severity rate from this cause in blast furnaces is 10.5 days.

CONTROL OF ACCIDENT CAUSES IN THE DEPARTMENTS.

A satisfactory summary of the four chapters on this subject can not be made. It is possible to touch only upon some conspicuous points.

In order to determine the importance of the influences which act upon accident causes it is necessary to follow the course of the rates from year to year and also to know somewhat intimately the history of the changes in equipment and method which have occurred during the same period.

Blast furnaces.[1]—In blast furnaces the characteristic cause groups are subdivisions of the general group of "hot substances." They are "breakouts," "explosions" connected with slips, and "gas flames." Each of these has its appropriate remedy in some form of structural improvement. Asphyxiating gas is also a serious menace in the blast furnace and must be controlled, if at all, by better construction.

The course of accidents from year to year will be shown to better advantage at a later point where the experience of the departments is detailed more fully. In this connection it is sufficient to call

[1] See Ch. III.

attention to the fact that the fairly steady decline which appears in the rates is not confined to any particular group of causes. Some causes are naturally much more sensitive to fluctuating industrial conditions than others, but all of them have been influenced by the efforts at prevention which have been in progress during the period.

Much light is shed upon the proper point for applying effort at accident control by considering the relation of special occupations to the causes. For example, it appears that injury from hot substances is much more common among the members of the cast-house crew than among other blast-furnace workers, while asphyxia is distributed almost uniformly. Such facts indicate quite definitely the limitations and particular direction of special effort.

Steel works and foundries present in a modified form the hazard of "hot substances." The effective control is along lines similar to those suggested for blast furnaces.

Open hearths.[1]—Among the occupations of open hearths common labor has much the highest frequency rate. In injuries due to "hot substances," for example, the rate is 90.3 cases against 41.9 cases for pouring-platform workers, who stand next. In fact, common labor has the highest rate in each cause group except "handling tools and objects" in which, naturally, the class of workers which includes the specially tool handling mechanics is highest with 25.0 cases, while common labor has 14.8 cases.

Bessemer steel works.[1]—The Bessemer department has two items of procedure peculiar to itself which require some special efforts at control. When the blast is turned into the converter many molten particles are thrown out. Ordinarily these are not of a size to be particularly dangerous, but at times they may cause serious burns. Screens protecting the workers are now frequently used with good effect, but more important probably is the adoption of a plan of work which does not require the men to expose themselves as much as formerly. The second item is the throwing of heavy masses of scrap into the converters. When this was done directly the men were exposed to great heat and often the masses of scrap would fall to the pit floor, seriously endangering any one working there. In the best plants this is now done behind water-cooled screens and through chutes which make a fall to the floor below nearly impossible.

Rolling mills.[2]—In heavy rolling mills the element of hazard which appears to be most difficult to control is "hot substances." In all other particulars there is marked improvement. This control has been largely due to the introduction of improved machinery both in the apparatus used directly in the rolling process and in such accessory apparatus as cranes.

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[1] See Ch. IV. [2] See Ch. V.

In tube mills there is a combination of mill processes with machine-shop-conditions, making the problem of control quite different. These mills have scored a remarkable success in the reduction of accident frequency, while the severity rate, fairly low at the beginning, has undergone relatively much less change.

The sheet mills present the unusual condition of a rising frequency rate while the severity rate is falling. This was found on analysis to be due to the group of employees particularly characteristic of this department. When all sheet mill workers are taken as a unit they show declining rates. The "hot-mill crews," however, when isolated, have rising rates in both frequency and severity. It is probable that the rate being generally lower than in other departments and the rise not being very conspicuous, less attention has been given to conditions than they have deserved.

Mechanical, fabricating, and yard departments.[1]—The control of accident causes in mechanical and fabricating operations must in the nature of the case be considerably a matter of personal care. So many of the operations are of a personal and manual character that the individual worker's attitude must be a material factor. Indeed, it has been found that whenever an effort which succeeds in interesting the men of such departments is undertaken the frequency of accident at once begins to decline in a remarkable manner.

Mechanics and fabricators are the typical machine users. It is therefore in these departments that the relative importance of machines and other similar forms of hazard can be most readily determined. In no year covered by this study did the contribution of machines to the severity rate exceed 30 per cent. The average is about 10 per cent and it sometimes drops to 4 per cent. The working machine is therefore not a negligible source of injury, but is of relatively minor importance.

The yard department has its chief danger in the operation of power vehicles. In the plants studied the greater number of cases arise from coupling and uncoupling cars. The obvious remedy is the introduction of automatic couplers. The severity rate receives its greatest contribution from the men being run down by moving locomotives and cars. A study of these cases shows beyond question that improvement in such matters as grade crossings, clearances, permanent signal apparatus, and safety appliances on cars and locomotives is the main factor in an improved condition.

THE HUMAN FACTOR IN ACCIDENT OCCURRENCE.[2]

The points summarized above pertain to the physical causes of accident. In the following section it is pointed out that the human factor has probably been charged with much more than its fair share

[1] See Ch. VI. [2] See Ch. VII.

of importance. It only rarely gives rise to serious injury without there being some factor of physical condition which could be remedied.

Labor recruiting.[1]—The accident rates of the inexperienced worker are uniformly high. The influence of inexperience is most clearly apparent in the study of "labor recruiting." In times of increasing industrial activity new men are taken on in larger numbers. Among them there will be, except in very unusual circumstances, a proportion of entirely inexperienced men. Even if not unfamiliar with the industry they will be new to the particular conditions of the plant into which they come. By dividing the number of new men taken on in a given time by the number of 300-day workers for the same interval a rate is obtained which may be called the "labor recruiting rate," i. e.—the number of new men taken on during the period per 1,000 300-day workers. This is an exact measure of the extent to which the introduction of new men is influencing the working force

When the experience of a number of steel mills is studied it appears that this factor of labor recruiting is of very great influence in the accident frequency rate. These rates follow the recruiting with remarkable exactness, rising when recruiting rises and falling when it falls except in special cases in which it is possible to identify other factors tending to nullify the natural effect of labor recruiting.

Geographic location.[2]—It seems possible to trace the influence of inexperience in the records of some steel plants so located that they naturally serve as ports of entry to the steel industry. It does not seem possible on other grounds to account for steadily higher accident rates in some such plants when the safety work being done in them is of fully as high quality as that found in other plants having definitely lower rates.

Influence of age.[3]—This is difficult to determine since workers in different age groups are rarely employed in tasks of sufficient similarity to admit satisfactory comparison in the matter of hazard. That is, the differences observed are due to the differences in work done rather than to any influence of age as such. In steel works the decades 20 to 29 years and 30 to 39 years are very closely similar in the work done. The younger group has very constantly a higher accident rate. This can hardly be due to any other cause than relative inexperience. Men of 20 to 29 years are the raw recruits of the industrial army, coming largely from nonindustrial pursuits. Their inexperience is reflected in their higher accident rate.

Inability to speak English.[4]—Obviously of all inexperienced men the one suffering the most serious handicap is the one who is both new to his task and also is unable to communicate freely with the man to whom he is responsible. Study of this condition shows that the accident rates of such workers are higher than of those familiar with the

[1] See pp. 133 to 140. [2] See pp. 140 to 141. [3] See pp. 141 to 144. [4] See pp. 144 to 146.

language. That this is not due to some racial peculiarity is indicated by the fact that the English speaking foreign born have rates scarcely higher than American born.

Day and night accident rates.[1]—The data studied indicate that in all heavy employments there is a very pronounced tendency to higher rates at night. The explanation lies along two lines: (1) Imperfect lighting, (2) an unsatisfactory condition of the worker due to various causes.

The experience of some plants indicates that this tendency can be controlled. Further study is necessary on this subject in order to determine more fully the facts of the situation and the best method of control.

Conjugal condition.[2]—No new studies of this subject have been made in connection with this report. In answer to questions concerning the effect of dependents upon the care exercised by the worker in carrying on his work a table prepared for the earlier report is reproduced. The conclusion derivable from it is that there is no measurable difference between the accident frequency rates of the married and the unmarried of the same age groups.

The effect of alcohol.[3]—Safety men are practically unanimous in the conviction that the use of alcohol is an important factor in causing accidents. In view of this attitude an effort was made in the course of this study to determine the basis of their view and to apply to it all possible tests. The conclusion was reached that it is entirely impossible to secure the same kind of evidence which may be obtained regarding physical causes. When a man is run down by a car that fact can be determined and recorded. It is a very different matter to determine whether alcohol had much, little, or nothing to do with his failure to escape from his dangerous position.

In only one plant were records found which appeared to have a definite bearing on this subject. This plant had higher rates at night. When the records of discipline for use of intoxicants were examined it was found that the rates for the night turn were much in excess of those for the day turn. Further, during the years covered the night rates for accident had declined more rapidly than those for the day. The same was true of the rates for discipline for alcoholic indulgence. That there is a possible causal relation in these parallel series of events is evident.

Distribution of accidents through the working hours.[4]—Undertaken primarily as a study of fatigue it has become increasingly evident that other factors enter in to such a degree that the fatigue effect is completely masked. There are also undetermined elements in the situation, such, for example, as distribution of employment through the working hours. These undetermined elements are of such weight

[1] See pp. 146 to 152. [2] See p. 152. [3] See pp. 153, 154 [4] See pp. 154 to 163.

that any final conclusions regarding the significance of the distribution curve is impossible until they are examined. The present presentation simply puts the accumulated records in form for reference and offers a provisional suggestion regarding an explanation of the form of the distribution curves.

CAN SERIOUS INDUSTRIAL ACCIDENTS BE ELIMINATED?[1]

This is the most interesting question which can be asked regarding accident occurrence. The usual opinion is that it is an entirely futile question, since it is a matter of common knowledge that they can not be.

The results of this study discredit this "common knowledge" at several points. For example, when causes of accident are followed closely from year to year it is found that certain causes which contribute but a small number of cases are responsible for large losses of time. The decreasing time loss from year to year shown in these causes has been due to improved physical conditions. This is very conspicuous in the case of hot metal "breakouts" in blast furnaces. A steady increase in strength of construction in the furnaces included in the study finally brought "breakouts" to an end. The result was a reduction in the severity rate of 58.9 days per 300-day worker when 1906 and 1913 are compared. On the other hand, causes depending largely on personal care, such as "handling tools," while showing great reduction in number, contributed but meagerly to the reduction of severity. Contrast 58.9 days per 300-day worker of decline in severity rates which was due to "the engineering revision" which stopped "breakouts" with 7.3 days in "handling tools," a part of which must be attributed to better tools.

If, as appears to be the case, serious accidents are mainly reduced by the process of physical improvement due to "engineering revision," no limit can be set to it. Human carefulness probably can not be speedily perfected, but physical conditions very possibly can be to a point making serious accident a very rare occurrence.

This contention is reinforced by study of causes of death. In a majority of cases it is evident that some improvement in physical condition could have been made which would have tended to prevent the accident.

It is impossible to summarize this section satisfactorily, but the above will serve to give an idea of the line of discussion which is followed.

NATURE OF THE INJURY.[2]

The nature of the injury is not so significant in accident prevention work as the cause of injury. Since, however, a considerable number

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[1] See Ch. VIII.
[2] See Ch. IX.

of cases must be met by appliances placed upon the worker the nature of his injury is an essential element in determining the appropriate safeguard. For example, the number of eye injuries is an index of the importance of the use of protective goggles.

Machine building and iron and steel.[1]—Instructive comparison is possible between machine building and the iron and steel industry. For example, in the years and plants covered machine building is below the iron and steel industry 56 per cent in frequency and 65 per cent in severity. This shows that injuries of the iron and steel industry are as a rule of higher severity than those of machine building. This has been shown elsewhere from other viewpoints. When, however, bruises and cuts are considered it appears that while machine building has 52 per cent less frequency its severity is only 24 per cent less than iron and steel.

Injury in the departments.[2]—Certain departments are characterized in a marked degree by certain kinds of injury. Blast furnaces, for example, have the danger of asphyxia [3] beyond all other departments. This hazard contributes 6.98 days per 300-day worker to the severity rate of blast furnaces and only 0.38 day to that of open hearths, the only other department in which asphyxia is of any significance.

The fabricating shops, with the constant shifting of large girders by means of cranes, suffer much from crushing injury (12.62 days). Burns have high severity in blast furnaces (9.61 days), Bessemer (10.44 days), and open hearths (6.36 days). Heat prostrations are of noteworthy severity in sheet mills (0.93 day), plate mills (0.63 day), and open hearths (0.42 day). These illustrations serve to show that study of such records may afford important clues to useful lines of preventive effort.

Infection.[4]—Infection was formerly distressingly common. A study of the available data indicates that the emphasis of recent years upon prompt report of cases to the physician has had a measurable effect. Infected cases have been declining at a more rapid rate than other cases.

Injury and occupation.[5]—Some important conclusions are possible when injuries are considered by occupational groups. It was possible to do this in three departments—blast furnaces, open hearths, and tube mills.

In blast furnaces the cast house men furnish the greater number of cases. Burns are most numerous (117.9 cases per 1,000 300-day workers). Hot metal has 97.3 cases. Hot water and steam are of

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[1] See pp. 179.

[2] See pp. 180 to 182.

[3] For detailed instructions regarding prevention methods see Asphyxiation from Blast-Furnace Gas Technical paper 106, U. S. Bureau of Mines.

[4] See pp. 183 to 184.

[5] See pp. 184 to 191.

considerable importance (10.3 cases) with the cast house crew. Common labor also suffers seriously from burns. The significance of these cases lies in the fact that many of them can be effectually prevented by the use of proper clothing and other protective devices.

Open hearths have no occupational group in which the hazard is comparable with cast house men in the blast furnace. Common labor is in them, as in most departments, the employment of the greatest danger. In every kind of injury this group has the greatest frequency. For example, bruises and cuts have a frequency of 299.3 cases per 1,000 300-day workers among common labor and 82.1 cases among unclassified workers, who rank next. The following illustrations will serve to indicate the kinds of injury which befall a common laborer in an open hearth: Bruises of hand or fingers, 117.9 cases per 1,000 300-day workers; burns from hot metal, 23.1 cases; crushing injuries of hand or fingers, 7.6 cases; eye injuries, 34.4 cases; fracture of hand or fingers, 9.9 cases; infections, 14.4 cases.

Tube mills again emphasize the hazard of the common laborer. It is instructive to compare tube mills with open hearths at some points. For example, bruises of hand and fingers have a frequency of 117.9 cases per 1,000 300-day workers in open hearths, while in tube mills the frequency is 197.8 cases. This at once suggests a constant difference to one familiar with the operations of both departments. The tube mills require a much larger amount of handling small pieces in the course of which minor injury to the hands might more frequently occur. Since these operations can more readily be conducted mechanically in tube mills, this rate suggests a field for possible improvement.

Use of hospital records.[1]—In several particulars the records of the emergency room or hospital are sure to be more precise than reports made to the safety office. Some points developed by study of such records may be summarized as follows: (1) It was found, on extending to a larger amount of material the inquiry of the earlier report regarding the more rapid decline of minor injury under intensive safety effort, that this condition is equally evident in the larger group here available for study. (2) The idea of measuring progress by average time lost per case is unsound. Since the minor cases decrease in number more rapidly it is almost always true that the average time per case will increase when active safety work is undertaken. (3) The recoveries of the first week are not distributed to the days in a manner similar to the distribution in successive weeks. In the weeks there is a regular decline from week to week. In the days the second, third, and fourth each have a higher per cent of recovery than the first.

Care of the injured.—Great improvement in methods of transporting injured men and in appliances for their care has characterized

[1] See pp. 191, 192.

the period under consideration. Without doubt this has had a great influence in saving cases which would otherwise have terminated fatally. The importance of this contribution to a lessened severity rate has not been given its full value.

Closer cooperation of medical staff, employment office, and safety department is essential to a satisfying progress.

PROGRESS OF THE SAFETY MOVEMENT IN THE INDUSTRY.[1]

The course of accident occurrence is traced from 1907 onward. This covers the entire history of the organized safety movement. The years 1906 and 1907 were at the climax of a period of intense industrial activity and in other respects afforded conditions which probably gave them the highest accident rate that ever occurred anywhere.

Since those years a far-reaching change has taken place. Then there were no compensation laws, the study of industry with intent to make it safe had not begun, and such organization as now characterizes every great plant was unknown. Now compensation laws are nearly universal, several powerful national organizations are in the field in a sustained and concentrated effort to spread the gospel of safety, and plant managers are learning that the effort has economic as well as humanitarian advantages.

It is appropriate to inquire whether measurable results have appeared. In the entire industry from 1910 to 1914 the frequency of accidents was reduced from 224.0 cases per 1,000 300-day workers to 150.1 cases. At the same time severity declined from 19.9 days per 300-day worker to 11.8 days. In the special plants in which it was possible to cover the period back to 1907 the changes were in frequency from 242.4 cases in 1907 to 101.3 cases in 1914; in severity from 27.1 days in 1907 to 9.6 days in 1914.

Illustrations from individual plants.—While it is not desirable to attempt comparisons between individual plants, since they are likely to combine the various hazards in such a manner as to give misleading results, they afford admirable opportunity for showing the effect of intensive effort to reduce accidents. For purposes of such comparison three charts are introduced. The first of these affords frequency rates from 1900 to 1913. The reduction is from 370 cases per 1,000 300-day workers to 115 cases. The second gives the same data from 1905 to 1913 and includes severity rates. It affords such contrasts as a severity rate of 54.3 days per 300-day worker in 1906 and 14.3 days in 1912. The third chart brings together the frequency rates of the departments of two plants for 1910. In one safety work had been in progress for some time, in the other it had not begun.

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[1] See Ch. X.

The following figures will illustrate the contrasts: In steel works, 192 cases per 1,000 300-day workers and 929 cases; in rolling mills, 124 cases and 542 cases.

Comparison with other industries.—When the iron and steel industry is compared with others, also recognized as extra hazardous, the following figures are significant: In the entire iron and steel industry the fatality frequency rate in the period 1910 to 1914 varies from 1.62 cases per 1,000 300-day workers to 0.85 case. In blast furnaces the range is from 3.46 cases to 1.73 cases. In coal mines, 6.05 cases and 4.67 cases are the limits, while in metal mines the range is from 4.45 cases to 3.92 cases.

Classes of plants.—In an earlier report plants were shown in three classes: A, with safety organization well developed; B, in process of development; C, not developed. At the present time class C has practically disappeared. It is instructive to compare class A with the entire industry in the period 1910–1914. Class A had a frequency rate of 167.1 cases per 1,000 300-day workers while the entire industry in 1910–1914 had 177.7 cases, and in 1914 150.1. That is to say, the best plants in 1910 had a less satisfactory frequency rate than the entire industry in 1914.

EXPERIENCE BY DEPARTMENTS AND OCCUPATIONS.[1]

The trend of events in a complex industry such as the iron and steel may be quite different from the movement in some of its constituent elements. It accordingly becomes necessary to scrutinize these elements with care and determine whether they follow the same course or are at variance with the industry, considered as a unit.

As a foundation for such a study, 11 of the most important departments are presented for the periods 1910–1914 and 1907–1914. The severity rates vary from 28.7 days per 300-day worker in blast furnaces to 7.7 days in tube mills in the 1910–1914 period and 31.6 days in blast furnaces to 8.7 days in tube mills in the 1907–1914 period.

Blast furnaces.[2]—Severity rates in blast furnaces decline from 38.4 days per 300-day worker in 1910 to 20.1 days in 1914. The highest rate is found in 1906, 143.1 days. This was due to an unusual fatality in that year. It can not, however, be regarded as wholly abnormal, since the following year, 1907, has a rate of 65.1 days. From these high points a decline occurred to 19.6 days in 1914.

For the purpose of studying the conditions in occupations, four groups of blast furnace workers were isolated—cast house men, common laborers, mechanics, and stockers. Since the volume of data in each year would be inadequate for reliable rates, the data of

[1] See Ch. XI.

[2] See pp. 206 to 211.

1905–1914 have been combined. It is found that cast house men have a severity rate of 72.5 days per 300-day worker, common laborers 36.8 days, stockers 36.7 days, mechanics 26.3 days; while the unclassified group has 64.9 days. This latter rate is due in considerable measure to exposure to asphyxiating gas.

Bessemer steel works.[1]—The conditions which obtain in such works make for great irregularity in the rates. While this is true, the generally downward tendency is clearly marked. The year 1913 is industrially more strictly comparable with the earlier years of each of the periods under consideration than any other. It will therefore be used for comparative purposes, except in cases specially noted. In 1910 the Bessemer converters had a severity rate of 43.0 days per 300-day worker; in 1913 this had become 28.0 days. In the special plants the 1907 rate is 19.2 days, changing to 13.1 days in 1913. The highest rate is 57.9 days in 1908. No satisfactory study of occupations was possible in the Bessemer department.

Open hearths.[2]—In this department the 1910–1914 period varies from a severity rate of 35.7 days per 300-day worker in 1910 to a rate of 20.8 days in 1914. The 1907–1914 period shows 52.8 days in 1907 and 29.8 days in 1913. The occupational rates in open hearths are as follows: Common labor, 40.8 days per 300-day worker; pitmen, 15.7 days; pouring platform men, 12.7 days; stocking floor men, 6.3 days. The unclassified workers include those engaged in transportation, which accounts in part for their high severity rate (28.2 days).

Foundries.[3]—In the 1910–1914 period there is a steady decline in severity rates from 1911 onward. The rates are 16.0 days per 300-day worker in 1911 and 12.8 days in 1913. In the special plants the rates are very irregular and do not show any tendency to decline.

Neither of the groups above can be analyzed by occupations, but another considerable foundry group can be so treated. These are strictly occupational rates: Cleaners, including chippers, 23.0 days per 300-day worker; molders, 19.4 days; melters, 6.0 days; core makers, 1.6 days. The high rate among cleaners is largely due to flying particles striking the eye.

Heavy rolling mills.[4]—The mills thus designated include blooming and slab mills and such structural mills as roll directly from the ingot. They are almost entirely mechanical in their operation. The 1910–1914 group shows severity rates of 24.4 days per 300-day worker in 1910 and of 10.8 days in 1914. The special plants have rates of 19.4 days in 1907, declining to 7.5 days in 1913.

Plate mills.[5]—This group of mills shows over the 1910–1914 period the most steady and uniform decline of any of the important depart-

[1] See pp. 212,213.
[2] See pp. 214 to 218.
[3] See pp. 219,220.
[4] See pp. 220 to 222.
[5] See pp. 223,224.

ments. The rate in 1910 was 24.8 days per 300-day worker. By 1913 this had dropped to 9.5 days. The special plants are much less regular, but record a decline from 30.7 days in 1907 to 12.4 days in 1913.

Sheet mills.[1]—The rates for these mills are distinctly lower than those of most of the departments. Consideration of what may be called their normal hazard would suggest that this lesser rate is not so pronouncedly different, as it should be. With vigorous attention to the problems of safety, a better record should be possible. In the 1910–1914 group the rates are 16.5 days per 300-day worker in 1910 and 10.1 days in 1913. The special plants show 13.1 days in 1907 and 8.5 days in 1913.

The hot mill crews in sheet mills have a severity rate of 6.0 days per 300-day worker, as against 17.8 days for all other occupations. Evidently the characteristic occupations of the sheet mill are much less hazardous than those which are shared with other departments.

Tube mills.[2]—Included in the operations of these mills are many processes similar to those of the machine shop. The presence of such processes accounts in part for a comparatively low severity rate. In the large group 1910–1914 this rate rose in the later years from 5.8 days per 300-day worker in 1910 to 10.0 days in 1913. This happened in spite of a very notable reduction in frequency rates. These declined during the period from 167.5 cases per 1,000 300-day workers in 1910 to 88.5 cases in 1913. In the special plants the severity rates are irregular but a downward tendency is established by comparing four-year periods 1907–1910 and 1911–1914. This comparison shows 9.6 days for the earlier period and 7.9 days for the latter.

The occupational severity rates establish that the skilled workers in these mills have small hazard. The rate of the pipe furnace crews is 1.1 days per 300-day worker, pipe finishing crews 3.6 days, while common labor has 23.0 days, and an unclassified group, including transportation workers, has 11.5 days.

Miscellaneous light rolling mills.[3]—The mills of this class are to a very considerable extent hand operated. They are characterized by a high frequency and relatively lower severity when compared with heavy rolling mills. Their severity rate declined in the 1910–1914 period from 16. 8 days per 300-day worker in 1910 to 14.5 days in 1913. The entire group, including some mills in part of mechanical operation, had for the period a severity rate of 12.8 days, while bar mills which are strictly hand operated had a rate of 10.7 days.

Fabricating shops.[4]—All such shops exhibit a tendency to high frequency rates due to the large amount of hand work involved. When the severity rates are considered they are rather below the average. In the 1910–1914 period there was a decline from 19.9

[1] See pp. 225 to 227. [2] See pp. 228 to 230. [3] See pp. 230, 231. [4] See pp. 231 to 233.

days per 300-day worker in 1910 to 13.9 days in 1913. In the special plants the change was from 35.3 days in 1907 to 8.5 days in 1913.

Wire drawing.[1]—The severity rates of this department are influenced a great deal by the prevalence of permanent disabilities due to loss of fingers from being caught in tangles of wire. This hazard is practically gone from the best mills and the rate has declined accordingly. The 1910–1914 period registers a decline from 12.3 days per 300-day worker in 1910 to 8.9 days in 1913.

Electrical department.[2]—This department is the only one whose rates are not fairly encouraging. In 1910 the severity rate was 15.8 days per 300-day worker, but rose to 35.6 days in 1913. This would be less serious if confined to a single year, but in 1914 the rate was still high (34.7). The high death rate, which is the main factor in this undue severity, demands the most careful consideration of electrical engineers. It does not prevail in the best plants. It is singularly unfitting that the sponsors of the National Safety Council permit their own department to fall out of step.

Mechanical department.[3]—The showing of this department is irregular. No improvement can be argued from the 1910–1914 period. The highest rate is in 1913 (18.3 days per 300-day worker) and the lowest in 1911 (11.4 days). When the longer period (1905–1914) is considered it becomes evident that there has been a very marked change for the better from the very high rates of the earlier years. Such a rate as 26.9 days per 300-day worker in 1908 is not reached in either group in any later year. However, fatality is much more frequent in this department than it should be.

Yard department.[4]—The contrast between the entire industry and the special plants so far as this department is concerned is very instructive. The decline in the 1910–1914 period from 26.5 days per 300-day worker in 1910 to 16.3 days in 1914 is considerably marred by the fact that in 1913 the rate was 25.6 days. The special plants, however, show a decline from 37.1 days in 1905 to 2.5 days in 1913. This very low rate is due to the fact that in six large plants having 2,751 300-day yard employees in 1913 there was not a single fatality. Such records can, and therefore ought to be, much more frequent than they are.

Erection of structural steel.[5]—So far as known no rates have hitherto been compiled for this kind of employment. It has been known that there was extreme hazard, but no definite measure was available. Both in frequency and severity rates this building and bridge work shows a higher hazard than any other department examined. The severity rate of 128.6 days per 300-day worker is equaled only by one unusual year in blast furnaces when the rate was 143.1 days.

[1] See pp. 234, 235.
[2] See pp. 236, 237.
[3] See pp. 237, 238.
[4] See pp. 240, 241.
[5] See pp. 242, 243.

For many reasons this employment presents many difficulties. Not the least of these are the conditions of haste which are nearly always present and the temporary expedients which must be adopted for the conduct of the work. It is not possible to determine whether this present condition is an improvement upon an earlier one which was still worse, but it must be suspected that these figures represent the best phase of a condition which at its worst is no less than a disgrace to the safety movement.

The period 1910 to 1914 as a standard of comparison.[1]—The years mentioned afford in several particulars an advantageous standard of reference. The safety movement had by 1910 spread widely enough to constitute an important factor. The years themselves are sufficiently varied in the character of the industrial conditions prevalent that they may fairly be regarded as typical when taken as a unit. The rates for the several departments are accordingly assembled in convenient shape so that the manager of any particular type of mill may readily compare his rates with them and so judge his relation to a fair standard of past experience.

THE METHODS OF THE SAFETY MAN.[2]

Safety organization.—Safety organization is now so well established and so well understood that extended discussion is not deemed necessary. One of the problems of organization is the maintenance of an effective degree of interest. If supervisors and workers alike can be held up to a continuing interest the problem of education is more than half solved. In view of this fact the present chapter is devoted to outlining methods which have proved effective in the practice of the iron and steel industry.

Records and charts.—No safety man proceeds far in his work without feeling the need of some form of presenting the facts in an impressive way to his colleagues. The commonest device for this purpose is a monthly chart. The serious defect of this method is due to the fact that when several departments are combined for the sake of comparison the chart becomes so confused that it is difficult if not impossible to understand it. To obviate this difficulty a method of preparing and plotting smoothed curves is described in detail. This method involves the use of data for the years ending with each month from the close of the first year onward. This use of overlapping periods of a full year eliminates the influence of local and temporary conditions and affords a smooth and intelligible curve. The method is applicable both to the presentation of departmental rates and comparison of causes.

Awards and bonus plans.—Probably no safety man has escaped the discouragement of realizing that a plan to which he had given careful

[1] See pp. 244, 245. [2] See Ch. XII.

and prolonged thought and which had produced satisfactory results was losing its force. It does not lessen this discouragement to realize that the more active he may be in using his plans the quicker they wear out. This has led to a search for some form of interest producer of more permanent character. This is furnished in the case of the supervisory men by the steady pressure of the compensation laws. If due care is not exercised in accident prevention costs begin to rise and unpleasant questions are likely to be asked. The safety man desires some automatic and permanent influence which shall exercise the same influence on the work people. He is apt to seek it in some form of bonus.

No attempt is here made to discuss the propriety of such systems. It is regarded as sufficient to point out that some successful safety men do not regard the plan favorably on the ground that its use tends to diminish the force of the humane motive. To this the advocates reply that the humane motive is in no way modified but is effectively supplemented. The fact to be recorded is that extensive experiments are under way in the use of bonuses. The results must be determined as they develop.

To afford a means of understanding the methods employed in such plans, a composite plan derived from the experience of a number of companies is described in detail.

Cooperation with other agencies.—The wise safety man will recognize that his success is largely a matter of close cooperation with home, school, church, and other agencies of the community. He has an opportunity far beyond his plant, which if properly utilized will return to him in a lowered accident rate.

CHAPTER I.

INDUSTRIAL ACCIDENT RATES.

The purpose of accident studies is the very practical one of finding out where and why accidents occur and how they may be prevented. The first stage in every such study is necessarily the counting and analysis of the accidents reported. In attempting this, two serious difficulties present themselves: First, the lack of a uniform definition of what is to be regarded as an "accident"; and, second, a confusion as to the proper derivation and use of accident rates. Failure to grasp the importance of these two points has been responsible for much loose thinking and many false conclusions, and also has been responsible for the present unsatisfactory character of accident statistics in this country.

DEFINITION OF "ACCIDENT."

First, then, what is to be regarded as an industrial accident for the purposes of statistical study? No definition has as yet been universally accepted. Some establishments and States attempt to take account of all injuries, however trivial. Others exclude those of a minor character and take account only of such as cause a loss of a specified amount of time. It is evident that the accident showing of a plant may be completely altered by a change in definition of accident, and that in the absence of a uniform definition all comparisons between the accident data of different plants, industries, or other groups become almost worthless. The precise definition is not so important. The important thing is that the same definition should be everywhere observed.

The most significant step so far taken toward such uniformity in this country is the recent action of the International Association of Industrial Accident Boards and Commissions in adopting a definition of "tabulatable accidents"—i. e., a definition not necessarily to be followed in the original reporting of accidents, but to be used in all statistical tabulations. The definition is substantially the same as the one long used by the Bureau of Labor Statistics in its accident investigations and employed in the present report:

"*Tabulatable accidents, diseases, and injuries.*—All accidents, diseases, and injuries arising out of employment and resulting in death, permanent disability, or any loss of time other than the remainder of the day, shift, or turn in which the injury was incurred, shall be classified as "tabulatable accidents, diseases, and injuries," and a report of all such cases to some State or National authority shall be required."

The States which belong to the International Association of Industrial Accident Boards and Commissions are thus committed to a uniform standard definition of the accidents which are to be tabulated. Some States may at first find it impossible to tabulate all accidents as required by the definition, but the desirability of doing so is apparent, and many have already made a beginning.

THE MEANING OF ACCIDENT RATES.

The second of the two above-mentioned difficulties—the determination and use of accurate accident rates—presents a more serious problem than that involved in the definition of accident. Here it is necessary not only to have uniformity, but to decide upon a correct method. In the early attempts at accident statistics, attention was limited to the number of accidents occurring in a given plant or group. But mere numbers, of course, meant nothing unless related to the number of persons exposed to accident. This led to the custom of expressing accidents in terms of so many per thousand workers, and constituted an approach to a correct method. To say that a given industry had an accident rate of 100 per thousand workers does convey a definite idea, and can be compared with a rate of, say, 300 per thousand workers in another industry. But the method was extremely crude, because the basic figure "1,000 workers" was indefinite and variable. Usually it was derived by rough estimate as to the number of persons employed, such as averaging the number employed at different times of the year or averaging the pay rolls of the year. But no such average could be at all an accurate measure of what was wanted. The number of days worked vary in different plants as do also the daily hours of labor. Two plants may have the same yearly accident rate, say, 200 per "1,000 workers," estimated on the above basis, but if one worked only 8 hours a day for 250 days and the other worked 12 hours a day for 365 days, it is clear that the real accident hazard is much higher in the former plant, in as much as the same number of accidents per 1,000 workers occurred during a much more limited period of time.

ACCIDENT FREQUENCY RATES.

From this weakness, it became evident that in order to get a rate that would measure real hazard, it is necessary to know not only the number of men employed, but also the time of their employment. The only way to obtain this is to ascertain the actual number of hours worked by all employees for the year. This gives the number of man-hours, i. e., the theoretical number of men required to produce the output of the plant in one hour, or what is the same thing, the theoretical number of hours required by one man to turn out the same product. Man-hours so derived constitute the correct basis upon which to calculate accident rates. But the term is unfamiliar and for practical purposes it is convenient to convert man-hours into full-time workers. The full-time worker, as defined by the joint committee of the International Congress on Social Insurance and the International Institute of Statistics, is one who works 10 hours per day for 300 days per annum, making a total of 3,000 hours per annum.

The full-time worker or 300-day worker, so defined, may seem at first thought to be a mere statistical abstraction. It is true that the full-time worker, like the average man, is a unit of measure, not a living, breathing man, but for the purpose of accident statistics a standardized workman to serve as a unit of measure is absolutely essential. Furthermore, the statistical full-time workman who is assumed to work 10 hours a day for 300 days in the year conforms very closely in most industries to the actual workman who enjoys good health and works every day the establishment is running.

Accident statistics, to be comparable, must be stated in terms of a common unit of measure. The 300-day worker is merely a unit of measure of the quantity of labor, just as the yard is the unit of measure for length. The number of 300-day or full-time workers is obtained by dividing the number of man-hours actually worked in an establishment by 3,000, the number of hours per annum assumed to be worked by the 300-day worker.

In those establishments which keep accurate records of the hours worked by each employee every day, the man-hours worked by the establishment can easily be obtained from the records and hence the number of full-time or 300-day workers can easily be computed. Few small establishments, however, keep any such accurate records of time worked. For the majority of small plants it is necessary to compute the number of man-hours worked and the full-time (300-day) workers. The method suggested by the conference called by Commissioner Meeker, which met in Chicago October 12 and 13, 1914, was as follows: "If this exact information is not available in this form in the records, then an approximation should be computed by taking the number of men at work (or enrolled) on a certain day of each month in the year and the average of these numbers multiplied by the number of hours worked by the establishment for the year would be the number of man-hours measuring the exposure to risk for the year."

By the method outlined, true rates are obtained as regards the risk of accident occurrence or frequency. These rates may be called accident frequency rates. Thus if the accident frequency rate, so derived, for the steel industry is 114 per 1,000 full-time workers, and is 118 for the machine building industry, it is correct to conclude that accidents are less frequent in the steel industry than in machine building, in the proportion of 114 to 118. All differences in the hours of labor, number of days worked, etc., in the two industries have been duly taken into account. Again, if a given plant shows an accident frequency rate of 100 one year and 90 the next, it is a correct conclusion that accidents have decreased 10 per cent in frequency.

ACCIDENT SEVERITY RATES.

Frequency rates of this character were computed and used in the report on accidents in the iron and steel industry, issued by the Bureau of Labor Statistics in 1913. In all the establishments covered the number of man-hours worked per year was obtained and the working force then reduced to so many full-time or 300-day workers.

The method was found practicable and, within limits, highly useful. But it had one serious weakness, namely, that frequency rates, as the name indicates, measure the frequency of accidents, but take no account of the severity of the resulting injuries, and experience has shown that the two things do not necessarily move in the same direction. The frequency rates may be the same in two plants in the same industry, and the hazards may be entirely different because one plant has very few severe accidents, while the other has a large proportion of serious accidents. To put all industries and all plants on a common basis a system of computing accident rates must be devised which will take into account the difference in economic significance between the accident which bruises the workman's thumb and the accident which breaks his back.

In other words, what is needed is some method of weighting injuries according to their severity. Several methods suggest themselves as possible—compensation paid, wage loss or time loss. A compensation system necessarily weights the importance of accidents in fixing a scale of benefits which aims to apportion the payment to the hurt. But compensation payments do not offer the universal measure desired because the benefits differ from State to State and are also subject to change within the same State. Wage loss due to injury offers perhaps a better measure of severity, but this, too, suffers under the handicap that wages differ from place to place and from time to time. Time loss as a measure does not suffer from these objections. An accident that causes 6 days' disability is precisely twice as serious as one causing only 3 days' disability, and this relation is always and everywhere the same.

The days lost because of injury may thus be taken as the most satisfactory measure of the true hazards of industry—of the burden imposed upon the worker and the community because of industrial accidents. The only difficulty in its practical application is that in case of death and permanent injuries the time lost must be estimated. For temporary disabilities, from which recovery is complete, the time losses are matters of record—2 days, 10 days, 6 weeks, as the case may be. But, if the accident results in death, the time loss is not so clearly measurable. It exists, however, and may be estimated as the number of working days by which the worker's life was curtailed. Similar estimates are possible in case of permanent injuries, such as loss of hand or foot.

After a study of the available information a table of time losses for injuries resulting in death, permanent total disability, and permanent partial disability was determined upon and applied in this report. The procedure followed was as follows:

FATALITIES.

In case of an injury causing death the time loss to the family and society is the expectancy of productive working life of the deceased workman. It is not possible to learn the age of all workmen killed in industrial accidents; but from estimates made by the Wisconsin Industrial Commission, from statistics obtained by several compensation commissions, and from the investigations of the Bureau of Labor Statistics, it seems reasonable to estimate that the average age of victims of fatal accidents is approximately 30 years. According to the American life tables, the life expectancy at age 30 is 35 years. This is for the population as a whole. Workingmen exposed to all the hazards of illness and accident in industry have a shorter expectancy of life than the average for the whole population. The expected productive life of workers is even shorter than their life expectancy. Exact data are lacking, but in the light of all obtainable information it seems fair to estimate the working time lost on the average by relatives and the community for each workman killed by accident as 30 years, or 9,000 working days, counting 300 working days to the year. This is admittedly an estimate. A mathematically accurate measure is obviously impossible. It is also unimportant. The main thing is to get the best possible approximation and to apply it to existing accident statistics for the purpose of comparing accident records plant by plant, industry by industry, and year by year.

PERMANENT TOTAL DISABILITIES.

If the loss of working time to families and to the community were the sole thing to be shown in accident statistics, the same time loss should be fixed for permanent total disabilities as for fatalities. Permanent total disability is, however, a greater burden to relatives and the community than death. In recognition of this obvious fact the time loss for permanent total disability has been fixed at 35 years or 10,500 working days. The relative importance or burdensomeness of permanent total disabilities as compared with fatalities is thus established rather arbitrarily. After further experience it may be advisable to change the relative weights. The system of weighting used does recognize, however, the undeniable fact that complete permanent incapacity of a worker is a greater burden than his death; and some recognition, even if unscientific, is better than ignoring the obvious facts.

PERMANENT PARTIAL DISABILITIES.

A proper weighting for permanent partial disabilities in terms of days lost is even more difficult than for death and permanent total disabilities. An examination of the various compensation acts in existence, however, gives a clue worth following in the quest for some method of estimating the severity of permanent partial disabilities in terms of days lost. First, it appears that all compensation acts agree in fixing the loss of an arm as the most serious injury less than total disability. Most acts, however, seem illiberal in the amount of compensation granted for this injury. The New York act is one of the most liberal. It grants for loss of arm compensation for 312 weeks, which is equivalent to 1,872 working days. Inasmuch as the New York scale is based on two-thirds of wages it may be assumed that the entire economic burden was recognized to be one-half greater than the benefit actually allowed. The loss of an arm would thus be equivalent to an economic loss of 468 weeks, or 2,808 days. This in turn is equivalent to about 31 per cent of the allowance fixed above for death (9,000 days) and 27 per cent of the time loss for permanent total disability (10,500 days). This seemed a reasonable valuation of the arm in relation to permanent total disability and death, and was thus adopted for the scale to be used by the bureau.

Having thus fixed a time value for the arm, it remained to value the other permanent partial disabilities. There is a striking similarity among the various acts in the relation of compensation benefits granted for loss of an arm to those granted for the lesser disabilities.

The degree of this uniformity is indicated by the following table in which the loss of an arm is rated at 100:

TABLE 16.—COMPARATIVE TIME ALLOWANCES FOR SPECIFIED DISABILITIES UNDER THE LAWS OF VARIOUS STATES: OTHER DISABILITIES COMPARED WITH LOSS OF ARM.

Weeks for which compensation is payable.

State.	Loss of—											
	Arm.	Hand.	Leg.	Foot.	Eye.	Thumb.	One joint of thumb.	First finger.	Second finger.	Third finger.	Fourth finger.	Great toe.
Connecticut[1]	208	156	182	130	104	38	19	38	30	25	20	38
Illinois[2]	200	150	175	125	100	60	30	35	30	20	15	30
Indiana[1]	200	150	175	125	100	60	15	30	30	30	30	30
Iowa[1]	200	150	175	125	100	40	20	30	25	20	15	25
Kentucky[1]	200	150	200	125	100	60	30	45	30	20	15	30
Maine[3]	150	125	150	125	100	50	25	30	25	18	15	25
Maryland[1]	200	150	175	150	100	50	25	30	25	20	15	25
Massachusetts[2]	50	50	50	50	50	12	12	12	12	12	12	12
Michigan	200	150	175	125	100	60	30	35	30	20	15	30
Minnesota[1]	200	150	175	125	100	60	30	35	30	20	15	30
Montana[1]	200	150	180	125	100	30	20	20	15	12	9	15
Nevada[2]	217	173	195	152	108	65	32½	39	30	22	17	30
New Jersey[2]	200	150	175	125	100	60	30	35	30	20	15	30
New York[1]	312	244	288	205	128	60	30	46	30	25	15	38
Ohio[2]	200	150	175	125	100	60	30	35	30	20	15	30
Oklahoma[1]	250	200	175	150	100	60	30	35	30	20	15	30
Oregon[4]	416	329	381	277	173	104	52	69	39	35	26	43
Pennsylvania[1]	215	175	215	150	125	......	......	......	......	......	......	......
Vermont[1]	170	140	170	120	100	40	20	25	20	15	10	20
Wisconsin[1]	240	160	160	120	120	40	20	20	15	8	10	20
Relative time allowance. (Loss of arm=100.)												
Connecticut	100	75	88	63	50	18	9	18	14	12	10	18
Illinois	100	75	88	63	50	30	15	18	15	10	8	15
Indiana	100	75	88	63	50	30	8	15	15	15	15	15
Iowa	100	75	88	63	50	20	10	15	13	10	8	13
Kentucky	100	75	100	63	50	30	15	23	15	10	8	15
Maine	100	83	100	83	67	33	17	20	17	12	10	17
Maryland	100	75	88	75	50	25	13	15	13	10	8	13
Massachusetts	100	100	100	100	100	24	24	24	24	24	24	24
Michigan	100	75	88	63	50	30	15	18	15	10	8	15
Minnesota	100	75	88	63	50	30	15	18	15	10	8	15
Montana	100	75	90	63	50	15	10	10	8	6	5	8
Nevada	100	80	90	70	50	30	15	18	14	10	8	14
New Jersey	100	75	88	63	50	30	15	18	15	10	8	15
New York	100	78	92	66	41	19	10	15	10	8	5	12
Ohio	100	75	88	63	50	30	15	18	15	10	8	15
Oklahoma	100	80	70	60	40	24	12	14	12	8	6	12
Oregon	100	79	92	67	42	25	13	17	9	8	6	10
Pennsylvania	100	81	100	70	58	......	......	......	......	......	......	......
Vermont	100	82	100	71	59	24	12	15	12	9	6	12
Wisconsin	100	67	67	50	50	17	8	8	6	3	4	8

[1] Payments under this schedule are exclusive or in lieu of all other payments.
[2] Payments under this schedule are in addition to payments on account of temporary total disability.
[3] Payments cover total disability. Partial disability may be compensated at end of periods given for not over 300 weeks in all.
[4] The periods named in this line are to be reduced by any time for which payments on account of temporary total disability have been made.

Because of the substantial uniformity between the States the scale of awards of almost any State would have given approximately the same relative importance to minor dismemberments compared to loss of arm. The New York scale was adopted as being one of the latest developed, and also because its system of classification of injuries was one readily adaptable to the form in which a large part of the data secured by the bureau was given.

As a result of the above procedure permanently disabling injuries, as well as death itself, were assigned values, expressed in terms of a common denominator—namely, workdays lost. These values, to repeat, are necessarily arbitrary, but the fact that they are not, and can not be, absolutely accurate, in no way diminishes their usefulness for the purpose in view.

The following table brings together the time losses for death and the more common forms of permanent disabilities as finally adopted for the bureau's scale. Columns of percentages based on this scale of time losses are also given, showing, first, the relative importance of the lesser injuries as compared with the loss of an arm, and, second, the relative importance of time losses from death and from the lesser injuries as compared with the time loss from permanent total disability. Other forms or combinations of disabilities than those shown in this list, such as minor injuries to the eye, may be assigned intermediate values. This is not done here as the classification is sufficiently fine to cover practically all of the data used in the present report. If it seems desirable, further elaboration of the table can easily be made without disturbing the basic scale.

TABLE 17.—TIME LOSSES FIXED FOR DEATH AND PERMANENT DISABILITIES.[1]

	Time losses in days.	Per cent of loss of arm.	Per cent of permanent total disability.
Death	9,000		85.7
Permanent total disability	10,500		100.0
Loss of members:			
Arm	2,808	100.0	26.7
Hand	2,196	78.2	20.9
Leg	2,592	92.3	24.7
Foot	1,845	65.7	17.6
Eye	1,152	41.0	11.0
Thumb	540	19.2	5.1
One joint of thumb	270	9.6	2.6
First finger	414	14.7	3.9
Second finger	270	9.6	2.6
Third finger	225	8.0	2.1
Fourth finger	135	4.8	1.3
Great toe	342	12.2	3.3
One joint of great toe	171	6.1	1.6

[1] For comparison of this scale with that proposed by the International Association of Industrial Accident Boards and Commissions see Appendix K.

This schedule supplies a series of constants by which death and permanent injuries may be weighted in terms of a common unit—time lost in days—which is also the same unit as that used for measuring temporary disabilities. Multiplying the number of deaths and permanent disabilities by the time loss determined for each and adding the products to the days lost through temporary disabilities, a figure is obtained which represents the total days lost from injuries. Dividing this number, representing total days lost, by the number of full-time workers gives as a quotient the average number of days lost per full-time worker. This last figure may be called the accident severity rate, since it shows the burdensomeness or seriousness of the accidents analyzed.

The whole process of working out the accident severity rate may be illustrated as follows: Plant A operated 4,200,000 man-hours in 1915, requiring 1,400 full-time (300-day, 10-hour-per-day) workers. During the year, 324 accidents occurred, resulting in 1 death and the loss of the following members: 2 arms, 1 foot, 5 thumbs, 25 first fingers, while the 290 temporary disabilities showed a time loss of 2,790 days. Applying the time losses in the above table to these data, the following results are obtained:

TABLE 18.—TIME LOSSES IN ONE PLANT.

	Time loss (in days).	
	Per case.	Total.
1 death	9,000	9,000
2 arms	2,808	5,616
1 foot	1,845	1,845
5 thumbs	540	2,700
25 first fingers	414	10,350
290 temporary disabilities		2,790
Total		32,301

The total number of days lost, 32,301, divided by the number of full-time workers, 1,400, gives an average of 23 days per full-time worker. This is what is here called the accident severity rate, expressed in terms of days. The accident frequency rate for the same group per 1,000 full-time 300-day workers would be $324 \div \frac{1400}{1000} = 231$.

ILLUSTRATIONS OF THE USE OF SEVERITY RATES.

The preceding paragraphs have explained the meaning of accident severity rates and the method by which they are obtained. The significance of such rates in their practical application is indicated in the two following illustrations:

In the table below comparison is made of the accident experience for a year of the iron and steel industry, as represented by a large plant, and of the machine-building industry, as represented by a group of plants. Frequency rates and severity rates are shown in parallel columns.

TABLE 19.—ACCIDENT RATES IN STEEL MANUFACTURE AND IN MACHINE BUILDING.

Industry.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Iron and steel (1913)	7,562	1.9	4.6	108.0	114.5	16.6	2.2	2.4	21.2
Machine building (1912)	115,703	.3	3.6	114.1	118.0	2.9	1.6	1.1	5.6

Examination of the columns giving total frequency rates and total severity rates shows that, on the basis of frequency, the machine-building plants were more hazardous than the steel plant—the respective rates being 118 as against 114.5 per 1,000 full-time workers. On the basis of severity, however, the steel plant was almost four times as hazardous as machine building—the days lost per full-time worker being 21.2 and 5.6, respectively. It is clear that as between these diametrically opposite showings of the relative hazards of the two industries, the severity rates offer a decidedly more accurate measure of true hazard. In machine building there is opportunity for many minor injuries, but the danger of serious injury is much less than in the steel industry. The severity rate brings out this fact.

The second illustration shows how, over a period of years, within the same establishment, accident severity rates may run counter to accident frequency rates. The next table gives data of this character. It shows the accident experience of a large steel plant over a period of four years. The plant is one in which most serious attention has been devoted to the prevention of accidents. Chart 1 presents the same material in graphic form.

TABLE 20.—ACCIDENT EXPERIENCE OF A LARGE STEEL PLANT, 1910 TO 1913.

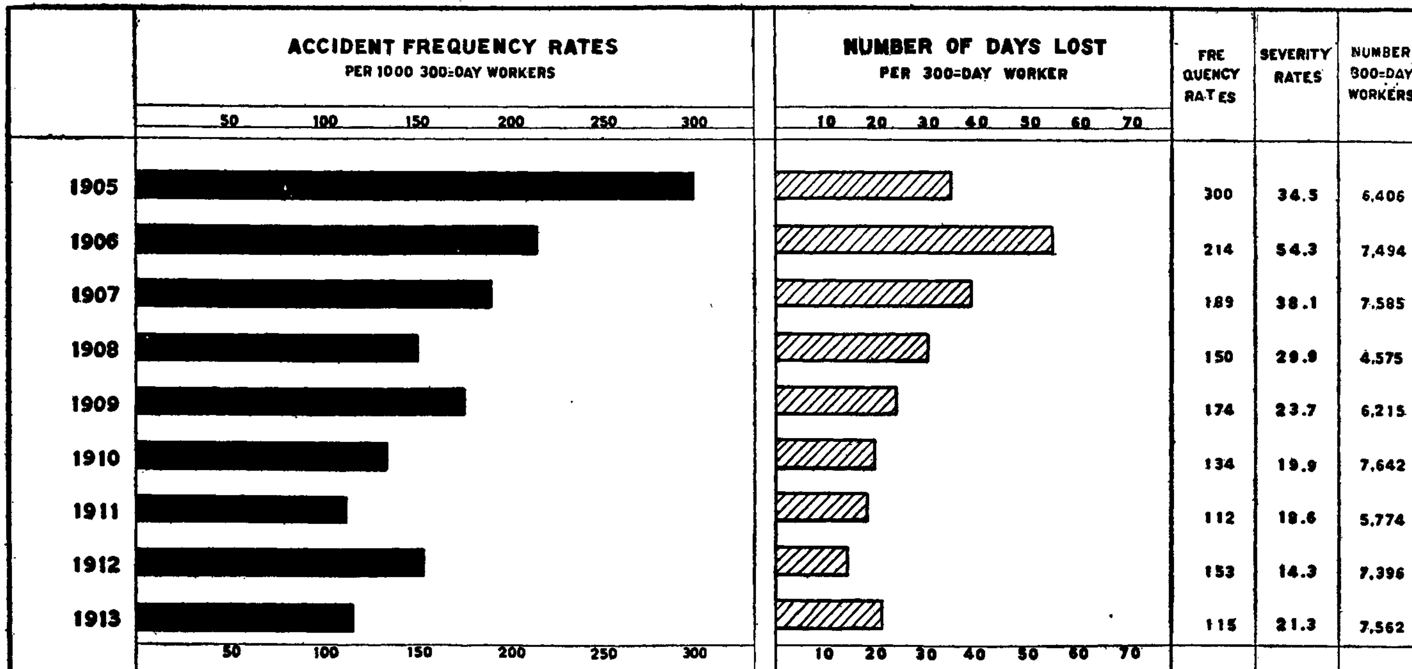
Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	7,642	1.7	4.3	127.5	133.5	15.3	2.4	2.2	19.9
1911	5,774	1.6	3.6	106.6	111.8	14.1	2.1	2.4	18.6
1912	7,396	.7	6.5	146.3	153.5	6.0	5.5	2.8	14.3
1913	7,562	1.9	4.6	108.0	114.5	16.7	2.2	2.4	21.3

Limiting attention to the columns showing total rates, it will be noted that in 1910 the frequency rate was 133.5 per 1,000 300-day workers and the severity rate was 19.9 days lost per 300-day worker. The next year, 1911, shows a decrease in both frequency and severity. In 1912, however, there was a marked increase in frequency—from 111.8 to 153.5—but the severity rate dropped from 18.6 to 14.3. In other words, accidents had considerably increased in frequency, but they were less serious in their total results. In 1913 this experience was reversed. A marked reduction occurred in accident frequency—from 153.5 to 114.5—while the severity rate jumped from 14.3 to 21.3. In other words, the year 1913, instead of being a "good" year, as it might be assumed to be under the system of frequency rates, was the worst of the four years covered by the table.

These illustrations bring up certain points which it seems desirable to emphasize. The first concerns the use of terms. Severity rates

CHART 1.—FREQUENCY AND SEVERITY OF ACCIDENTS IN THE IRON AND STEEL INDUSTRY.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.



	FREQUENCY RATES	SEVERITY RATES	NUMBER 300-DAY WORKERS
1905	300	34.5	6,406
1906	214	54.3	7,494
1907	189	38.1	7,585
1908	150	29.9	4,575
1909	174	23.7	6,215
1910	134	19.9	7,642
1911	112	18.6	5,774
1912	153	14.3	7,396
1913	115	21.3	7,562

derived in the manner explained are expressed for convenience in terms of workdays lost. For instance, the steel plant referred to above is represented as having a severity rate, in 1913, of 21.3 days lost per 300-day worker. The term "days lost" as thus used is to some extent a statistical abstraction, but it is close enough to concrete fact to permit of its use in its ordinary sense without any considerable degree of error, provided that the weighting scale employed is a reasonable one. In any case, however, the real significance of severity rates is in their use, not as positive amounts, but as relative amounts, as indicating the relation between groups. Thus, to recur to the example of the steel plant mentioned, the important fact is that the severity rate for 1913 shows an increase over that for 1912 in the relation of 21.3 to 14.3.

This leads to a second point which can not be too much emphasized: The fact that inasmuch as the real significance of severity rates is in the measurement of relative hazards, the character of the weighting scale used becomes comparatively unimportant. Thus, by changing the weights in the scale offered above, the resulting severity rates may be considerably altered in their positive amounts, but unless the changes are of a very radical character the relations between the rates for different groups will remain substantially the same. In other words, it is desirable to have the scale used as accurate as possible, but the fact that a completely accurate scale can not be devised does not impair the value of accident severity rating.

Another fact deserving emphasis is that severity rates have a very important advantage over frequency rates, in that the effect of errors in reporting is minimized. Accident reports are probably never absolutely complete, and, as a rule, the completeness of reporting is in direct proportion to the seriousness of injury. The more serious the injury the greater the likelihood of its being reported. Frequently the reporting of minor injuries is extremely incomplete. Inasmuch as the accuracy of frequency rates depends upon the completeness of accident reports, and as all accidents have the same weight, a failure to report any considerable number of minor accidents renders the rates obtained of very little value. Such is not the case with severity rates. Here the disabilities are weighted according to their importance, and a large group of minor disabilities has comparatively little effect upon the derived severity rate. Thus, from the material available concerning the iron and steel industry, it is estimated that the total exclusion of all disabilities of less than two weeks will rarely diminish the total severity rate for that industry as much as 1 per cent, whereas such an exclusion would diminish frequency rates as much as 60 per cent. In the machine-building industry, according to data collected by the bureau for that industry, the corresponding percentages are 7 and 70.

GROWING RECOGNITION OF THE IMPORTANCE OF SEVERITY RATING.

It is safe to say that all who have been concerned with accident studies and accident-prevention work have felt the need of some system of severity rating, such as that developed in the present chapter. The International Association of Industrial Accident Boards and Commissions has recognized the importance of the subject and through its committee on statistics has the matter now under consideration. The committee has unanimously approved the principle of severity rating. The discussion now concerns simply the scheme of rating to be adopted. The one worked out and applied in the present report is believed to meet the necessary tests of a simple, workable system. It has already been approved and adopted by a number of important establishments.

USE OF RATES IN THE STUDY OF ACCIDENT CAUSES.

Frequency and severity rates, as above described, may be applied to the measurement of accident causes. This procedure is logical and, as carried out in detail in a later chapter, produces interesting and very valuable results. Inasmuch, however, as the computation of accident rates according to causes is somewhat novel, a brief preliminary description of the method used is desirable.

For any plant, department, occupation, or other industrial group for which the amount of employment and the number of accidents are known, an accident rate may be computed. This total rate may then be apportioned among the various causes responsible for the accidents. For example, in a group of blast furnaces, with a total frequency rate of 200 cases per 1,000 full-time workers, it was found on analysis that 58 of each 200 cases were due to molten metal, 27 to handling tools and objects, leaving 115 as due to miscellaneous causes. The frequency rate of molten metal as a cause of accident in these blast furnaces was, therefore, 58 per 1,000 workers; of handling tools, 27 per 1,000 workers, etc.

The value of such rates to the safety man is clearly evident. They indicate, in the example given, that molten metal was the most important single cause of accident in blast furnaces, and the one to which especial attention must be directed.

In the case just cited, the department was taken as the unit, the rates being based on the total employment for the department. If a smaller unit, such as the occupation, be used as a basis, the rates would be based on the amount of employment in the individual occupation. In the case of the above group of blast furnaces it was possible to isolate certain important occupations, to draw accident rates for each, and to apportion such rates among the different causes. Thus it was found that while the frequency rate for the blast-furnace department as a whole was 200 per 1,000 workers, the frequency rate for the "cast-house men" was 380 per 1,000 workers employed in that occupation. Analysis of causes of accidents showed this total of 380 to be made up of a rate of 201 cases from molten metal, 43 from falling objects, and 136 from "miscellaneous causes."

These occupational cause rates are even more valuable to the safety man than are the preceding departmental cause rates, as they indicate still more precisely the points of greatest hazard. Unfortunately it is not often possible to use the occupation as a unit as plants rarely keep records of employment in such detail, and even if this is done the number of employees in the occupation is often so small as to be inconclusive.

These cause rates, whether based on the department, the occupation, or any other group, are true accident rates, analogous to the death rates by disease as used in mortality studies. In such studies it is customary to divide the general death rate for a community into specific rates for the various diseases causing death. Thus a general death rate of 20 per 1,000 for a given city may be made up of the following specific rates—tuberculosis 5, typhoid fever 2, other causes 13. These rates, it may be noted, measure the real prevalence of the several diseases in a way that percentages can not do. Thus, in the year noted, deaths from tuberculosis constituted 25 per cent of all deaths (5 out of 20). Suppose that in the following year a typhoid epidemic increased the typhoid rate from 2 to 7 and thus caused the general rate to jump from 20 to 25, the tuberculosis death rate of 5 per 1,000 would remain as before, but expressed in percentages tuberculosis would have decreased from 25 per cent (5 out of 20) to 20 per cent (5 out of 25) as a cause of death. The percentage change would suggest a great decrease in the tuberculosis hazard, which, however, as the rate accurately indicates (5 per 1,000), remained absolutely stationary. The attempt to study causes of death by means of percentage figures is thus liable to be entirely misleading. Rates, on the other hand, offer an absolutely reliable measure. This is equally true, and for the same reasons, in the study of accident causes.

The above illustrations of the use of cause rates were limited, for the sake of simplicity, to frequency rates. Severity rates can, of course, be applied in precisely the same way and with even more valuable results, inasmuch as severity rates, as pointed out above, are a truer measure of accident hazard than are frequency rates.

USE OF RATES IN THE STUDY OF NATURE OF INJURY, LABOR RECRUITING, AND OTHER FACTORS.

Frequency and severity rates may also be applied to the study of the nature of injury in precisely the same way as they may be applied,

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as described above, to the analysis of accident causes. Thus, in a group of blast furnaces, with a total frequency rate of 191 cases per 1,000 full-time workers, it was found on analysis that 89 out of each 191 cases resulted in bruises and lacerations, 45 cases in burns, 10 cases in fractures, and 47 cases in various other injuries. This being so, it is quite correct to say that bruises and lacerations in these blast furnaces had a frequency rate of 89 cases per 1,000 workers, burns a frequency rate of 17 cases, and so on. These are true rates, with the same superiority to percentages as a measure of the frequency and severity of injuries of various kinds as was noted to be true in the case of accident causes.

Moreover, outside the accident field proper, there are many collateral subjects to which the rate method may be very profitably applied. An important instance of this is the employment of new men. By relating the number of 300-day workers to the number of new men hired during a given time, a rate is obtained which may be referred to as the "labor recruiting rate." As is later shown (p. 133), there is an interesting and important connection between this "labor recruiting" rate and the accident rate. Usually, the taking on and use of new men has a marked tendency to increase the accident occurrence of a plant.

In similar manner, rates based on the amount of employment may be derived for production, labor costs, sickness, and many other subjects.

CHAPTER II.

THE PHYSICAL CAUSES OF ACCIDENTS.

It can not be too often repeated that the true object of accident statistics is to offer practical information for use in the active work of accident prevention. From this standpoint the exact degree in which accidents occur is a matter of somewhat subordinate importance. The important thing is to learn precisely how and why they occur. This involves primarily the study of accident causes. It is with these that the safety man is chiefly concerned. The knowledge that his industry or plant has a high accident rate may be an incentive to harder work on his part, but has little other practical value. He must trace back the high rate to its causes before he can be in a position to apply effective remedial measures.

The word "causes" as here employed refers solely to what may be called physical causes—that is to say, those incident to machinery, structure, and mechanical appliances. The workman himself is sometimes regarded as a cause of accident, but, as usually applied, this term is an improper one. This subject is discussed in Chapter VII.

In all of this discussion of causes it must be constantly borne in mind that all comparisons are on the rate basis. The method used in computing frequency and severity rates was explained in the preceding chapter, as also was the application of such method to the derivation of cause rates. It is sufficient in this place to repeat that cause rates so derived are true rates, analogous to disease rates in mortality studies. Thus, in the next table, hot metal, as a cause of accident in the steel industry, is spoken of as having a frequency rate of 20.9 cases per 1,000 workers. This means that for each 1,000 workers employed in the industry there were 20.9 cases of accident due to hot metal.

The classification of causes used in this report, as in previous reports of the bureau, had necessarily to be worked out prior to the recent adoption of a standard classification by the International Association of Accident Boards and Commissions. The two classification schedules, however, are not greatly dissimilar as regards the major groupings, although the terms used are not always the same.[1]

PRINCIPAL ACCIDENT CAUSES IN THE IRON AND STEEL INDUSTRY.

The following two tables show, in condensed form, the relative importance of the principal causes of accidents in the iron and steel industry as a whole. Eleven major causes, or rather groups of

[1] For the association schedule see Bulletin No. 201 of the United States Bureau of Labor Statistics, p. 73.

causes, are listed in Table 21, and where the available material permitted these are further subdivided in Table 22. The data upon which the tables are based are combined from a large number of plants, representing a total of 191,846 300-day workers. The accompanying chart projects most of the information of the tables in graphic form.

TABLE 21.—ACCIDENT RATES FOR THE PRINCIPAL GROUPS OF ACCIDENT CAUSES IN THE IRON AND STEEL INDUSTRY, 1905 TO 1914 COMBINED.

[Based upon an exposure of 191,846 300-day workers.]

Cause.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Boilers and steampipes	....	0.04	0.50	0.54	[1]	[1]	[1]	0.02
Engines and motors	0.01	.07	.67	.75	[1]	[1]	[1]	.17
Power transmission	.01	.03	.07	.10	[1]	[1]	[1]	.10
Working machines	.08	.82	14.43	15.33	0.75	0.44	0.21	1.40
Cranes and hoists	.29	.72	15.53	16.54	2.63	.35	.32	3.30
Hot substances	.30	.14	20.49	20.93	2.72	.19	.36	3.27
Falling objects	.17	.46	35.67	36.30	1.50	.19	.54	2.23
Falls of worker	.16	.05	12.33	12.54	1.45	.05	.21	1.71
Handling tools and objects	.02	.61	34.93	35.56	.19	.32	.41	.92
Power vehicles	.21	.44	5.92	6.58	1.92	.39	.13	2.44
Miscellaneous	.15	.30	28.78	29.23	1.36	.29	.38	2.03
Unclassified and not reported	.02	.16	5.77	5.95	[1]	[1]	[1]	.17
Total	1.42	3.84	175.16	180.42	12.86	2.31	2.59	17.76

[1] Not computed because the number of cases is too small.

CHART 2.—ACCIDENT RATES FOR PRINCIPAL ACCIDENT CAUSES IN THE IRON AND STEEL INDUSTRY.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

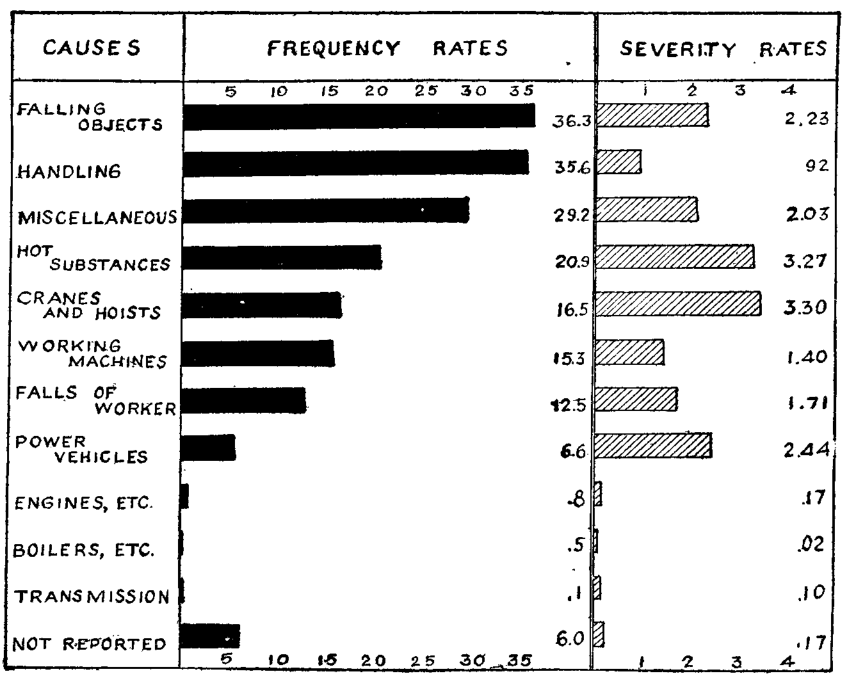

TABLE 22.—ACCIDENT RATES FOR THE SUBDIVISIONS OF THE GROUPS OF ACCIDENT CAUSES SHOWN IN TABLE 6.

Cause.	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).
Boilers and steam pipes	0.54	0.02
Engines and motors	.75	.17
Power transmission	.10	.10
Working machines:		
Adjusting	.87	.13
Operating	7.51	.42
Oiling and cleaning	.33	.11
Repairing	.43	.29
Breakage	.15	....
Objects flying from machine	4.42	.27
Unclassified	1.62	.18
Total	15.33	1.40
Cranes and hoists:		
Adjusting loads	2.88	.09
Operating	.09	.06
Oiling and cleaning	.06	.10
Repairing	.11	.06
Breakage	.48	.25
Falling loads	2.34	1.04
Hoisting and lowering	1.89	.28
Unclassified	8.69	1.42
Total	16.54	3.30
Hot substances:		
Corrosives	.18	.01
Electricity	1.78	.67
Explosives	.35	.33
Flames	1.79	.26
Hot metal	5.30	.61
Hot metal flying	7.85	1.11
Unclassified	3.68	.28
Total	20.93	3.27
Falling objects:		
Collapse of scaffolds	.60	.16
Stored or piled material	2.16	.28
From trucks, etc	1.67	.19
From buildings	.70	.06
Unclassified	31.17	1.54
Total	36.30	2.23

Cause.	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).
Falls of worker:		
From ladders	0.68	0.11
From scaffolds	.54	.20
From vehicles	.69	.01
From structures	1.29	.65
From other elevations	.68	.22
Into excavations	.17	(1)
Into unguarded openings	1.05	.16
Unclassified (largely insecure footing)	7.44	.44
Total	12.54	1.71
Handling tools and objects:		
Tools in hands of worker	9.35	.20
Tools in hands of fellow worker	1.25	.02
Sharp objects	8.06	.09
Loading and unloading	3.06	.15
Lifting	2.92	.03
Objects flying from tools	3.79	.28
Unclassified	7.13	.15
Total	35.56	.92
Power vehicles	6.58	2.44
Miscellaneous:		
Running into objects	4.88	.06
Poisons	.01	(1)
Flying objects n. o. s	10.45	.29
Doors, windows, etc	.27	.01
Asphyxiating gas	.81	.81
Heat	.74	.20
Cold	.01	(1)
Projecting nails	1.28	.01
Violence	.04	(1)
Moving objects n. o. s	10.74	.65
Unclassified and not reported	5.95	.17
Total	29.23	2.03
Grand total	180.42	17.76

[1] Less than 0.005.

Examination of the rates for the several causes, as listed in Table 22, develops some interesting points of comparison.

In the first place, it is apparent that the production and distribution of power—represented by the first three items—is of relatively small importance as a cause of accident, the severity rate for boilers and steam pipes, engines and motors, and power transmission, combined, being only 0.29 day lost per worker as against 17.76 days for all causes. Since in modern plants the distribution of power is largely electrical, a portion of the severity rate of 0.67 day per worker charged, later in the table, to "electricity" might properly be assigned to power distribution. But even with this addition, the total severity rate for power production and distribution is relatively very small.

Coming next to "working machines," it will be noted that the greatest frequency (7.51 cases per 1,000 workers) and the highest severity (0.42 day per worker) occur in the operation of such machines. This is mainly due to accidents resulting from the worker's being caught by gears or belts or by the moving work. This type of accident has tended to decrease rapidly in recent years. Injuries due to "objects flying from machines" (frequency rate, 4.42 cases per 1,000 workers; severity rate, 0.27 day per worker) are largely injuries to the eyes. These are preventable by the use of proper protective goggles. It may also be pointed out that "repairing of machines" is shown to have a rather high severity rate (0.29 day per worker).

In "cranes and hoists" the most serious single element is seen to be the falling load. Since breakage of any part of the crane itself is shown as a separate item, the group listed as "falling loads" includes those cases, first, where chains or cables break, and, second, the less frequent cases where the load slips from the loop and falls. The latter type of accident comes about from imperfect adjustment of the loop or from the fault of the crane operator in improper lifting or sudden movement, and it can only be prevented by the selection and instruction of the men. As regards defective chains and cables, which are responsible for the majority of "falling loads," the main reliance so far has been upon the careful inspection and annealing of chains. The most recent studies [1] of the matter seem to indicate that no amount of effort in this regard will prevent serious accidents unless the greatest care is used in determining and applying rules regarding safe loads. The high rates for "falling loads" in the iron and steel industry add emphasis to those studies. The only other item under "cranes and hoists" needing special comment is the severity rate of 0.25 day per worker for "breakage." The size of this rate suggests the need which existed for such revision in the specifications for crane construction as has been made in recent years. Many older types of cranes were seriously lacking in strength and were often subjected to usage far beyond the stress for which they were designed.

Next to "cranes and hoists," with a total severity rate of 3.30 days per worker, comes "hot substances," with a total rate of 3.27 days, as the most serious group of causes. Of this total rate of 3.27 days, "hot metal" and "hot metal flying" together contribute 1.72 days. These items, indeed, stand out preeminently as the distinctive hazards of the industry. The considerable frequency (1.78 cases per 1,000 workers) and the rather high severity (0.67 day per worker) of accidents due to electricity are also to be noted.

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[1] See Proceedings of National Safety Council, Fourth Congress, 1915, p. 613, et seq., and of Fifth Congress, 1916, p. 501.

"Falling objects" shows the highest frequency rate (36.3 per 1,000 workers) of any of the groups, and also ranks high in severity (2.23 days lost per worker). The high rates of this group are due, not so much to unusual or serious hazards of any kind as to the multiplicity of simple accidents such as the letting fall of objects which are being handled or carried. These can be reached through better working methods and thorough instruction of the men. The fall of stored or piled material contributes an important share of the total severity rate (0.28 day per worker) and this hazard has been, and will be still further reduced with the development of standard specifications for piling material and removing it from the piles.

"Falls of worker" illustrates forcibly two points: First, the danger of insecure scaffolds. Falls from these are largely due to some defect in construction of the scaffords or failure properly to safeguard them with railings. Second, the hazard of insecure footing on floors, stairs, and other places. It was not possible to isolate the cases of the second class, but it is known that a considerable majority of the cases entered as "unclassified" were due to the factor of insecure footing.

The high severity rate of "falls from structures" (0.65 day per worker) was very largely due to an extraordinarily large number of such accidents in blast furnaces. A moment's consideration of blast furnace structure, as shown in plate 1, will explain the danger confronting mechanics who are obliged to climb about and work upon such furnaces. The rate reflects to a considerable degree the earlier conditions when the safeguards seen in the plate were not installed.

"Handling tools and objects" stands next in its frequency rate (35.6 cases per 1,000 workers) to falling objects (36.3 cases) but its severity rate (0.92 day per worker) is much the lowest of the major groups, and when it is observed that of the total severity rate of 0.92 day, 0.20 day is due to the worker's use of his tools and 0.28 day to objects flying from tools it is evident that there are practically only two important remedies possible, namely, greater care and skill on the part of the worker and the use of protective goggles, as a very large part of the severity of accidents due to objects flying from tools arises from injuries to the eye.

Power vehicles on tracks show the highest severity rate (2.44 days per worker) in proportion to the frequency (6.58 cases per 1,000 workers) of any of the larger cause groups. Comment upon this fact will be made in a later section.

The miscellaneous group requires no comment except that the high severity rate of asphyxiating gas (0.81 day per worker) arises almost wholly from its presence in blast furnaces and that heat (producing cramps and exhaustion) is an important factor almost exclusively in open hearths, plate, and sheet mills.

IMPORTANCE OF PRINCIPAL ACCIDENT CAUSES IN DIFFERENT DEPARTMENTS.

The preceding tables and discussion brought out, in a broad way, the relative importance of the various accident causes for the iron and steel industry as a whole. Each of the 11 cause groups there listed will now be discussed with reference to its importance in the different departments of the industry—blast furnaces, Bessemer, etc.

BOILERS AND STEAM PIPES, ENGINES AND MOTORS, AND POWER TRANSMISSION.

Table 23 shows, by departments, the frequency and severity of accidents due to the first three cause groups listed in the preceding table—namely, boilers and steam pipes, engines and motors, and power transmission.

It is to be borne in mind that in this, as in all the following "cause" tables, the rates shown are based on the employment in the particular department concerned. Thus, the frequency rate of 1.8 cases for boilers and steam pipes in blast furnaces means that of each 1,000 300-day workers in the blast furnaces there were 1.8 cases of injury due to boilers and steam pipes.

TABLE 23.—BOILERS AND STEAM PIPES, ENGINES AND MOTORS, AND POWER TRANSMISSION AS CAUSES OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Cause.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Boilers and steam pipes	1.8	0.3	1.1	0.1	0.3	0.2	0.5	0.2	0.1	1.8	0.2
Engines and motors	2.2	.2	.8	......	.1	1.0	.6	.9	.3	1.6	.1
Power transmission	......	......	......	......	......	.3	.3	.2	.1	.2	......
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Boilers and steam pipes	.09	.04	.03	.01	.07	.03	.01	.01	(1)	.04	(1)
Engines and motors	.34	.02	(1)	......	.01	.01	.04	.94	.20	.31	(1)
Power transmission	......	......	......	......	......	.33	.01	(1)	.01	.51	......
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.005.

Inasmuch as the three causes dealt with in the above table are of relatively small importance in the iron and steel industry, no discussion of the rates as shown seems to be necessary.

WORKING MACHINES.

The following table shows the frequency and severity of accidents due to the various "working-machine" hazards. It seems desirable again to repeat that the rates shown are, in each case, based on the employment in the particular department. Thus a total frequency rate of 3.3 for working machines in blast furnaces means that for each 1,000 300-day workers in the blast furnaces there were 3.3 cases of injury due to working machines. Chart 3 projects the data of this table in graphic form.

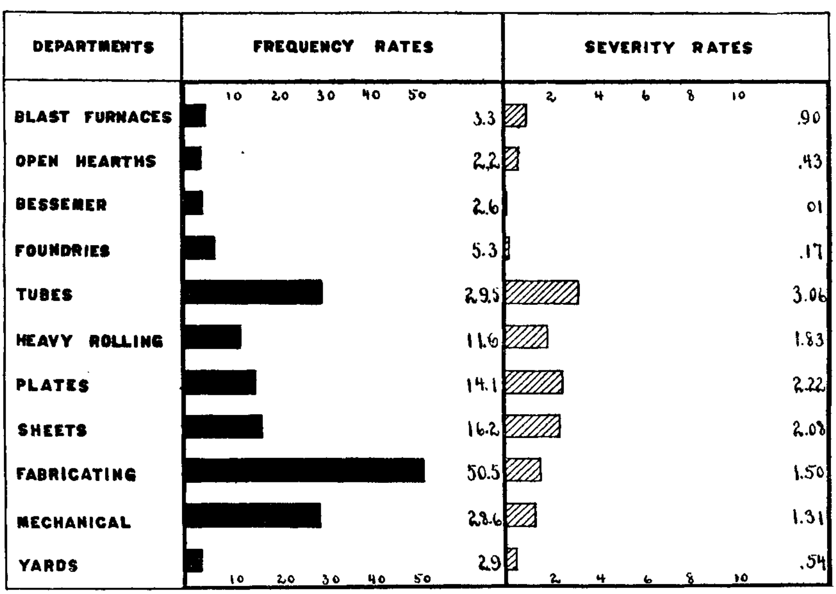
TABLE 24.—WORKING MACHINES AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Working machines.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Adjusting work or machine	0.3	0.1	......	......	0.3	1.1	1.3	1.0	1.7	2.5	0.1
Operating	1.3	1.4	0.9	2.4	16.0	4.1	6.3	12.1	23.9	13.6	.9
Oiling and cleaning	.7	.1	.5	......	.3	.4	.3	.7	1.0	.3	......
Repairing	.3	(1)	.2	.1	......	1.0	.9	.9	.1	.4	.1
Breakage	......	......	.2	......	.1	.3	.1	.2	.5	......	......
Objects flying from machine	.2	.2	.2	2.3	7.8	1.7	2.8	.8	23.0	10.8	.9
Not classified	.5	.4	.8	.5	5.2	2.9	2.4	.4	.3	1.0	1.0
Total	3.3	2.2	2.6	5.3	29.5	11.6	14.1	16.2	50.5	28.6	2.9
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Adjusting work or machine	(2)	......	......	......	0.01	0.06	0.04	0.54	0.04	0.16	0.49
Operating	0.18	0.17	(2)	0.10	1.38	.51	.39	.78	.56	.41	.02
Oiling and cleaning	.69	.23	(2)	......	.02	.01	.03	.51	.05	.01	......
Repairing	.01	......	(2)	.03	......	.76	.75	.22	(2)	.55	(2)
Breakage	......	......	......	......	(2)	.01	......	(2)	.01	......	......
Objects flying from machine	.01	.02	......	.03	1.39	.08	.85	.01	.85	.15	.01
Not classified	.01	.01	......	......	.26	.39	.16	.02	(2)	.03	.02
Total	.90	.43	0.01	.17	3.06	1.83	2.22	2.08	1.50	1.31	.54
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.05. [2] Less than 0.005.

CHART 3.—WORKING MACHINES AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



The great variation in rates between departments is in accordance with the machine activities of each. That fabricating shops (with 50.5 cases per 1,000 workers), tube mills (with 29.5 cases), and the mechanical department (with 28.6 cases) lead in frequency, and that tube mills (with 3.06 days lost per worker) lead in severity will appear appropriate to those familiar with the industry. The high severity rates for plate mills (2.22 days per worker) and for sheet mills (2.08 days) is perhaps less likely to fit in with preconceived ideas.

Two hazards of particular importance incident to "working machines" are "the operating of the machine" and "objects flying from the machine." The first of these may be met by better safeguards and greater skill and care. What better safeguards have done to reduce accidents in machine operations of all kinds will become evident when, as is later done, the course of accident rates in a machine-using department is followed from year to year. As to the second important hazard—objects flying from machines—the steadily increasing use of eye protectors in places where flying chips are at all frequent will doubtless cut the rates toward the vanishing point.

The "repairing" of machines may be noted as having a relatively low frequency rate, but with a high severity rate in most departments. Thus the severity rate for "repairing" is higher in heavy rolling mills (0.76 day per worker) than it is for any other cause in this department, and a similar situation exists in the case of the mechanical department.

CRANES AND HOISTS.

The next table (with accompanying chart) shows the frequency and severity of accidents resulting from the use of cranes and hoists.

TABLE 25.—CRANES AND HOISTS AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Cranes and hoists.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Adjusting loads	0.6	4.5	2.3	10.6	1.2	2.1	4.4	0.8	6.5	1.4	1.6
Operating	.4	.1	......	......	.1	(1)	......	.2	......	.1	.1
Oiling and cleaning	.3	.1	......	.1	......	......	......	......	.2	.1	.1
Repairing	......	.2	.6	.1	......	(1)	.1	.1	.1	.4	......
Breakage	.9	.6	......	1.1	.3	.7	.6	.1	.2	.7	.1
Falling loads	.6	2.0	2.0	3.4	1.2	1.7	4.3	.1	9.1	1.6	1.8
Hoisting and lowering	.6	1.0	1.4	4.3	1.0	1.4	1.5	1.9	8.7	.7	.6
Not classified	4.9	12.6	10.8	15.7	7.2	7.1	15.5	3.1	12.5	5.6	7.7
Total	8.4	21.0	17.0	35.4	11.1	13.0	26.3	6.3	37.2	10.4	12.0

[1] Less than 0.05.

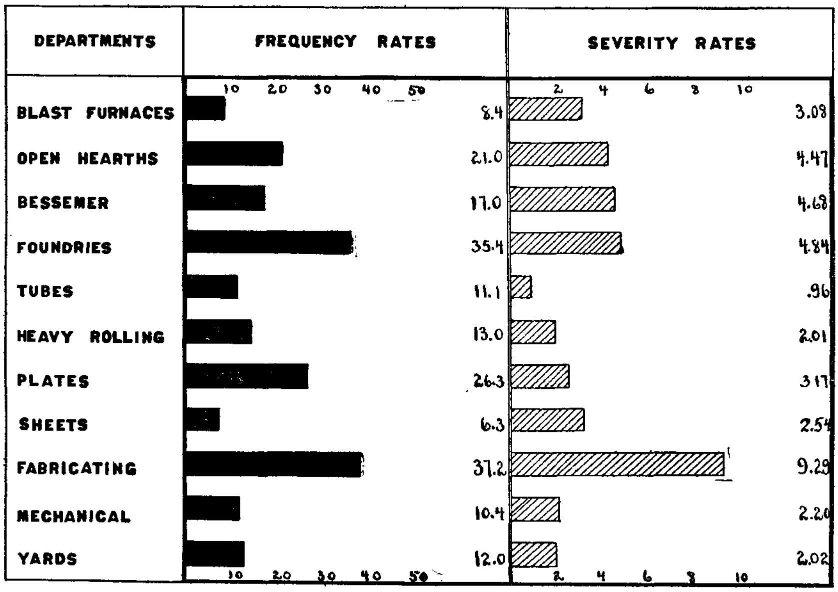
TABLE 25.—CRANES AND HOISTS AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914—Concluded.

Cranes and hoists.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Adjusting loads	......	0.12	0.03	0.42	0.03	0.06	0.14	0.05	0.07	0.04	0.10
Operating	0.67	......	......	......	(1)	(1)	......	.12	......	(1)	.01
Oiling and cleaning	(1)	.74	......	......	......	(1)	......	......	(1)	.02	(1)
Repairing	......	.10	.03	(1)	......	......	(1)	.02	.01	.48	......
Breakage	.02	.75	......	1.19	.04	.25	.01	(1)	(1)	.49	(1)
Falling loads	.66	.77	1.53	1.60	.03	.31	.08	.15	6.59	.03	1.51
Hoisting and lowering	.01	.45	.02	.20	.64	.05	.03	1.03	.50	.02	.07
Not classified	1.72	1.54	3.07	1.43	.22	1.34	2.90	1.16	2.12	1.12	.33
Total	3.08	4.47	4.68	4.84	.96	2.01	3.17	2.54	9.29	2.20	2.02
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

1 Less than 0.005.

CHART 4.—CRANES AND HOISTS AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



This table brings out the fact that the high accident hazards of cranes and hoists are remarkably uniform for the several departments. This is true for both frequency rates and severity rates.

The fabricating shops lead in the frequency of accidents from cranes and hoists, with a total rate of 37.2 cases per 1,000 workers in such shops, and also lead in severity, with a rate of 9.29 days per worker. The constant use of the crane in every step of the fabricating processes suggests that high accident rates from this cause are to be expected. But the actual rates, as just quoted, are unduly in excess of those for the other departments. There is no reason why they should be so. Safety men in charge of fabricating shops should examine this situation critically. It ought to be improved.

When the details of the table are examined, it becomes evident that the excessively high rates of fabricating shops are due mainly to the item "falling loads," which has a frequency of 9.1 cases per 1,000 workers and a severity of 6.59 days per worker. No other department approaches either this frequency or this severity, though "falling loads" stands at the head of the crane hazards listed in a majority of the departments. As has already been pointed out, the falling of loads results more frequently from the failure of chains than from any other single cause, and in this connection reference may again be made to important recent discussions on the subject.[1]

The question of safe load for chains intrudes constantly and is far from settled. Neither can there be said to be well founded opinion regarding the usefulness of chain annealing, although it may confidently be asserted that some annealing is a danger trap. A false sense of security is fostered by it and the end is death.

It is probable that substitution of cables for chains wherever practicable would tend to accident reduction. The cable gives warning before letting go altogether. A weldless chain of English manufacture is on the market, which shows tests of such a character as to make it worthy of consideration.

A very considerable part of crane hazard arises from ill-considered methods of signaling. In an operation essentially hazardous a precise coordination between the men engaged is of the utmost importance. One large company, on looking into this matter of signals, found that in its plants the same signal was used for precisely opposite purposes.[2] It needs no comment to indicate the danger arising if a man were transferred from one plant to another.

HOT SUBSTANCES.

The importance of hot substances as causes of accidents in the several departments is shown in the next table (with accompanying chart).

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[1] Proceedings of National Safety Council, 1915, p. 613, et seq., and 1916, p. 501, et seq. See safety code for hoisting chains, Appendix A.

[2] For details regarding signaling, construction, crane practice, etc., see "Safe practices," Vol. I, No. 4 published by National Safety Council.

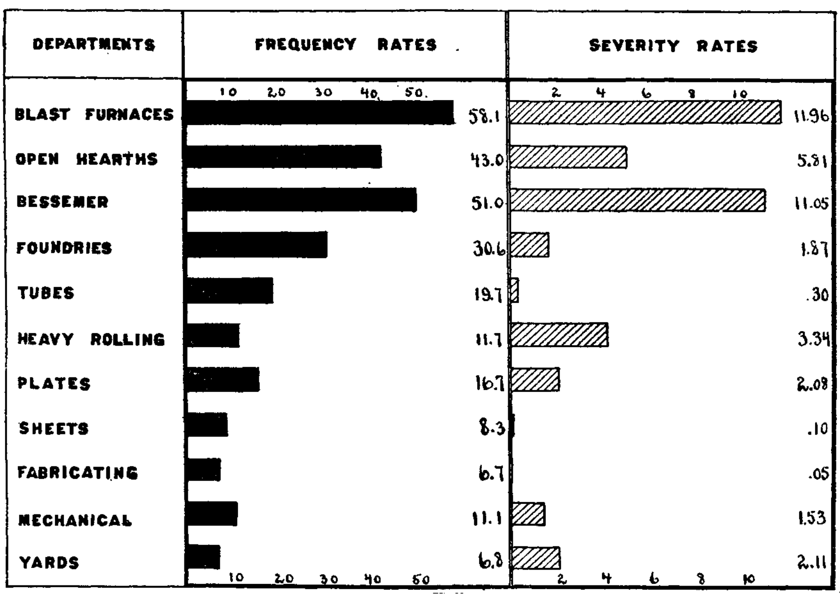
TABLE 26.—HOT SUBSTANCES AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Hot substances.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Corrosives	0.1	0.3	0.2	......	0.3	(1)	0.1	0.5	0.1	0.3	0.2
Electricity	2.5	1.5	.9	1.3	2.2	2.2	3.6	.3	2.2	2.1	.5
Explosives	1.4	.6	.8	.2	.6	.5	......	.5	......	.1	.3
Flumes	5.9	4.4	2.6	2.1	.9	.9	1.7	.8	.4	.9	.5
Hot metal	3.8	10.1	11.1	4.8	12.2	3.6	6.8	5.2	3.4	1.6	.7
Hot material flying	28.6	19.5	30.5	19.3	......	3.2	3.3	......	......	3.8	2.1
Hot water and steam and other	15.8	6.6	5.1	2.9	3.5	1.6	1.3	1.1	.6	2.5	2.5
Total	58.1	43.0	51.0	30.6	19.7	11.7	16.7	8.3	6.7	11.1	6.8
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Corrosives	(°)	0.03	0.01	......	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Electricity	0.68	.01	(2)	0.02	0.03	1.46	1.28	(2)	0.01	1.43	0.98
Explosives	1.58	.49	1.53	(2)	.01	.24	......	0.01	......	(2)	.53
Flumes	1.44	.05	1.42	1.17	.01	.25	.02	.01	(2)	.01	(2)
Hot metal	.09	1.32	4.41	.24	.18	1.02	.71	.06	.02	.02	.01
Hot metal flying	6.36	3.79	3.57	.39	.06	.26	.02	.02	.02	.04	.54
Hot water and steam and other	1.81	.12	.11	.05	......	.10	.05	......	......	.03	.04
Total	11.96	5.81	11.05	1.87	.30	3.34	2.08	.10	.05	1.53	2.11
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.05. [2] Less than 0.005.

CHART 5.—HOT SUBSTANCES AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



Measured by the severity of the injuries inflicted, hot and corrosive substances, as a cause of accidents in the iron and steel industry, stand a close second to cranes and hoists. But unlike cranes and hoists, the hazards of which are spread through all departments, the hazards of hot substances are largely localized in a few departments, particularly so in the blast furnace (severity rate 11.96 days per worker), Bessemer (11.05 days), and open hearths (5.81 days).

That these three departments should lead in the matter of accidents from hot and corrosive substances is, of course, to be expected from the nature of the work. When, at a later page, the course of the accident rates in these departments is traced from year to year, it will appear that very important reduction in hot metal injuries has taken place. But, in spite of this, it remains true that further study of this hazard should produce greater results than at almost any other point. Also it may be expected that American surgeons will make thorough trial of the method of treating burns which seems to have had such remarkable success in France.

As regards the frequency of accidents from hot and corrosive substances, foundries, with a rate of 30.6 cases per 1,000 workers, are exceeded only by blast furnaces and steel works. Therefore, it is of much interest to note that, in severity, foundries are exceeded also by heavy rolling mills (with 3.34 days per worker), plate mills (2.08 days), and yards (2.11 days). The burn has usually been regarded as the most important foundry injury. As a matter of fact, it is characteristic but much less important than several others, for the reason that the hot metal hazard in foundries is present for only a limited portion of the day.

The low severity rates in sheet mills (0.10 day) and fabricating shops (0.05 day) are noteworthy.

The prominence of electricity as a cause of accident in the mechanical department (frequency rate, 2.1 cases per 1,000 workers, severity rate, 1.43 days per worker) is the result of the repair work which is carried on from time to time when the current can not be turned off. The strictly electrical men, if they could be isolated, would show still higher rates. The more extended use of various protective devices now available should improve this condition.

FALLING OBJECTS.

The falling object is among the most frequent causes of accidents in almost all departments, but the resulting injuries are, on the whole, less severe than those due to cranes and hoists and to hot substances. The following table (with accompanying chart) shows the frequency and severity of accidents due to falling objects of all kinds in each of the departments:

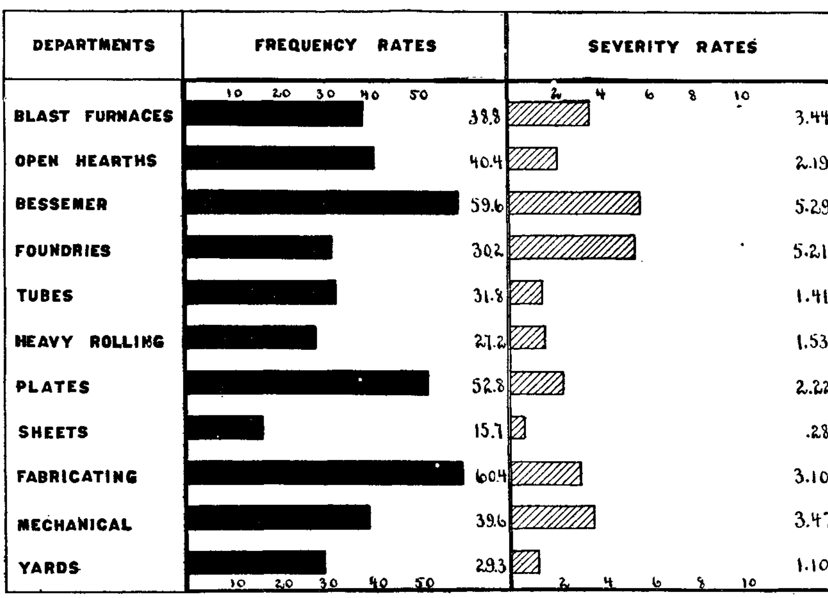
TABLE 27.—FALLING OBJECTS AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Falling objects.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Collapse of building or scaffold	1.8	0.4	0.5	0.3	0.1	0.3	0.4	......	0.3	2.1	0.6
Stored or piled material	3.3	1.1	2.1	.5	4.6	1.5	2.4	1.2	3.1	.9	4.1
From trucks or vehicles	2.7	1.1	8.6	1.9	1.0	.3	.5	1.2	4.5	.7	2.3
From buildings, etc.	2.9	.7	1.4	.3	.1	.2	.4	......	1.3	1.1	.4
Objects dropped in handling and other	28.0	37.2	47.1	27.3	25.9	24.8	49.1	13.4	51.3	34.7	21.8
Total	38.8	40.4	59.6	30.2	31.8	27.2	52.8	15.7	60.4	39.6	29.3
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Collapse of building or scaffold	0.75	0.05	0.01	([1])	([1])	0.01	0.02	......	([1])	0.96	0.02
Stored or piled material	.05	1.12	.03	([1])	0.11	.30	.72	0.03	0.03	.02	.07
From trucks or vehicles	.03	.02	.19	1.22	.25	.01	.01	.02	.68	.01	.53
From buildings, etc.	.04	.01	.01	.01	([1])	([1])	.01	......	.03	.53	.01
Objects dropped in handling and other	2.58	.99	5.04	3.97	1.05	1.21	1.46	.23	2.36	1.95	.47
Total	3.44	2.19	5.29	5.21	1.41	1.53	2.22	.28	3.10	3.47	1.10
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.005.

CHART 6.—FALLING OBJECTS AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



The table indicates that the fabricating shops have the highest frequency rate from falling objects (60.4 cases per 1,000 workers) and that these cases are of considerable severity (3.10 days per worker). The Bessemer department has the next highest frequency rate (59.6 cases per 1,000 workers) and the highest severity rate from this cause of any of the departments (5.29 days per worker). This is easily understood when it is remembered that during each heat large masses of scrap are thrown into the converter. Under earlier conditions no sufficient precautions were taken to prevent these masses from falling to the floor below and serious injury was distressingly common.

Somewhat contrary to what might be expected from observation, foundries (with 5.21 days per worker) rank next to the Bessemer department in severity. This is due to the shifting and adjusting of heavy flasks. The mechanical department also shows a higher severity rate (3.47 days) than does fabricating. This is due to the difficulties of hurried repair work.

Reference to the detailed cause items under "falling objects" will disclose some points of interest. Thus, objects dropped in handling have much the greatest frequency in every department. In fabricating shops this runs to 51.3 cases per 1,000 workers, and in the Bessemer department the rate (47.1 cases) is almost as large. The corresponding severity rates are also very high. It is evident, as suggested by these rates, that the problem is almost wholly one of developing better methods of manual manipulation and of training the men to apply them. It has so far been the general view that anybody of the necessary physical strength can lift and carry and needs little training or supervision in order to deal with his simple task. These seriously high rates indicate the need of a radical revision of that idea.

The item of "stored and piled material" shows greatest severity in open hearths (1.12 days per worker) and plate mills (0.72 day). Better piling methods are evidently needed.

"Material falling from trucks and vehicles" causes most severe accidents in foundries (1.22 days per worker), while fabricating shops (0.68 day) and yard operations (0.53 day) are next in order.

FALLS OF WORKER.

The frequency and severity of injuries due to the falling of the worker are shown, for each department separately, in the next table (with accompanying chart).

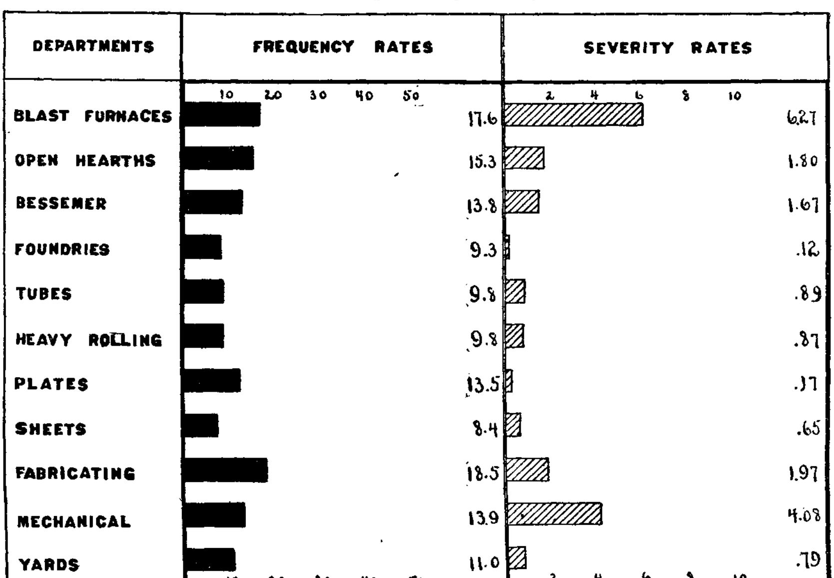
TABLE 28.—FALLS OF WORKER AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Falls of worker.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
From ladders	1.3	1.0	0.2	0.4	0.3	0.3	0.7	0.5	0.9	1.4	0.4
From scaffolds	1.1	.4	.5	......	.2	.2	.3	.5	1.3	1.2	.3
From vehicles	.6	1.1	.9	.1	.7	.6	1.0	.6	.3	.3	1.2
From structures	3.8	1.6	2.1	.4	.4	.9	.5	.4	1.4	1.9	1.4
From other elevations	.8	.5	.9	.8	2.1	.6	.6	.1	.5	.6	.7
Into excavations	.1	.1	.5	......	.1	.1	.3	.1	......	.3	.8
Into other openings	1.6	1.4	1.8	1.1	.3	.9	1.5	.6	.7	1.3	.9
Due to slipping and other	8.3	9.1	7.1	6.6	5.6	6.2	8.6	5.7	13.4	7.0	5.5
Total	17.6	15.3	13.8	9.3	9.8	9.8	13.5	8.4	18.5	13.9	11.0
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
From ladders	0.05	0.02	(1)	0.01	0.02	0.01	0.01	0.01	0.59	0.02	0.49
From scaffolds	.02	.41	1.36	......	(1)	(1)	.01	.01	.01	.96	(1)
From vehicles	.03	.02	.02	(1)	.03	.01	.02	.01	(1)	(1)	.03
From structures	4.04	.05	.05	.01	.01	.50	.01	.01	.59	2.00	.03
From other elevations	.03	.06	.03	.02	.67	.25	.01	.47	.59	.02	.15
Into excavations	(1)	......	.03	......	(1)	(1)	(1)	(1)	......	.01	.01
Into other openings	.67	.39	.04	.01	.01	.02	.02	.01	.01	.49	.02
Due to slipping and other	1.44	.85	.15	.07	.15	.09	.10	.12	.19	.58	.07
Total	6.27	1.80	1.67	.12	.89	.87	.17	.65	1.97	4.08	.79
Number of 300-day workers	*13,489*	*24,453*	*6,660*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.005.

CHART 7.—FALLS OF WORKER AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



The frequency of injuries from falls, as shown by the first part of the table, exhibits a very great uniformity throughout the departments, the highest frequency rate being 17.6 cases per 1,000 workers in blast furnaces and the lowest 8.4 cases in sheet mills.

Severity, on the other hand, shows much greater variation, the blast furnaces having the highest severity rate (6.27 days per worker), with the mechanical department second (4.08 days). In recent years injuries from falls in blast furnaces have considerably decreased as a result of the provision of permanent and substantial means for the hoisting of parts and material for the use of the riggers.

In each department it may be noted that "slipping" is the most frequent cause of falls, the fabricating shop leading with a rate of 13.4 cases per 1,000 workers. Much less frequent but decidedly more severe are "falls from structures," blast furnaces leading with a severity rate of 4.04 days per worker, the mechanical department next with 2 days, and the fabricating shops third with 0.59 day. These high rates from "falls from structures" are, of course, primarily due to the necessity of working at elevations. The remedy is the proper provision of stairways, railings, and safety belts.

HANDLING TOOLS AND OBJECTS.

The following table (with accompanying chart) shows, by departments, the frequency and severity of accidents due to the handling of tools and objects:

TABLE 29.—HANDLING TOOLS AND OBJECTS AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Handling tools and objects.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Tools in hands of worker	8.4	7.0	9.3	8.8	6.1	11.5	10.7	2.1	15.6	15.0	6.9
Toolsi n hands of fellow worker	2.5	2.2	.8	1.5	1.0	.6	.7	.5	1.1	2.2	.9
Sharp objects	3.8	7.0	3.5	3.3	14.8	3.6	15.0	26.0	3.4	5.2	3.2
Loading and unloading	2.5	2.4	4.1	.8	1.2	2.7	1.2	.1	......	.5	6.1
Lifting	2.1	3.8	5.0	3.0	3.8	2.5	4.9	.6	2.2	3.5	2.5
Objects flying from tools	2.3	.9	2.4	22.8	2.1	2.2	2.2	.5	10.1	6.5	2.1
Not classified	5.2	6.8	5.9	9.2	13.0	8.4	4.0	4.3	21.9	5.9	5.4
Total	26.8	30.2	30.8	49.4	42.1	31.5	38.7	34.1	54.2	39.0	27.1

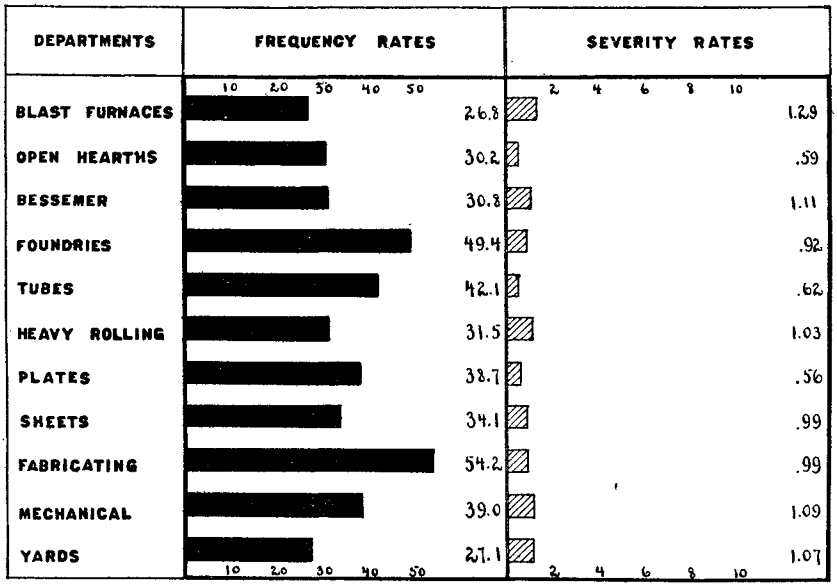
TABLE 29.—HANDLING TOOLS AND OBJECTS AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914—Concluded.

Handling tools and objects.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Tools in hands of worker	0.20	0.12	0.10	0.07	0.11	0.21	0.17	0.05	0.10	0.35	0.60
Tools in hands of fellow worker	.04	.02	(1)	.04	.02	.01	.01	.01	.01	.02	.02
Sharp objects	.07	.08	.04	.03	.21	.03	.13	.26	.02	.04	.05
Loading and unloading	.03	.04	.10	.02	.03	.32	.02	.47	.01	.12	.14
Lifting	.01	.03	.07	.02	.04	.03	.07	.02	......	.04	.03
Objects flying from tools	.83	.14	.70	.61	.02	.21	.11	.07	.58	.43	.10
Not classified	.11	.16	.10	.12	.20	.22	.06	.11	.28	.09	.13
Total	1.29	.59	1.11	.92	.62	1.03	.56	.99	.99	1.09	1.07
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] Less than 0.005.

CHART 8.—HANDLING OBJECTS AND TOOLS AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



It has already been pointed out that the handling of tools and objects is a most fertile cause of accident, but that the resulting injuries are relatively of low severity. This, it will be noted in the table, is true of all the departments, both frequency and severity rates being quite uniform in the different departments.

It is important of course that these minor injuries from the handling of tools and objects should be controlled. But the wise safety man will not be deluded by possible success here. It may cover up ghastly failure in some other group of causes of low frequency but high severity.

Examination of the list of cause items in the table brings out very clearly some departmental characteristics. The two distinctly tool-using departments—fabricating (with a rate of 15.6 cases per 1,000 workers) and mechanical (with a rate of 15 cases)—exceed all others in the frequency of accidents due to tools in the hands of the worker. But when severity is considered another phase of the matter comes out, the severity rates being for fabrication 0.10 day per worker and for the mechanical department 0.35 day. With frequency rates almost identical why should the mechanical department have a severity rate three times as high? The reply is that in fabrication the tool using is done under ordinary shop conditions while the mechanic doing repair work must often labor under serious handicaps as to time and place of work.

The "handling of sharp objects" varies very greatly in the departments. Sheet mills lead in frequency (26 cases per 1,000 workers), followed by plate mills (15 cases) and tube mills (14.8 cases). Also the severity rates are highest in these mills: Sheet mills, 0.26 day per worker; plate mills, 0.13 day; tube mills, 0.21 day. This fact calls clearly for better hand protection in this kind of work.

POWER VEHICLES.

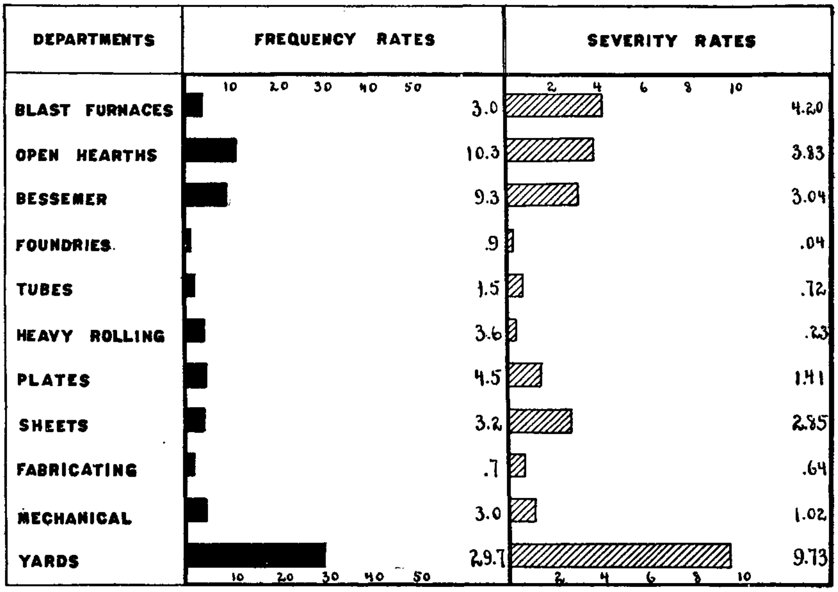
The frequency and severity of injuries due to power vehicles are shown by departments in the following table (with accompanying chart):

TABLE 30.—POWER VEHICLES AS A CAUSE OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (CASES PER 1,000 300-DAY WORKERS).										
Power vehicles......	3.0	10.3	9.3	0.9	1.5	3.6	4.5	3.2	0.7	3.0	29.7
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Power vehicles......	4.20	3.83	3.04	0.04	0.72	0.23	1.41	2.85	0.64	1.02	9.73
Number of 300-day workers............	*3,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

CHART 9.—POWER VEHICLES AS A CAUSE OF ACCIDENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



Consideration of the table indicates that in all the departments in which the power vehicle enters as an operative factor it causes comparatively few injuries but that these injuries are liable to be of a severe nature. The severity is, naturally, most conspicuous in transportation activities and the yard operations, the severity rate there (9.73 days per worker) being exceeded by only one other cause group—i. e., hot substances in blast furnaces (11.96 days) and in the Bessemer department (11.05 days).

Further discussion of the power vehicle as a cause of accidents in yard operations will appear later in the section devoted to accident control in the yard department.

MISCELLANEOUS CAUSES.

The next table covers a group of unrelated causes, none of which are of sufficient importance to warrant separate presentation.

TABLE 31.—MISCELLANEOUS CAUSES OF ACCIDENTS: FREQUENCY AND SEVERITY RATES, BY DEPARTMENTS, 1907 TO 1914.

Miscellaneous causes.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Running into objects	3.0	3.2	1.7	3.0	8.5	4.1	8.6	6.7	7.5	4.7	2.2
Flying objects	12.1	11.6	18.3	12.2	13.8	8.2	11.2	1.0	8.0	15.0	12.6
Doors, windows, etc	.2	.1	.5	.4	.3	.2	.3	.4	.4	.3	.2
Gas (asphyxiating)	7.1	.4	.8	...	...	.2	.2	...	.6	.9	.3
Heat	.1	1.6	.2	.1	.5	.7	1.6	1.6	.1	.2	.2
Frost	...	...	...	...	...	...	.1	...	...	...	...
Projecting nails	1.8	.8	.8	2.3	1.2	.5	1.3	.3	3.0	2.5	1.3
Violence	.1	.1	...	...	...	.1	.1	...	...	...	...
Moving objects	8.3	6.0	10.4	8.2	7.6	14.4	25.0	6.7	15.7	7.7	7.2
Total	32.7	23.8	32.4	26.5	31.8	28.4	48.3	16.8	35.3	31.2	24.0
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Running into objects	0.04	0.03	0.06	0.03	0.15	0.04	0.09	0.07	0.06	0.12	0.03
Flying objects	.43	.27	.30	.53	.18	.31	.24	.01	.05	.33	.69
Doors, windows, etc	.01	.36	.01	[1]	.01	[1]	[1]	.02	[1]	[1]	[1]
Gas (asphyxiating)	10.54	.38	.01	...	...	[1]	[1]	...	[1]	.01	[1]
Heat	[1]	[1]	[1]	[1]	.01	.03	.63	.95	[1]	[1]	[1]
Frost	...	...	...	...	...	...	...	[1]	...	...	...
Projecting nails	.02	...	[1]	.02	.01	[1]	.01	[1]	.01	.02	.01
Violence	[1]	...	...	...	...	.01	...	...	...	...	...
Moving objects	.19	.18	1.62	.15	.13	.65	1.11	.16	1.54	.63	.16
Total	11.23	1.23	2.01	.74	.48	1.04	2.09	1.22	1.67	1.12	.90
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,431*

[1] Less than 0.005.

The most outstanding fact in this table is the importance of asphyxiating gas in the blast furnaces (frequency 7.1 cases per 1,000 workers; severity 10.54 days per worker). This is the highest severity rate for any single cause covered by this study.

None of the other causes under the miscellaneous group seems to call for special comment.

SUMMARY OF ACCIDENT CAUSES, BY DEPARTMENTS.

The following table shows the accident rates by leading cause groups and by departments, thus bringing together the principal items of the present chapter in one table:

TABLE 32.—ACCIDENT RATES BY PRINCIPAL CAUSE GROUPS AND BY DEPARTMENTS, 1905 TO 1914.

Cause of accident.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Boilers and steam pipes	1.8	0.3	1.1	0.1	0.3	0.2	0.5	0.2	0.1	1.8	0.2
Engines and motors	2.2	.2	.8	......	.1	1.0	.6	.9	.3	1.6	.1
Power transmission	......	......	......	......	......	.3	.3	.2	.1	.2	......
Working machines	3.3	2.2	2.6	5.3	29.5	11.6	14.1	16.2	50.5	28.6	2.9
Cranes and hoists	8.4	21.0	17.0	35.4	11.1	13.0	26.3	6.3	37.2	10.4	12.0
Hot substances	58.1	43.0	51.0	30.6	19.7	11.7	16.7	8.3	6.7	11.1	6.8
Falling objects	38.8	40.4	59.6	30.2	31.8	27.2	52.8	15.7	60.4	39.6	29.3
Falls of worker	17.6	15.3	13.8	9.3	9.8	9.8	13.5	8.4	18.5	13.9	11.0
Handling tools and objects	26.8	30.2	30.8	49.4	42.1	31.5	38.7	34.1	54.2	39.0	27.1
Power vehicles	3.0	10.3	9.3	.9	1.5	3.6	4.5	[1] 3.2	[1] .7	3.0	29.7
All other	[2] 40.2	29.4	40.7	31.1	42.9	34.5	58.3	18.8	39.4	38.6	28.3
Total	200.6	192.4	226.5	192.4	188.9	144.5	226.3	112.4	268.2	187.5	147.3
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Boilers and steam pipes	0.09	0.04	0.03	0.01	0.07	0.03	0.01	0.01	(3)	0.04	(3)
Engines and motors	.34	.02	(3)	......	.01	.02	.04	.94	.20	.31	(3)
Power transmission	......	......	......	......	......	.33	.01	(3)	.01	.51	......
Working machines	.90	.43	.01	.17	3.06	1.83	[4] 2.22	2.08	1.50	1.30	.50
Cranes and hoists	3.08	4.47	4.68	4.84	.96	2.01	3.17	2.54	9.29	2.20	2.02
Hot substances	11.96	5.81	11.05	1.87	.30	3.34	2.08	.10	.05	1.53	2.11
Falling objects	3.44	2.19	5.29	5.21	1.41	1.53	2.22	.28	3.10	3.47	1.10
Falls of worker	6.27	1.80	1.67	.12	.89	.87	.17	.65	1.97	4.08	.75
Handling tools and objects	1.29	.59	1.11	.92	.62	1.03	.56	.99	.99	1.09	1.07
Power vehicles	4.20	3.83	3.04	.04	.72	.23	1.41	[1] 2.85	[1] .64	1.02	9.73
All other	[2] 12.00	1.11	3.07	.84	.61	1.39	2.23	1.20	1.69	1.01	1.05
Total	43.54	20.29	29.95	14.04	8.65	12.61	14.12	11.64	19.44	16.63	18.33
Number of 300-day workers	*13,849*	*24,453*	*6,661*	*7,938*	*14,539*	*37,364*	*14,346*	*19,119*	*15,764*	*19,332*	*18,481*

[1] In sheet mills and fabricating, yard operations are included with the rest of the mill, slightly raising the rates.
[2] Includes asphyxiating gas (frequency 7.1, severity 10.5 days).
[3] Less than 0.005.
[4] Includes one case of loss of both eyes.

COMPARISON OF CAUSES IN THE IRON AND STEEL INDUSTRY WITH THOSE IN MACHINE BUILDING.

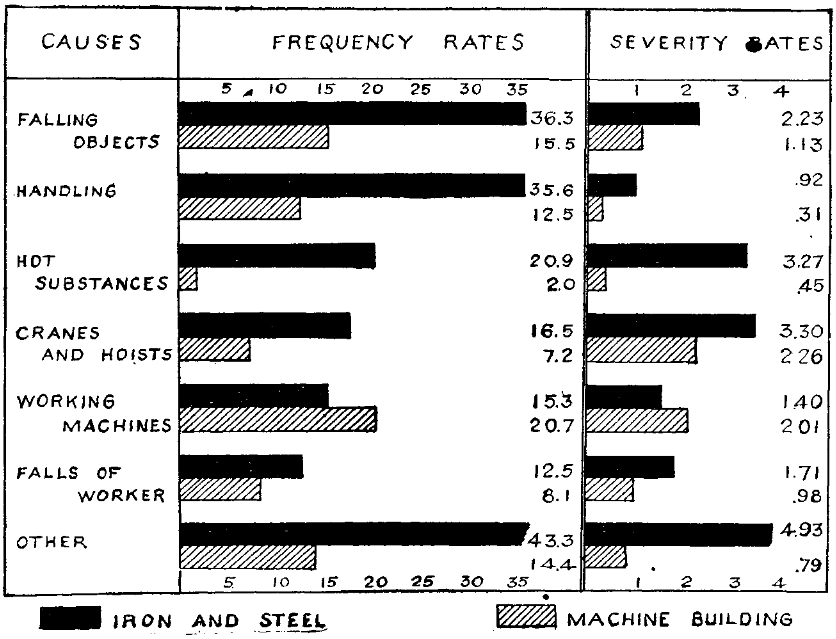
An instructive comparison may be made between the iron and steel industry and machine building by means of the accompanying chart. This presents six of the important cause groups which are common to both industries. The black bars represent the rates in iron and steel, the light bars the rates in machine building plants. The period covered is that from 1907 to 1914.

On the whole there is remarkable uniformity in the relations displayed. With one exception machine building has lower rates both in frequency and severity than iron and steel. Since machine building plants are preeminently machine using it is not surprising that in the case of working machines both frequency rates and severity rates are in excess for machine building.

If the comparison were made for a recent year much more improvement would appear in the iron and steel rates than in those for machine building. Particularly would this be true in the case of working machines.

CHART 10.—COMPARISON OF ACCIDENT CAUSES IN THE IRON AND STEEL AND MACHINE BUILDING INDUSTRIES.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



CHAPTER III.

CAUSES OF ACCIDENTS IN BLAST FURNACES.

The preceding chapter gave a brief statement of the more important accident causes in the iron and steel industry. It is now the purpose to consider each of the important departments of the industry with reference to the principal causes in that particular department.

The classification of accident causes already presented will be followed as regards the main cause groups. But the subclassifications will be varied to suit the peculiarities of each department.

Table 33 presents the cause rates for blast furnaces from 1905 to 1914. The rates shown are based upon the total employment in the department during each year.

TABLE 33.—CAUSES OF ACCIDENTS IN BLAST FURNACES, BY YEARS, 1905 TO 1914.

Cause.	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).									
Working machines	......	6.3	5.7	6.3	4.0	1.3	4.3	2.3	2.4	......
Cranes and hoists [1]	6.2	15.9	8.3	9.4	16.1	5.2	7.2	4.6	6.0	2.6
Hot substances:										
Breakouts	11.4	25.4	8.9	2.4	6.1	......	......	......	......	......
Sparks and splashes	47.9	18.2	31.3	10.2	14.8	12.6	12.3	10.3	12.7	5.1
Spills	......	.8	.6	......	......	.7	......	......	......	......
Explosions	3.1	6.3	3.8	3.9	2.7	2.2	......	1.1	3.0	1.7
Furnace slips	13.5	13.5	5.7	16.5	2.0	1.5	3.6	......	......	......
Gas flames	9.3	14.3	7.0	6.3	4.7	5.2	8.0	......	.6	.9
Hot water, steam, and other	63.5	29.3	44.1	29.8	14.1	11.8	15.9	15.4	9.7	9.5
Total, hot substances	148.8	107.8	101.5	69.1	44.4	34.0	39.9	26.5	25.9	17.2
Falling objects [1]	115.5	64.2	55.6	40.9	36.3	42.9	16.6	20.0	18.7	9.5
Falls of worker [1]	22.9	23.8	22.4	25.9	14.1	23.6	10.1	15.9	7.8	12.9
Handling tools and objects	44.7	26.1	32.6	25.9	30.3	32.5	28.3	22.3	16.9	12.9
Power vehicles	4.2	4.8	5.7	3.2	3.4	5.9	.7	1.8	1.2	......
Gas (asphyxiating)	6.2	22.2	8.9	3.2	6.9	14.0	2.9	3.4	1.2	4.2
Unclassified [2]	68.7	45.2	56.8	37.7	47.1	25.9	15.9	24.6	10.9	15.5
Not reported	7.3	15.1	6.4	.8	5.4	1.5	.7	2.9	......	......
Total	424.6	331.2	304.0	222.1	207.9	187.6	126.8	124.6	91.1	75.0
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).									
Working machines	......	7.2	0.2	1.8	0.1	(3)	0.1	0.3	(3)	......
Cranes and hoists	(3)	14.6	1.6	.3	6.5	0.5	.2	.6	5.6	0.2
Hot substances:										
Breakouts	18.9	43.3	.3	.1	12.3	......	......	......	......	......
Sparks and splashes	.6	1.2	2.1	.3	.3	.3	.2	.1	.2	1.0
Spills	......	(1)	(1)	......	......	.1	......	......	......	......
Explosions	.1	.1	.7	.1	.1	(3)	......	(3)	(3)	.8
Furnace slips	2.6	.3	6.5	.8	(3)	(3)	.3	......	......	......
Gas flames	9.5	8.0	.1	(1)	.1	.1	6.6	......	(3)	(3)
Hot water, steam, and other	.8	7.9	1.2	.8	.3	.3	1.2	.2	1.6	.2
Total, hot substances	32.5	60.8	10.7	2.1	13.0	.7	8.3	.4	1.9	2.0
Falling objects	11.2	15.0	.9	1.4	7.0	.7	.3	.3	.2	.3
Falls of worker	(3)	7.5	11.9	7.8	12.3	13.8	.4	.3	5.6	.4
Handling tools and objects	2.2	8.2	.4	.4	.3	1.4	.5	.5	.9	.9
Power vehicles	(3)	14.3	11.8	.5	6.1	2.1	6.5	(3)	(3)	......
Gas (asphyxiating)	9.4	15.4	23.1	14.1	12.2	6.8	6.5	5.2	5.4	15.5
Unclassified [2]	(3)	(3)	3.2	4.0	1.1	1.3	.3	.4	.3	.2
Not reported	(3)	(3)	.1	(3)	.1	(3)	(3)	.1	......	......
Total	56.8	143.1	65.1	33.5	58.6	27.3	23.2	8.0	19.9	19.6
Number of 300-day workers	*961*	*1,262*	*1,566*	*1,274*	*1,486*	*1,353*	*1,380*	*1,749*	*1,658*	*1,160*

[1] Further details under the item will be found in Table 103.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

Table 33 shows how the great reduction in accident rates which occurred in blast furnaces during the period 1907 to 1914 was spread among the different accident causes. With few exceptions, each of the causes listed shows a marked reduction over that period, but in some instances the reduction is much more noteworthy than in others. Thus, in the case of cranes and hoists there was an apparent but gradual and irregular improvement, whereas in the case of hot substances the rate reduction was very striking—in severity, from 32.5 days in 1905 and 60.8 days in 1906 to 2.0 days in 1914—and one important early form of "hot-substance" accident—breakouts—entirely disappeared in the later years.

The following analysis of the rate changes for each of the causes listed in the table aims to point out the reasons for the changes. Where reduction in rates has occurred, the contributing influences, such as improved operative methods and safety efforts, will be noted. Where little or no improvement has taken place, the reason for failure will be indicated as far as possible.

WORKING MACHINES.

The characteristic machines of the blast-furnace department are few in number and they are responsible for relatively few accidents. But in two years, 1906 and 1908, the table shows high severity rates for machines. The high rate of 1906 (7.2 days) was due to a fatality occurring at the pig machine. This machine consists essentially of an endless belt carrying a series of cast-iron pans, into which the metal is poured at a certain point. As the belt moves forward, carrying the filled pans, the metal is cooled by water sprays or by being carried through a water bath. When the belt passes over the farthest roller and the pans begin the return journey the cooled pigs of metal drop out, either on a stock pile or sometimes into cars. At times, however, a pig adheres to the pan and is liable to drop at a later point. In the case cited there was a passage under the pig-machine trestle, and such a "sticker" falling caused the death of a man passing beneath. As a result of the accident this particular passage has been closed. In other similar cases a guard which will catch the falling pig has been put in place.

The high rate of 1908 (1.8 days) was due, in large part, to the loss of a foot at the mud gun. Plate 1 illustrates this machine and shows at the place marked "A" a funnel-shaped part through which clay for closing the tap hole is fed. Formerly there was simply an opening into the barrel of the gun. The man using his foot to push the clay into the barrel might be caught by the descending piston and the foot crushed so that it would have to be amputated.

The number of accident cases in connection with machines being small, all comparisons between years must be made with considerable reservation.

CRANES AND HOISTS.

The blast furnace has one hoisting apparatus peculiar to itself—the skip hoist. The accident hazards of the skip, however, are of small importance. The injuries due to hoisting apparatus, for which the rates are shown in the table, are from forms of hoists in no way peculiar to this department.

In 1905, as shown in the table, the frequency of accidents from this cause was low and the severity of such accidents negligible. But in the next year, 1906, the rates rose rapidly, due in all probability to increased industrial activity. Comparing the rates of that year with those of 1913, which was a year of very similar activity, it will be noted that a marked reduction had occurred—in frequency, from 15.9 to 6.0 cases per 1,000 workers, a reduction of 62 per cent; and in severity, from 14.6 to 5.6 days per worker, a reduction of 62 per cent. These reductions followed the introduction of various safety methods. One important improvement may be briefly described. While the forms of hoisting apparatus used are not peculiar to blast furnaces, there is an unusually large amount of hoisting which requires temporary arrangements. For example, whenever repairs are to be made at the top of the furnace the riggers, who do the work, must attach their tackle to some part of the furnace top and make a hoist of possibly more than 100 feet. Under the old conditions when there were no adequate stairways and platforms and no permanent points of attachment designed for the purpose this was necessarily extremely hazardous. This hazard is reflected in the rates for hoists and also in those for falls of worker.

The complete revision of stairways, railings, platforms, and other means of safe access affects most importantly the danger incident to hoisting operations.

HOT SUBSTANCES.

This group of causes stands out as of peculiar importance and interest in the blast furnace department. Reference to the table will show a remarkable diminution in their influence during the period covered. Comparing the years 1906 and 1913, which are closely similar as regards industrial and labor conditions, the following decline in the accident rates (due to hot substances) may be noted: In frequency, from 107.8 cases per 1,000 workers in 1906 to 25.9 cases in 1913, a reduction of 76 per cent; and, in severity, from 60.8 days per worker to 1.9 days, a reduction of 97 per cent. Such striking reductions in accident hazards constitute a very great triumph for safety man and blast furnace superintendent.

An examination of the subcauses under the general group of "hot substances" will bring out the particular places and conditions in which the most striking improvements have been effected.

BREAKOUTS.[1]

In the furnaces under consideration breakouts were severe as late as 1909. Thereafter they were entirely absent. The reason for this striking change can be given in a few words—increased strength of construction. The importance of better construction will appear repeatedly as this discussion progresses.

SPARKS AND SPLASHES.

The injuries from sparks and splashes are numerous and of sufficient severity to merit attention. They must be combated by appliances and personal protection. In drawing off the cinder from the cinder notch the flying of molten material is frequent. Plate 2 shows how this may, in a measure, be guarded against. Above the cinder notch is suspended a shield which can be readily lowered when it is necessary to open the cinder notch.

But the main danger from this source arises at the tapping hole, where the metal is drawn off. Plate 3 illustrates the early, unsafe method by which the tap hole is opened directly by man power. It is evident that when the molten metal comes pouring out there is every chance that, in the event of even small explosions, very severe burns may ensue. Plate 4 shows how in well-conducted plants at the present time the crew necessary to carry on the operation is reduced by the substitution of an air drill for the hand-operated bar, the tapping hole and adjacent runner are securely covered, and the men are safeguarded by the use of proper leggings. With one additional precaution, this arrangement would approach perfection. Rarely, but often enough to deserve attention, an eye is lost from a stray spark. The chance that this would happen is so small with the protection illustrated that the wearing of protective goggles might seem unnecessary. But when it is noted that for the cast-house men about 9 per cent of the accidents are accidents to the eye[2] the small trouble of using protectors may seem worth while.

As the metal flows away from the tapping hole along the runners, there is frequent occasion to direct its course by introducing gates. Formerly these were shovel-shaped iron affairs, which the helper must put in position by hand, getting away quickly enough, if possible, to avoid scorching and splashing metal. In modern practice the gates are hung above the runner and lowered by a lever or other mechanism from a safer distance. (See to left of E in plate 5.) This new arrangement favors safety in another very important way. A very small quantity of moisture on a gate will produce a very violent

[1] For methods of prevention see Bulletin 140 of United States Bureau of Mines. Occupational Hazards at Blast Furnaces and Accident Prevention, by Frederick H. Wilcox, 1917.

[2] See Table 68.

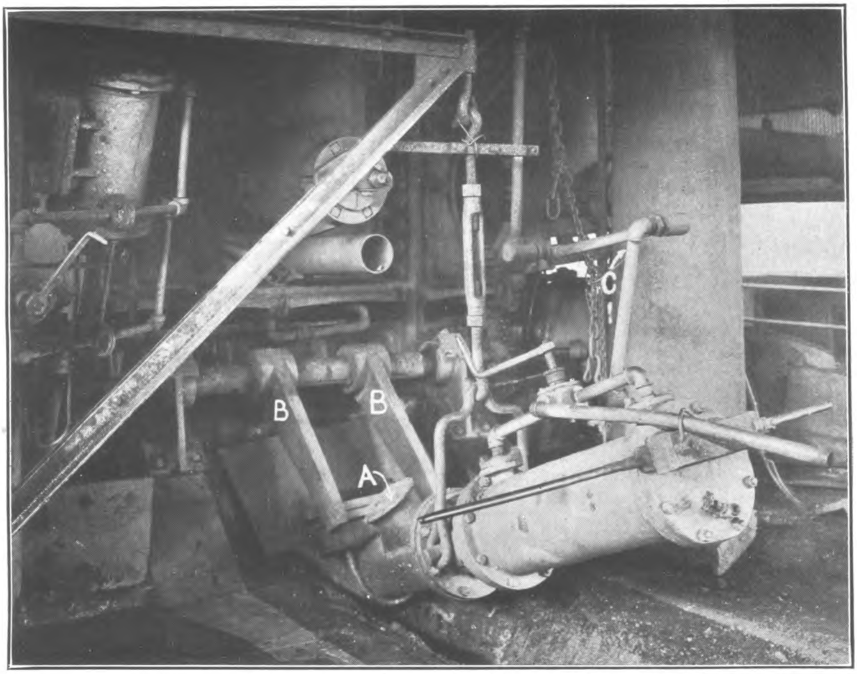


PLATE 1.—MUD GUN IN POSITION FOR CLOSING TAP HOLE.

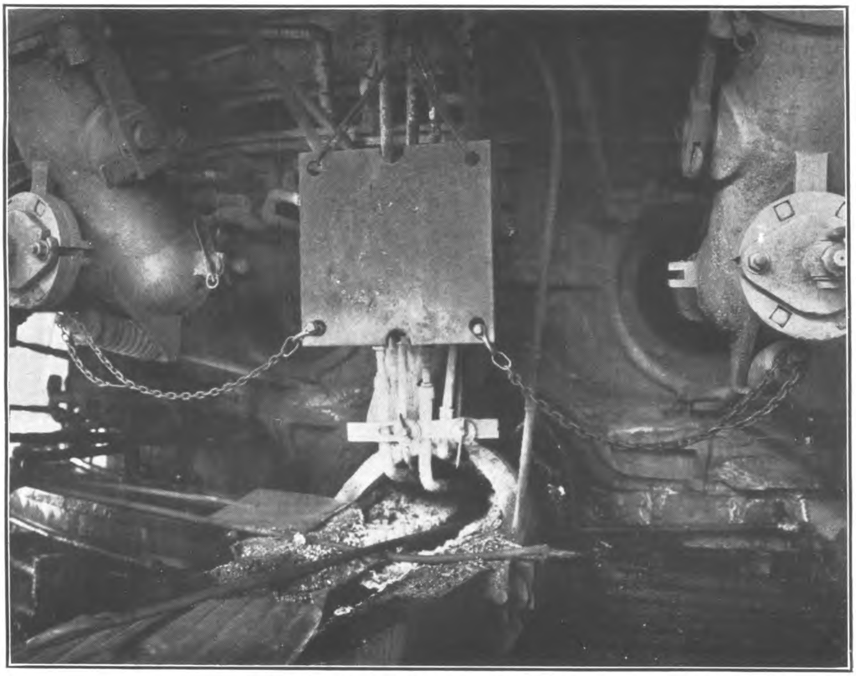


PLATE 2.—CINDER NOTCH, WITH GUARD.

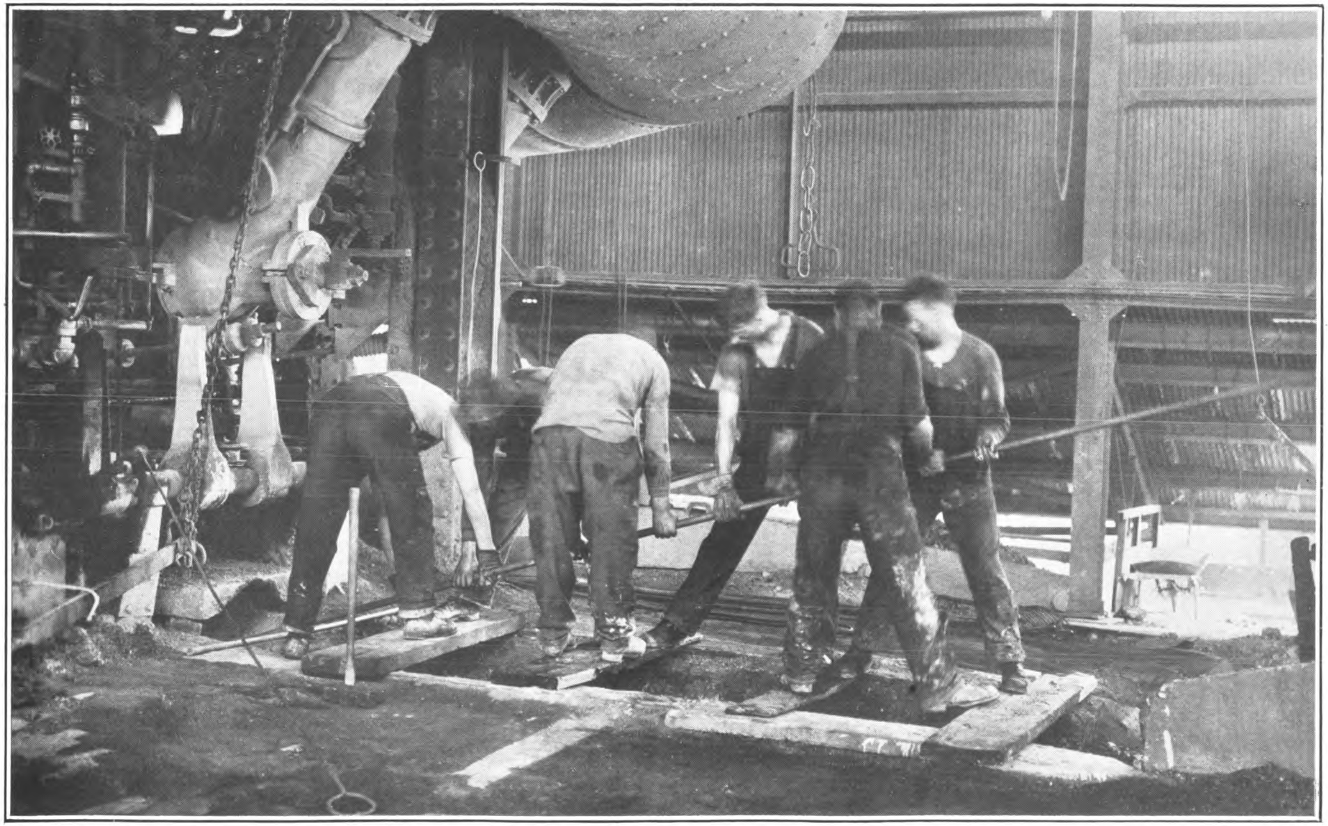


PLATE 3.—OLD, UNSAFE METHOD OF DRILLING A TAPPING HOLE.

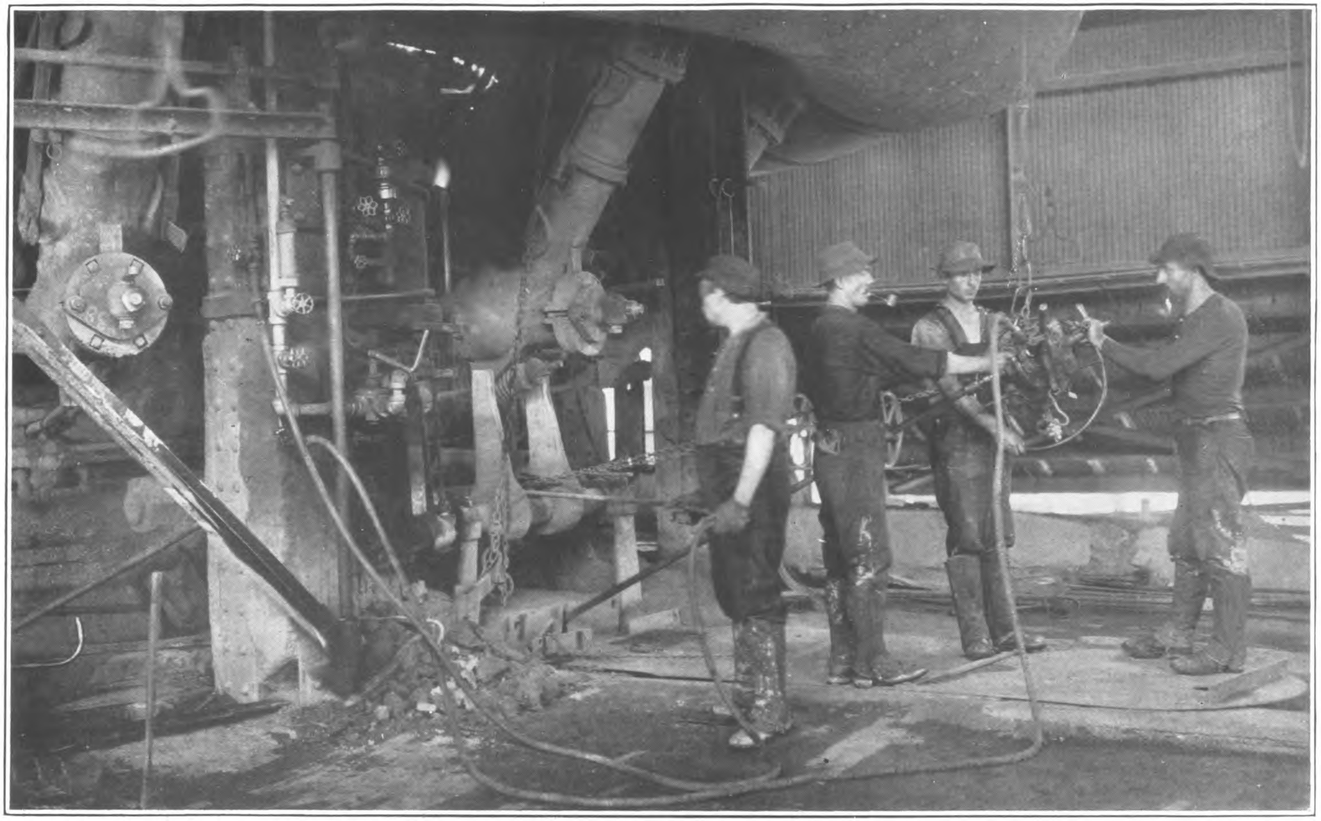


PLATE 4.—IMPROVED METHOD OF DRILLING A TAPPING HOLE.

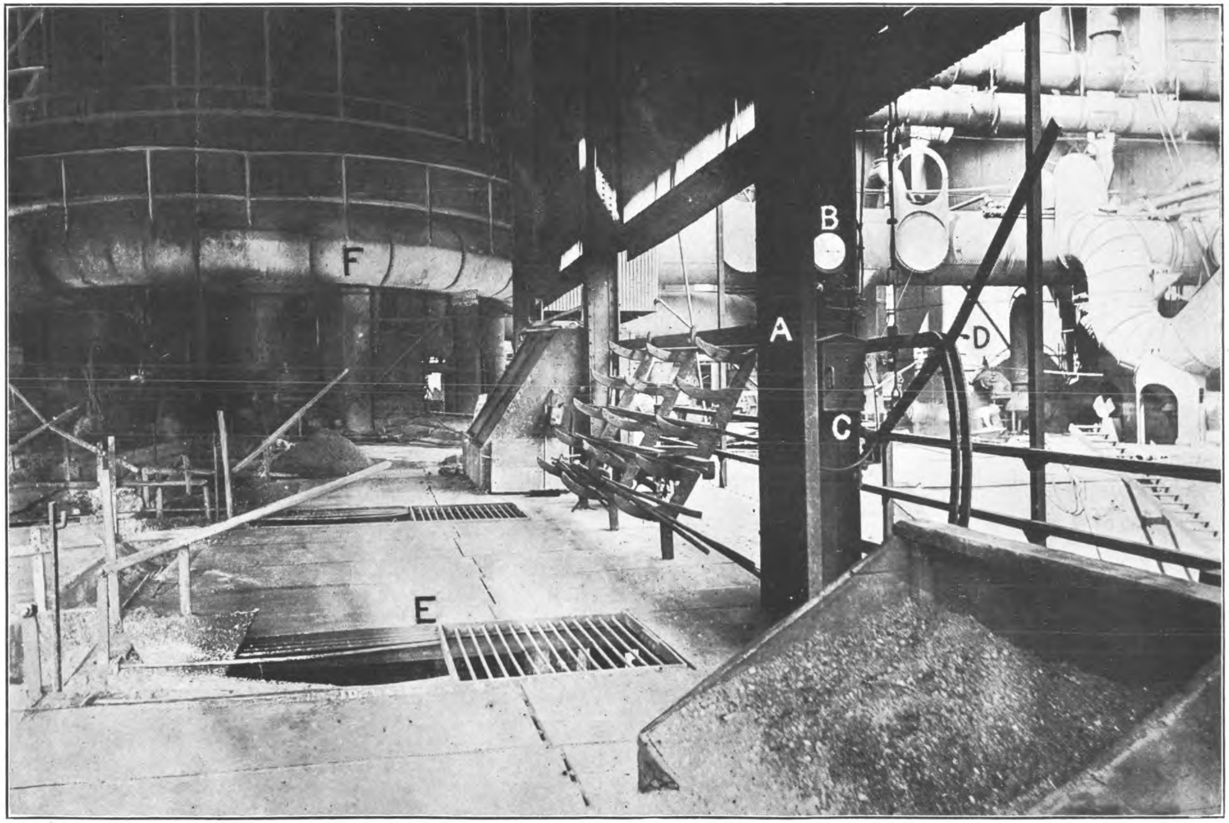


PLATE 5.—PORTION OF CAST HOUSE FLOOR

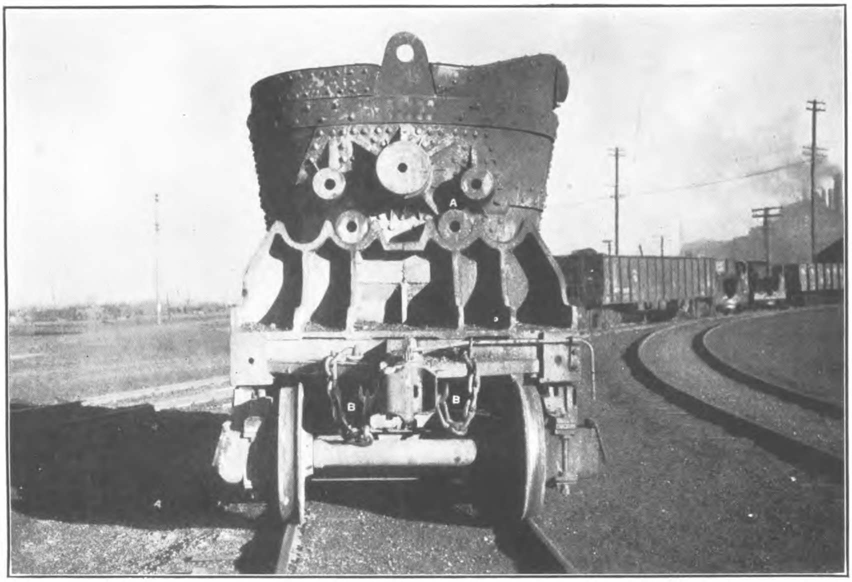


PLATE 6.—HOT METAL LADLE AND CAR, SHOWING DOUBLE TRUNNIONS AND SAFETY CHAINS.

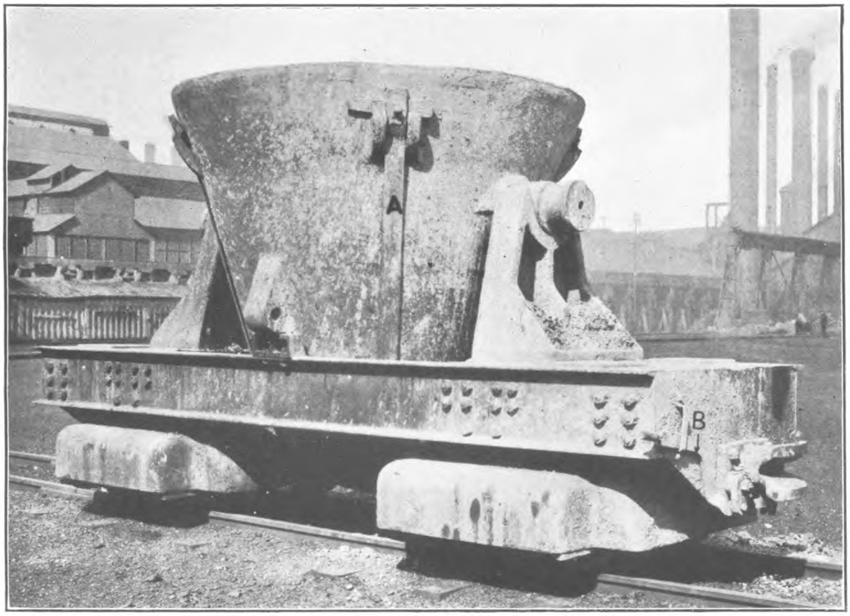


PLATE 7.—AUTOMATIC COUPLER ON CINDER LADLE CAR.

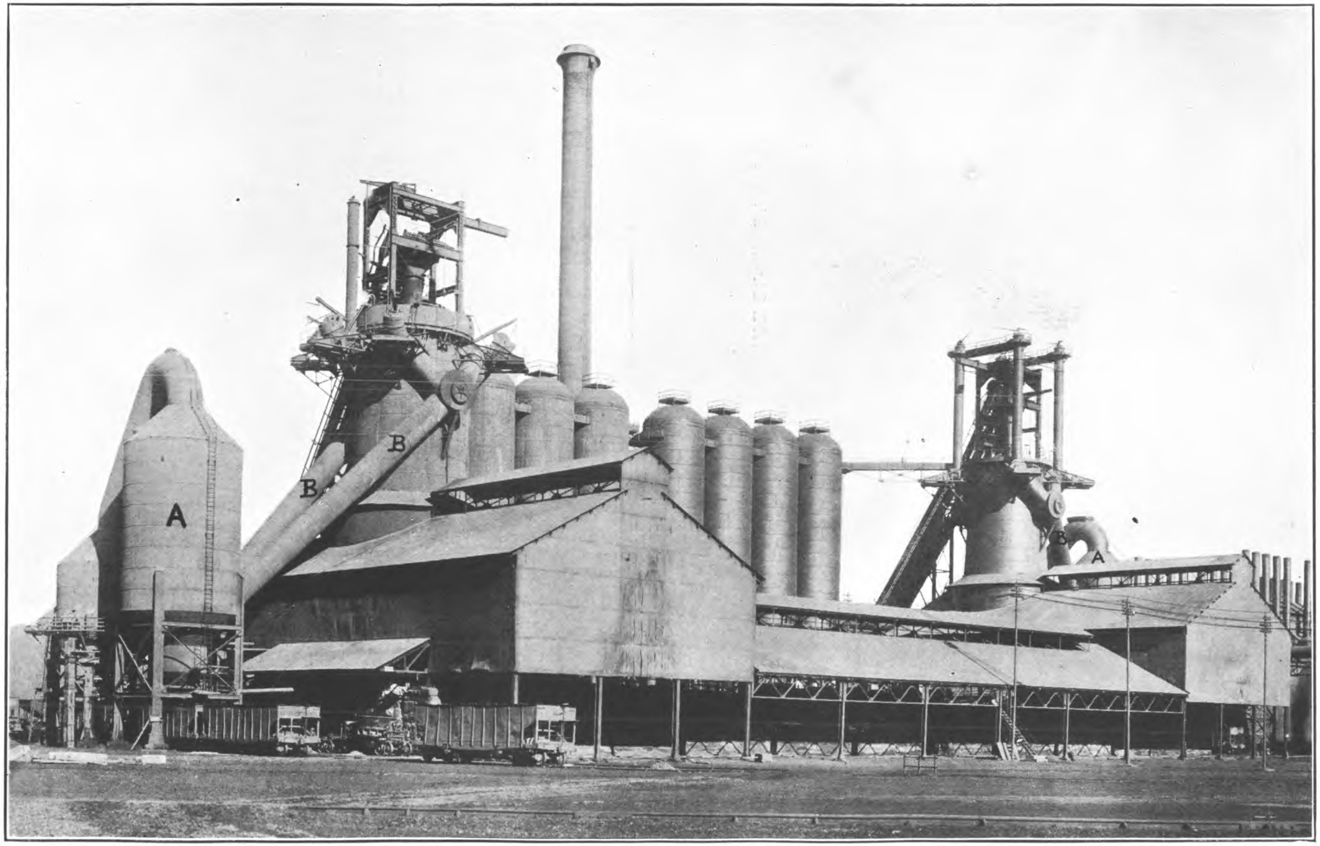


PLATE 8.—MODERN BLAST FURNACE PLANT, SHOWING DUST CATCHER.

explosion. When the gate hangs in position above the molten stream it is always thoroughly dry and may be safely brought in contact with the metal. It would quite often happen under older conditions that, in spite of efforts on the part of the helper, some moisture would remain on the gate and produce an eruption of the metal serious enough to cause the helper's death and perhaps injure a number of other workers.

The possibility of splashing also occurs in the transportation of molten metal about the yard. Here there are two dangers to be guarded against: (1) It is sometimes necessary to couple ladle cars after the hot metal or cinder is placed in them. This presents a very serious menace if the construction of the car requires the coupling to be done by hand. Some metal is almost sure to slop over at the moment of striking. Automatic couplers are in successful use on such cars (plates 6 and 7). (2) For convenient use the ladles must be suspended when pouring at a point not much above the center of gravity. If such a ladle were supported on the car by the trunnion used in pouring, it would be difficult to block it so that in moving it might not sway and so discharge some of its contents. The double-trunnion ladle, illustrated in plate 6, greatly decreases this hazard.

SPILLS AND EXPLOSIONS.

Spills—i. e., where a ladle drops from a crane or upsets on a track—were not of serious moment in the blast furnaces covered by this study. As shown in the table the frequency rate was only 0.2 case per 1,000 workers and the severity rate was negligible.

The "explosions" listed in the table are those of relatively minor importance occurring in the hot metal. Sometimes these explosions have serious consequences, but none such occurred in the furnaces here covered.

FURNACE SLIPS.

Furnace slips may cause injury in two ways—by burns from the hot stock ejected from the furnace and by bruises and crushing injuries from the stock falling on a worker. The present section is chiefly concerned with the former kind of injury—burns—but for convenience of treatment the discussion of furnace slips and their prevention is given here.

The table shows that in the plants covered burns from furnace slips, while of much importance during the early years, diminished and then disappeared entirely after 1911. If the accidents due to crushing injuries from the falling stock be added, the high rates in the early years and the decline in the latter years would be even more striking. To indicate at all clearly how, in the best practice, such an important and serious accident cause as the furnace slip has been practically eliminated from blast-furnace hazards requires a fairly full exposition of blast-furnace operation, including a description of a modern furnace.

The modern furnace.—A furnace consists of (1) the stack or furnace proper; (2) the blowing engines; (3) the stoves. Plate 8 shows two stacks with the stoves between them. These elements represent three steps in the development of furnace practice. At first the furnace consisted of a tower of masonry lined with brick, into which fuel, ore, and limestone were dumped at the top. From the tower top the gases generated escaped freely, taking fire and blazing up like a torch. To this tower a blowing apparatus was later added, forcing cold air through the burden. Arrangements which were then made to warm the air have finally developed into the highly effective stoves of present practice.

A vertical section of the furnace discloses three portions—(1) a cylindrical portion at the bottom, the hearth; (2) above this an inverted truncated cone, the bosh; (3) still above an upright truncated cone, the stack. The shape of the stack permits free downward movement of the burden. When in this movement the zone of fusion is reached in the bosh, the bulk decreases and the diameter is lessened proportionately. Around the furnace, near the junction of the stack and bosh, is a circular pipe—the bustle pipe (Pl. 5 "F"). This carries air forced by the blowing engines through one of the stoves. A series of smaller pipes extend from the bustle pipe into the furnace, terminating in the tuyeres. This was originally a simple apparatus, but in it a very complicated process goes on; and to govern and control this process mechanisms have been added until, as a whole, a modern furnace is a most complicated and delicate construction.

In the illustration, plate 8, there is seen at the right the inclined hoistway, by which the materials (coke, limestone, and ore) are lifted and dumped into the top of the stack.

The slip.—The above description will enable the reader unfamiliar with the blast furnace to understand the nature of the hazard to which attention is now directed, namely, the furnace slip.

The essential feature of a slip is that the mass of material in the furnace is checked in its downward movement, and the burning away of the fuel below this point takes away the support. Then suddenly the obstruction is overcome and the entire burden drops down to a new level. When it is remembered that this may be a mass as much as 20 feet in diameter and 60 feet high, it is obvious that the mechanical effect may be tremendous.

An understanding of the conditions bringing about a slip requires a somewhat particular statement of the processes within the furnace. When a furnace is "blown in," a mass of fuel in the hearth is ignited, and upon the burning mass the ingredients of the burden (ore, limestone, and coke) are gradually placed from the top of the stack. As the original fuel burns away the coke, coming down with the burden, takes fire. At some point in this process the tuyeres are put in place and a blast of hot air turned into the stack. The burning of the coke gives rise to carbon monoxide. Carbon dioxide is expelled from the limestone, leaving lime. This dioxide, in turn, unites with carbon and becomes monoxide. These gases and free carbon react on the iron ore, robbing it of its oxygen and reducing it to a metallic state. Reaching the "zone of fusion," the iron and the lime melt. The heavy molten iron sinks to the bottom of the hearth, the melted limestone slag floating on top. As these materials are assorted in accordance with their weight important chemical reactions take place, by which substances which would injure the quality of the iron are taken up by the slag. The slag is drawn off at intervals from the cinder notch and the iron from the tapping hole, as already noted.

This process gives rise to comparatively little trouble with ore of a granular character; but when the great deposits of rich ore were discovered in the Mesaba region of Minnesota, and at the same time a tremendous demand for iron and steel arose, factors entered the situation which have brought about a revolution in construction and practice. The ores originally used permitted a fairly free passage of the gases toward the furnace top. With the introduction of earthy, powdery Mesaba ore the burden became relatively impervious and the serious troubles of blast-furnace men began.

The readiest method of indicating how a slip comes about is to follow a hypothetical case. Let it be supposed that the impervious burden deflects the blast to one side of the stack. The part no longer supplied with heated gases begins to fall in temperature. The lower portion, pasty and on the verge of fusion, congeals, and in so doing adheres to the furnace wall. Thus begins what furnace men call a "hang." Once started, it may extend until it nearly or quite reaches the opposite wall, becoming a "scaffold." The free descent of the material is checked and all the processes are disturbed. As combustion proceeds below a scaffold its support is rapidly removed. To restore the action of the furnace, various expedients are used, such as rapidly increasing the burden at the top or sudden alternations of blast pressure. If the hang is slight, the slip may occur in the regular course of events, with the ejection from the furnace top of dust only. If it reaches the dimensions of a scaffold, the sudden downward rush may be accompanied by ejection of large masses.

It is probable that under some circumstances explosive compounds may be formed and the slip be accompanied by an explosion resulting in great destruction. This may come about as follows: If an almost complete scaffold has formed, the carbon below it may be entirely consumed. When the break comes, the oxygen of the blast is suddenly mixed with the gases above and with incandescent coke dust. This may give rise to an explosive mixture which will blow out the entire contents of the furnace, and, of couse, in so doing wreck the top mechanism and endanger everyone in the vicinity.

This cause of danger is evidently one which might be very serious. How serious is illustrated by one case of an old type of furnace filled by men working at the furnace top. Fourteen lost their lives when an explosion followed a slip. At another furnace the whole stack was wrecked by the explosion and 12 men died. The methods by which the hazard has been lessened must therefore be of the keenest interest.

The solution of the problem of production, as also that of safety, goes down to the fundamentals of blast-furnace practice.

First must come a rational treatment of the raw materials. Nothing can be done with the ore. The Mesaba product is at once among the richest and the most easily mined material anywhere available. The furnace man must use it and develop his methods accordingly.

For satisfactory use coke must be of uniform quality. The importance of this deserves illustration. A group of furnaces had for some days been working badly, ejecting 6 to 10 carloads of flue dust, when under normal conditions 2 carloads was the limit. There seemed no explanation. Finally the superintendent discovered that the coal being used in the coke ovens was being crushed to unequal degrees of fineness. Now, whenever crushed material is manipulated there is a tendency for the coarse particles to become aggregated in one place and the fine particles in another. The result of this sorting was, in the case under consideration, that some of the coke was of finely crushed material and easily broke down into a powder which tended to fill in between the other materials of the burden. This would obstruct the free movement of the gases and so cause trouble. The portion of the coke made up of the coarser particles was more readily inflammable and so tended to produce areas of greater heat in some portions of the furnace. This unequal heating tended to aggravate the results arising from the stoppage due to the powdering of the portion of coke made from finer material. Correction of the crushing process gradually brought the furnaces to normal action.

In another plant the screening apparatus, by which the "breeze" was removed from the coke, was out of order and supplies had to be taken from the cooling beds. In a few hours the furnaces were hanging and slipping seriously.

The substitution of the "by-product" ovens for the old "bee hive" process is not only a great gain in conserving vast amounts of valuable material formerly thrown away, but makes possible a product which is much better, both for operation and safety.

The physical condition of the limestone must also have attention. If the limestone masses are too small, ore and coke breeze will tend to pack between them and obstruct the blast. On the other hand, if too large they may descend to the lower levels of the furnace without being reduced completely to lime. This makes a demand upon the heat at a critical time, when it is needed for other purposes. This disturbance may give rise to various difficulties. Fine lime dust is still more troublesome. It operates to obstruct the blast and tends to "lime scaffolds," very difficult to dislodge. Careful crushing of limestone and screening to uniform size is well worth while.

With these precautions regarding the physical condition of the coke and limestone must go precautions in conveying and placing the material in the furnace. As has already been suggested, all material consisting of particles of different sizes undergoes in shifting from place to place a process of sorting by which the large and small particles become segregated. In order to overcome this tendency, precautions must be taken at various stages. Where the manipulation is manual, as loading into barrows with shovel or fork, this tendency to sorting is in a measure overcome. It is this fact that has kept in use a good many hand-filled furnaces and led to the building of new ones, in spite of the hazard involved. The steady reduction in number of hand-filled furnaces and lessened number of top fillers employed is a very great gain from a safety standpoint.

With their disappearance, however, the problem of maintaining a uniformity in the blast-furnace burden enters a new phase. These workmen, under competent direction, could put the material into the furnace in fairly uniform condition. To produce equal uniformity by mechanical means has taxed the ingenuity of blast-furnace constructors. The perfect solution is perhaps not yet reached.

In general it may be said that this sorting of material, tending to produce a burden not uniform in composition and leading on to most troublesome results, occurs whenever material slides down an incline and drops from the edge. In transit from bin to furnace there are six such points, (1) from bin to larry car, (2) from car to skip, (3) from skip to hopper, (4) from hopper to little bell, (5) from little bell to large bell, (6) from large bell to stack. It should be explained that the top of the stack is closed by two bell-shaped valves, one above the other. By proper manipulation of these valves the top is always closed, so that gas can not escape and so is compelled to pass into the pipes, called "downcomers" ("B," plate 8).

The commonest means of combating this sorting tendency is by devices at the top. For example, many furnaces are provided with rotary tops. After each load is dumped from the skip such a top automatically revolves a certain distance. The loads are thus discharged into the stack from different positions tending to mix them in such a way as to provide a more uniform burden. Other constructors have experimented with various positions of the skip when delivering its load and with the introduction of baffles into the hopper. After prolonged trial a position and a system of baffles were discovered which very perfectly attained the desired end.

Still another device involves beginning at an earlier point. The material is received from the bins into cylindrical buckets, which rotate as they are filled. These are then carried on larries to the hoist, where, instead of being emptied into a skip, the bucket itself is hoisted to the top of the stack. This cylindrical bucket has a bell-valve bottom and is dumped directly on the small bell of the furnace.

These illustrations serve to indicate the lines along which inventive genius has worked in solving the problem of handling the huge quantities of material required for the modern furnace and at the same time securing the results formerly attained by workmen operating under supervision.

This revision of structure and method accounts for the major part of the reduction in the severity rates of "furnace slips," as shown by the table. That frequency suddenly became nil in 1912 is due to the introduction of an improved valve at the upper end of the upright pipes seen extending above the furnace top in the illustration. This effectually prevented the ejection of anything but fine dust, and from this time onward even annoyance from slips disappeared in these blast furnaces.

GAS FLAMES.

Reference to the table will show that the severity of injuries from gas flames was very high in the early years—9.5 days in 1905 and 8.0 days in 1906. It then practically disappears, except for one unfortunate year, 1911, when there was a rate of 6.6 days. The high rates in the early years were due in part to the extensive use of hand filling at that time. It would sometimes happen that flames would burst out when there was no slip or explosion, and severe burns, fatal at times, would result. For the most part, however, the decline in severity rates is to be attributed to improvements in controlling valves.

Incidentally a great lessening of danger has come to the stove men and stove cleaners from the use of washed gas. Great quantities of flue dust are caught in the "dust catchers" (shown at "A," plate 8). The dust laden gas enters these catchers, which form practically a great enlargement of the downcomer, and the current moving more slowly, the coarser dust falls. There is much, however, almost impalpable, which passes on. If this is fed directly to the stoves, the openings between the checker bricks, with which the stove is filled, become choked, and this may cause flames to burst out at unexpected places, causing injury. In modern practice the gas is sent first to a washer, where the dust is caught by water sprays and the gas goes on perfectly clean. This freedom from obstructing matter makes possible more efficient stoves and also safer operation.

It so happened that the plants under consideration did not have, during the years covered, any gas explosions causing an appreciable amount of injury, except those already noticed under furnace slips, but since such cases do occur and can be illustrated from the experience of other plants, this is an appropriate place to discuss them and their remedies.

An interesting illustration occurred in the operation of a certain furnace when on one occasion the blast was cut down. The engines slacked up but did not stop. Since they remained partly active, it is difficult to understand how gas from the furnace found its way back into the air cylinders. However, an explosive mixture was formed, ignited, and the engine was wrecked, causing the death of two persons and injury to others.

To understand the remedy devised by this plant to prevent similar accidents in the future, some description of engines and stoves is necessary. The main which brings the air from the engines to the stoves, divides, a branch going to each of the stoves. After passing the stoves, the air, highly heated, goes to the bustle pipe around the furnace. There is also a pipe direct from engines to furnace, known as the cold blast. It is used when it is desired to lower the temperature of the furnace and at other times it is closed by a valve.

Up to the time of the explosion above noted, this valve was hand operated in this particular plant, and it seems probable that it was because the valve was imperfectly closed that the gas was able to make its way to the air cylinders. The outcome of the explosion was the invention of valves for both the hot blast and cold blast. When pressure is on, these valves remain open. They can be adjusted to close at any determined diminution of pressure and would seem to be a perfect protection against such a disaster as that described above.

A second illustration is that of a furnace which was being dismantled prior to relining There remained in the lower part a small amount of burning material. From this there evidently arose a sufficient amount of carbon monoxide to form an explosive mixture. A gang of men were carrying some object which required the combined effort of six or more. In the course of the operation, they were in a line directly in front of the opening where a tuyere had been removed. An explosion occurred and a stream of flame was driven through the opening directly along the line of men. Several were instantly killed and others seriously burned. It is evident that the combination which rendered this so serious was extremely unlikely to be repeated;

but the incident forcibly illustrates the need of the utmost care to prevent the formation of such explosive mixtures. Smouldering fires in confined spaces should be extinguished or the space flooded with such quantities of air that the proportion of gas may not rise to the explosion point. In the process of "blowing in" a furnace there is danger that the gases generated may mingle with the air in the upper part of the stack or in the mains in explosive proportions. An excellent safeguard is to fill these spaces with an inert gas. The most readily available is steam.

Again, it may be noted that whenever pressure is lowered in the mains there is a tendency for the gases to cool and contract. This might, if the engines were stopped, produce even a negative pressure. Since perfect exclusion of air is difficult, if not impossible, it may filter in and give an explosive mixture. A dust catcher ("A," pl. 8) twisted into unrecognizable shape proved the possible force of an explosion so originating. It is very common to build furnaces with a pair of stacks. It is possible whenever there is more than one to provide junctions between the mains in such a way that there will be a constant supply and constant pressure of hot gases in those parts where cooling and intake of air would otherwise be liable to occur. This precaution, with arrangements for the use at times of live steam, gives excellent results.

FALLING OBJECTS.

Tracing the rates for falling objects from year to year, as given in the table, it appears that a notable decline has occurred in both the frequency and severity of accidents due to this cause. Comparing similar industrial years, frequency, in 1906, shows 64.2 cases per 1,000 workers and in 1914 only 18.7 cases, a decline of 71 per cent. Between the same years severity changed from 15.0 days per worker to 0.2 day, a decline of 99 per cent.

The high rates in the earlier years were due primarily to those kinds of "falling object" hazards which the blast furnace has in common with all departments. Those which may be regarded as characteristic of the blast furnaces—incident to the storage of iron ore, coke, and limestone—were responsible for only a very small fraction of the accident rates quoted above, the storage of stock having been deprived of its more hazardous features through the substitution of mechanical for hand labor. For example, when ore was transferred from stock pile to skip in hand barrows it would happen from time to time that the removal of ore from the foot of the pile would cause it to cave down upon the men. At the present time in most important plants this transfer is entirely accomplished by mechanical means. The men who control the apparatus are exposed to comparatively little danger.[1]

[1] See Table 103.

FALLS OF WORKER.

Of the falls incident to distinctively blast-furnace operations, those into ore pockets and bins show the greater number. Next come falls from the transfer and larry cars.

The bulk of the cases, however, are of a character common to all departments, blast furnace workers being especially liable to falls from structures. A glance at plate 8 will show that a furnace has many points where work must be done and from which a fall would be serious. The illustration shows the modern installation of stairways, railed walks, and permanent supports for attaching hoisting apparatus, which have contributed very greatly to reduce such accidents. Evidently such reduction would have a larger influence upon the severity rate than upon the frequency rate, as a fall from such a lofty height almost always means death or serious injury.

Reference to the Table 33 will show fairly high but declining rates in the period covered. Comparing the years 1906 and 1913, which as has been noted were industrially very similar, the decreases appear as follows: Frequency rates, in 1906, 23.8 cases per 1,000 workers, and in 1913, 7.8 cases, a reduction of 67 per cent; severity rates, in 1906, 7.5 days per worker, and in 1913, 5.6 days, a reduction of 25 per cent.

HANDLING TOOLS AND OBJECTS.

It was thought that in this group the handling of pig iron might show itself to be a source of serious injury. But such did not prove to be the case, partly because accidents due to this cause are usually of minor severity and partly because the handling of pig iron by hand in the plants under study disappeared almost entirely some years ago.

From year to year, as shown in the table, the rate variations have been very considerable, but the severity rate was of serious importance only in 1905, when it was 2.2 days, and in 1906, when it was 8.2 days.

POWER VEHICLES.

The power vehicle hazard in blast furnaces is a rather varied one. The great quantities of raw material (ore, coke, and limestone) which must be brought in demand railway operations on a large scale. The storage and handling of this material introduces the need for transfer cars to shift it from place to place and of so-called larry cars to convey the stock to the skip hoists of the furnaces.

As might be expected from the evident importance of the power vehicle hazard, the early years show rates particularly high in severity, such for instance as a rate of 14.3 days in 1906. The control of this hazard almost to the point of disappearance in later years has been almost wholly the result of a practically complete rebuilding of the transportation facilities. Much that was formerly done at grade is now carried upon trestles. Ample clearances have been provided and the whole system simplified and coordinated to a degree which can scarcely be appreciated except by one familiar with both situations.

The result of these efforts may be seen in the figures of the table. In frequency rates the decline is from 4.8 cases per 1,000 300-day workers in 1906 to 1.2 cases in 1913, a reduction of 75 per cent. In severity rates the decline is from 14.3 days in 1906 to 0.04 days in 1913, a reduction of 99 per cent.

ASPHYXIATING GAS.[1]

Examination of the table indicates that asphyxiating gas was during the whole period covered an accident cause of serious importance. The frequency rates are relatively low but the severity rates are high and do not show the same marked decline as do the rates for most of the other causes. Thus, for the five-year period 1905 to 1909 the rate was 15.4 days, whereas for the five-year period 1910 to 1914 it was 7.6 days, a reduction of only 50 per cent; and the rate for the year 1914 (15.5 days) was as high as for the year 1906 (15.4 days). Also it must be remembered that in addition to its direct action, asphyxiating gas contributes to many accidents charged to other causes. This is true in many falls.

Some structural changes have been of much importance in controlling this cause. Formerly gas mains were carried underground and were simply bricked in. It was impossible to make them gas tight in the first place and any flaws which developed later would not be called to attention unless they became very bad. As a result there was constant leakage into the porous ground which was likely to be built up around the furnace. This probably was more influential in injury to health than in causing asphyxia, but at frequent intervals conditions would favor the accumulation of gas in some inclosed space and some one would be overcome. The substitution of overhead mains has very much modified this condition for the better.

An operative rule against going without a companion into inclosed spaces where gas might possibly accumulate has saved lives.

The disappearance of hand-filled furnaces is of importance in this connection, as may be illustrated by the following example: The bell of a hand-filled furnace had been warped by overheating, allowing the gas to escape. The wind drove the gas toward the hoist. As a result men were constantly being overcome. An unusually large

[1] For detailed instructions regarding control of asphyxiating gas see Asphyxiation from Blast-Furnace Gas. Technical paper 106, U. S. Bureau of Mines.

crew were on the top. Part of them, keeping out of the way of the gas, pulled their unconscious comrades into fresh air and thereupon took their places. Those who did not immediately recover were sent down the hoist and others came up. Finally a man was overcome just as he was emptying his barrow on the bell. He fell against the bell and was severely burned. The combined effect of gas and burns caused his death. In trying to rescue him the foreman and several others were overcome. The effort to keep this furnace operating was abandoned.

The insidious character of the poison appears from another example. The horizontal mains became gradually filled with flue dust. It had been the custom to clean this out by sending a gang of shovelers into the main. The main was shut off from the furnace and manholes were left open for some time. The foreman of the gang then went down one manhole and walked to another without experiencing any ill effects. Believing that the gas was thoroughly out of the main, he sent in the shovelers and they began work. Apparently much gas was caught in the dust, for within a few minutes several men were overcome. In rescue efforts some 30 men went into the pipe. A majority became unconscious from the gas, including the assistant superintendent of the plant. Since that time, arrangements have been made to remove the dust by means of a stream of water.

Still another case will emphasize the extreme care necessary where this factor enters the situation. In a blast furnace yard was a small motor house. The only openings into it were such cracks as might exist around a door and one window, together with the space around the shaft of the motor where it went through the wall. On a rather inclement night two men sought shelter in the building between tours of duty as watchmen. They were found dead from gas in the morning. Apparently the gas found its way in around the motor shaft, the wind being in a direction favorable to bringing it there.

Such inclosed spaces might often be kept free from danger at the cost of a ventilating fan and a small amount of electrical current. A single death outweighs many such provisions.

Finally oxygen helmets (plate 9) and resuscitation apparatus have materially assisted in preventing asphyxiation and in the restoration of many who otherwise would very probably have swelled the death list. There are now available smaller and less expensive oxygen outfits which can be used in those cases of repair work where it is practically impossible to avoid a gas-laden atmosphere.

The results of applying these various methods of control have been important. They should doubtless be applied both more generally and more vigorously.

UNCLASSIFIED CAUSES.

As has been earlier explained, this group of causes, being simply a storage place for items which do not seem to demand consideration, has no particular significance. It may be pointed out, however, that while the frequency rates for this group are high in all the years, the severity rates are of negligible importance.

COMPARISON OF ACCIDENT CAUSES, 1906 AND 1913.

In the preceding discussion comparison is constantly made between the rates in 1906 and those in 1913, these two years being selected, as noted, because of their similarity as regards productive and labor conditions. The following table brings together, in convenient form, the data for these years for each of the causes. The frequency and severity rates are shown, and also the percentage of reduction which occurred between the two years.

TABLE 34.—COMPARISON OF ACCIDENT RATES IN BLAST FURNACES FOR YEARS OF SIMILAR INDUSTRIAL ACTIVITY, BY CAUSES, 1906 AND 1913.

Cause.	Accident frequency rates (per 1,000 300-day workers).		Percentage of reduction, 1906 to 1913.	Accident severity rates (days lost per 300-day worker).		Percentage of reduction, 1906 to 1913.
	1906	1913		1906	1913	
Working machines	6.3	2.4	62	7.2	(1)	99
Cranes and hoists	15.9	6.0	62	14.7	5.6	62
Hot substances	107.8	25.9	76	60.8	1.9	97
Falling objects	64.2	18.7	71	15.0	.2	99
Falls of worker	23.8	7.8	67	7.5	5.6	25
Handling tools and objects	26.1	16.9	35	8.2	.9	89
Power vehicles	4.8	1.2	75	14.3	(1)	99
Asphyxiating gas	22.2	1.2	95	15.4	5.4	65
Total	331.2	91.1	72	143.1	19.9	86
Number of 300-day workers	*1,262*	*1,658*		*1,262*	*1,658*	

[1] Less than 0.05.

OCCUPATIONS AND CAUSES.

In the preceding pages the blast furnaces have been treated as a unit. It is known, however, that the hazard of the different occupations is not uniform. The following table is presented in order to show these differences and afford some measure of their importance. This table shows for such occupations as could be isolated the accident frequency rates by cause groups. It is to be emphasized that the rates, in each case, are based upon the number of employees in the particular occupation.

It was not possible to compute severity rates for these occupations.

TABLE 35.—ACCIDENT FREQUENCY RATES IN BLAST FURNACES, BY OCCUPATIONS AND CAUSES, 1905 TO 1914.

Cause.	Cast house.[1]	Labor.	Mechanics.[2]	Stockers.[3]	Unclassified.[4]	Total.
Working machines	3.7	2.4	3.0	....	6.3	3.4
Cranes and hoists	11.1	9.5	10.9	6.8	1.7	8.2
Hot substances	201.2	63.1	20.2	19.2	42.6	58.0
Falling objects	43.5	59.6	25.9	42.9	19.0	39.2
Falls of worker	25.8	19.5	14.2	10.2	17.0	17.5
Handling tools and objects	50.8	37.7	18.3	12.4	12.3	26.7
Power vehicles	.7	5.9	.5	4.5	2.0	3.0
Asphyxiating gas	5.9	7.3	6.3	5.6	8.6	7.1
Unclassified	37.6	45.4	28.9	55.3	29.6	37.4
Total	380.2	250.5	128.1	156.9	139.1	200.6
Number of 300-day workers	*1,357*	*4,930*	*3,760*	*886*	*3,006*	*13,849*

[1] Includes bar and clay men, cinder snappers, keepers and helpers, ladle men, etc.

[2] Includes blacksmiths, boiler makers, bricklayers, carpenters, handy men, machinists, millwrights, painters, repair men, riggers, pipe fitters, etc.

[3] Includes bottom fillers, cagers, dust men, larry men, skip hoist men, stockers, top fillers, weighers, etc.

[4] Includes blowers, crane hookers, cranemen, engineers, firemen, foremen, lever men, loaders, oilers, pig-machine men, scrap men, stove cleaners, stove tenders, switchmen, washers, and others.

Considering the total line of the table it appears that cast-house men have much the highest frequency rate (380.2 cases per 1,000 workers). Since the high mortality due to breakouts in the early years was chiefly among these workers, the severity rate also may be presumed to be high. Examining the cause rates for cast-house men it appears that hot substances hold first place with a rate of 201.2. Cast-house men also show the highest rates from cranes and hoists (11.1), from falls of worker (25.8), and from handling tools and objects (50.8).

Common labor shows high rates at all points where it has been possible to isolate it. The blast furnaces are no exception. Their rate (250.5) is not so high as in some other departments, but is gravely important. Laborers suffer most frequently from hot substances (63.1), though their rate from this cause is much below that of cast-house men. They have the highest rate (59.6) of any occupation from falling objects.

Mechanics in blast furnaces do not have a rate (128.1) in excess of the general mechanical department (187.5),[1] but their exposure to hot metal and asphyxiating gas undoubtedly gives them a higher severity.

Further light is thrown on the importance of asphyxiating gas as a cause of injury in blast furnaces by the uniform distribution of the hazard among all classes of workers as shown by this table. It is evidently a pervasive factor which touches practically every worker The highest rate (8.6) is found among the unclassified workers. This is in some measure due to the inclusion of stove cleaners, stove tenders, and gas washers in this group. These workers are more exposed to this hazard than are the others.

[1] See Table 108.

CHAPTER IV.

CAUSES OF ACCIDENTS IN STEEL WORKS AND FOUNDRIES.

ACCIDENT CAUSES IN THE OPEN HEARTH DEPARTMENT.

The open hearth is now the most important of the steel-making processes. The decline in ore suitable for making Bessemer steel has been steadily forcing that process into the background. It will doubtless regain some of its lost importance with the further development of the duplex process, in which the Bessemer process is used for a preliminary purification, the final removal of impurities being accomplished in an open hearth.

The following table shows the frequency and severity rates for the principal accident causes in the open hearth department over the eight-year period 1907 to 1914. The separate causes listed are those which seem to be most characteristic of this department. General causes which open hearths have in common with other departments are grouped under the head of "unclassified." The rates shown are based on the total employment in the open hearths covered by the table during each year as shown.

TABLE 36.—CAUSES OF ACCIDENTS IN OPEN HEARTHS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines [1]	4.7	1.4	3.1	3.2	2.2	1.5	0.8	1.2
Cranes and hoists [1]	38.1	25.5	21.5	22.4	19.0	13.9	12.2	12.9
Hot substances:								
Breakouts	11.4	2.4	6.6	3.2	.4	4.3	3.9	....
Sparks and splashes	17.4	16.5	14.6	8.3	14.7	15.9	8.9	14.1
Spills	1.3	....	....	.3	....	....	....	....
Explosions, other than ingot	8.4	.9	4.2	3.8	....	1.1	4.5	....
Ingot explosions	5.4	3.8	5.2	1.9	6.2	2.6	3.1	2.0
Gas flames	4.7	6.6	4.9	4.5	3.3	3.4	2.2	2.8
Unclassified	14.4	6.6	13.2	14.3	15.4	10.8	10.5	6.0
Total, hot substances	63.0	36.8	48.7	36.3	40.0	38.1	33.1	24.9
Handling tools and objects [1]	45.2	23.5	35.5	33.4	24.6	25.2	23.2	22.5
Power vehicles [1]	16.7	7.6	10.8	8.3	8.1	12.5	14.7	2.5
Unclassified [2]	145.6	108.0	111.1	87.6	59.4	65.6	67.4	50.7
Total	314.3	202.8	230.7	191.2	153.3	156.7	151.3	115.2
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	3.1	(1)	0.1	0.1	(1)	(1)	(1)	(1)
Cranes and hoists	16.6	0.3	3.5	6.9	3.7	0.9	0.5	0.3
Hot substances:								
Breakouts	.2	(3)	.1	.1	(3)	2.6	.1	....
Sparks and splashes	.2	.3	.2	.1	.3	.3	.5	.7
Spills	(3)	....	....	(3)	....	....	....	7.2
Explosions, other than ingot	15.2	4.2	.5	.2	....	(3)	5.1	....
Ingot explosions	.1	.1	.2	.1	.2	.1	.2	(3)
Gas flames	(3)	.1	(3)	(3)	(3)	(3)	.1	(3)
Unclassified	3.6	.1	3.4	.2	.4	.2	.5	.2
Total, hot substances	19.9	4.8	4.4	.7	.9	3.2	6.5	8.1
Handling tools and objects	.3	.2	.4	1.0	.3	.5	.5	.7
Power vehicles	11.1	.2	1.2	.4	3.7	4.2	6.2	1.3
Unclassified [2]	1.4	2.2	5.0	5.0	1.2	3.7	16.0	1.2
Total	52.8	7.5	14.6	14.1	9.9	12.6	29.8	11.6
Number of 300-day workers	*2,987*	*2,120*	*2,872*	*2,138*	*2,725*	*3,525*	*3,603*	*2,483*

[1] Further details under this item will be found in Table 104.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

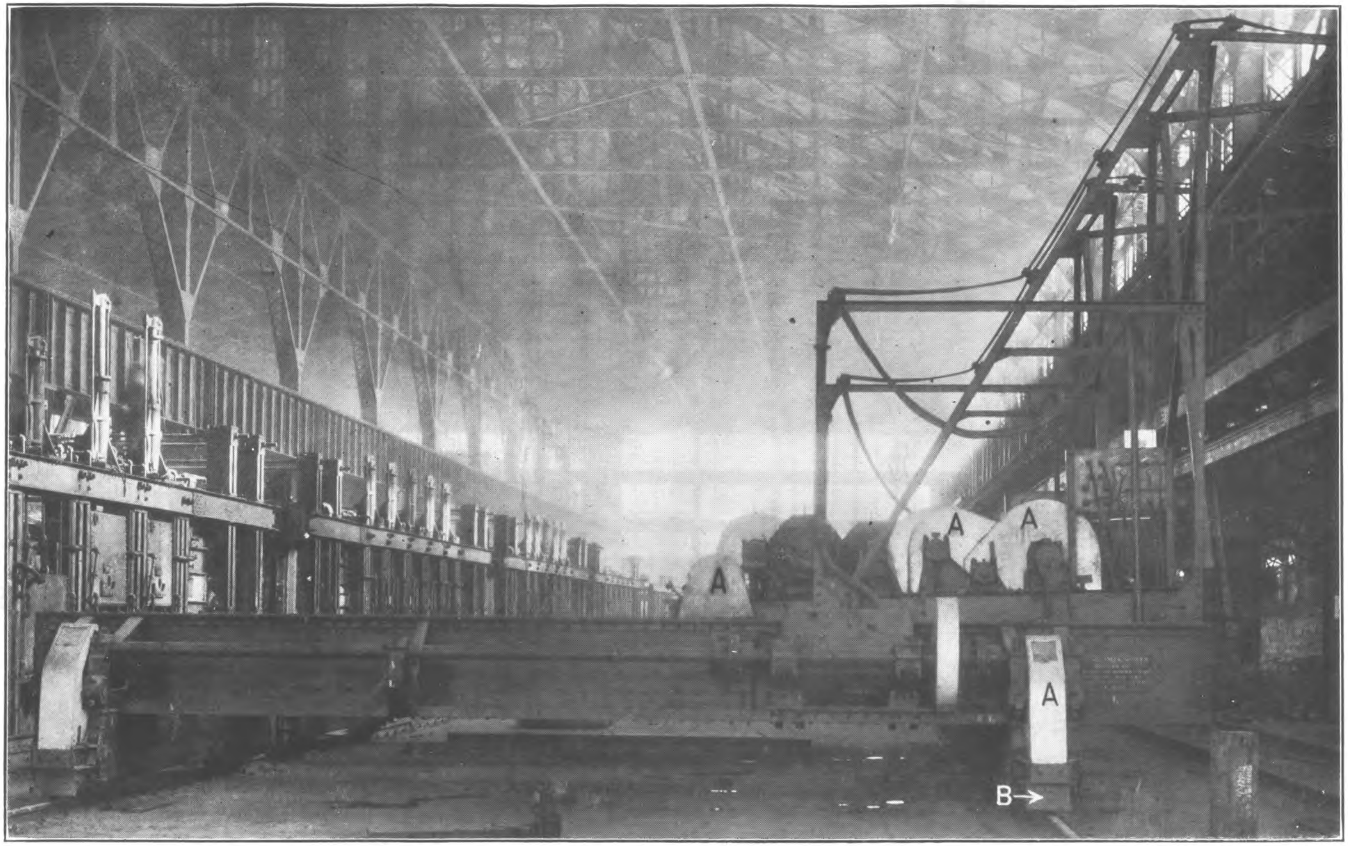


PLATE 9.—OPEN HEARTH CHARGING FLOOR, CHARGING CAR IN FOREGROUND.

PLATE 10.—PIT SIDE OF OPEN HEARTH, FROM POURING PLATFORM.

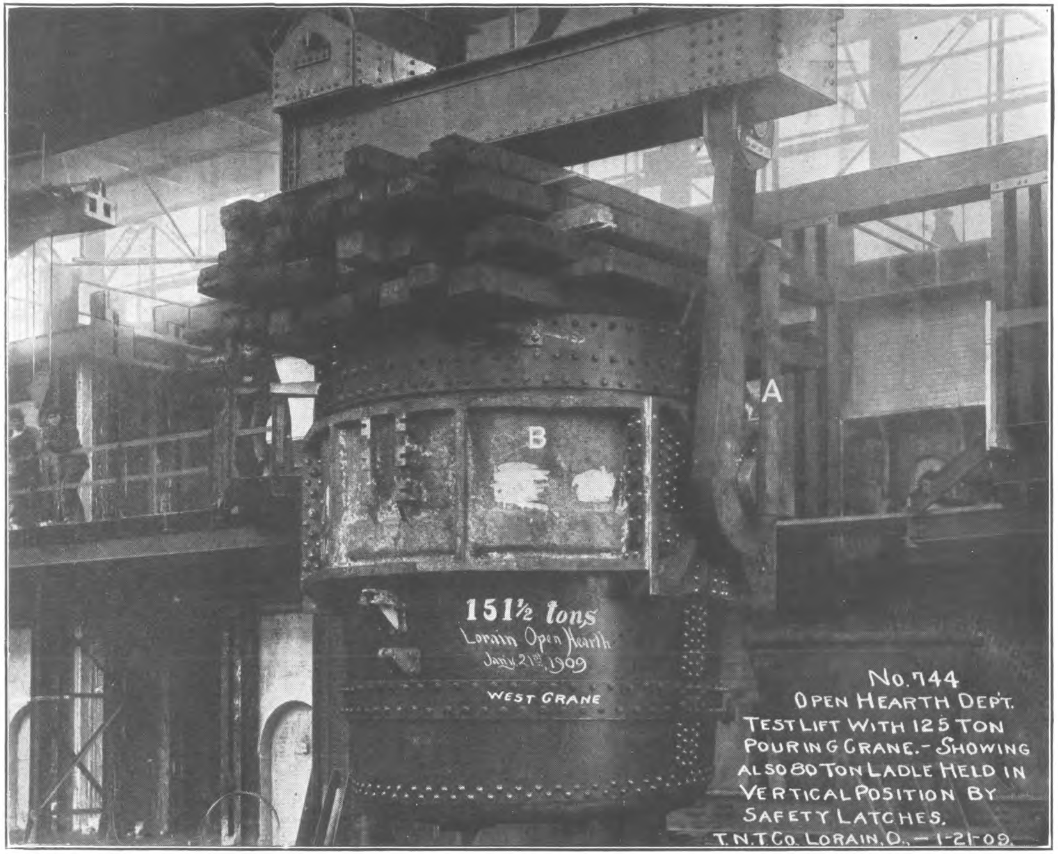


PLATE 11.—OPEN HEARTH HOT METAL LADLE, WITH SAFETY LATCH ON TRUNNION.

PLATE 12.—SAFETY CHAMBER ON HOT METAL CRANE.

Over the eight-year period covered by the table the accident rates for the open hearth department as a whole show a marked decrease. The frequency rates declined from 314.3 cases per 1,000 workers in 1907 to 151.3 cases in 1913, which was a year of similar industrial character to 1907. The severity rates, as between the same years, declined from 52.8 days to 29.8 days, with all the intermediate years showing still lower rates.

The rates for most of the individual cause groups also showed a general decline between the years mentioned, but the character of the change was by no means the same in all cases. This can best be brought out by a consideration of the listed causes in order.

WORKING MACHINES.

The only machine of importance in the open hearth department is the charging car (see plate 9), by means of which the boxes containing scrap are lifted from the cars in which they are brought on to the stocking floor and thrust into the furnace. Under former conditions, the operator of the charging car was often endangered by uncovered gearing. The covering of this gearing (see "A," in plate 9), together with the placing of a fender on the rail wheel, which otherwise was a frequent cause of injury to the feet of stocking-floor workers (see "B"), has reduced to a minimum the hazard of the charging car.

CRANES AND HOISTS.

The main difference between the cranes used in the open hearths and those found elsewhere is the adaptation of the former to the handling of hot metal. In early construction the width of the stocking floor of an open hearth was no greater than necessary to accommodate the charging car. As a result the hot metal was necessarily carried overhead by the crane. Both the weight and the character of the load made this objectionable. In later construction a greater width was given and a track introduced, seen at the right of the charging car in plate 2. Along this track the ladles of molten metal are pushed until opposite the furnace to be charged. From these they are lifted by the crane and carried the comparatively short distance across the width of the floor.

On the pit side the cranes take the ladles ("F," plate 10) from the furnace and bring them across the pit to the platform "A," where the metal is drawn into the molds, whose tops appear at "C." It is obvious that there are two points of danger in this process. While the ladle is being moved a break or overset may cause a spill of the metal, or, arrived at the pouring platforms, sparks may fly from the stream as it falls into the mold. In case of a spill, every one in the vicinity is endangered by the intense heat. Particularly is this true of the craneman, exposed by his position and having no easy means of escape.

Two methods have been used to combat this hazard: (1) Greater strength and better design of both the crane and ladle; and (2) better means of escape or protection, particularly to the craneman.

Plate 11 illustrates a ladle undergoing a test. Formerly the hooks by which the ladles were suspended were made solid. Now many of them are made of plates bolted together, thus increasing the strength and lessening the chance of sudden breakage without warning. At "A" is seen a latch falling into a groove in the trunnion. When this latch is in place an upset from overfilling is nearly impossible.

A means of escape for the craneman is illustrated in plate 2, at "B." This is a gallery on a level with the crane cage, to which the craneman can escape if a spill occurs. In plate 12, at "A," is seen a safety chamber into which the craneman can pass in emergency and from which he can operate the crane. This arrangement has two advantages which the gallery does not have. It can be applied where a gallery would be impossible, and it permits the craneman to contribute to the safety of others by controlling the crane. An illustration will enforce the importance of this. A spill occurred and the craneman was forced to leave the cage without stopping the travel of the crane. It moved down the building, the ladle hanging by one hook and dropping metal constantly. The craneman realized the danger and, running down the gallery outside the building, succeeded in getting back into the cage and stopping the crane. It is easy to see that this return might have been very difficult, even impossible. The safety chamber would have afforded him protection and opportunity to control the mechanism.

HOT SUBSTANCES.

Breakouts.—Breakouts are much less important in open hearths than in blast furnaces, but from time to time they inflict an amount of injury which is not to be neglected. Sometimes, indeed, they are extremely serious. For example, in some open hearths it is still necessary to have a pit in front of the furnace in order to depress the ladle sufficiently to receive the metal. In one open hearth of this type, two men went down into this pit to clean up accumulated material. The tap hole of the furnace gave way and the men were covered by the white hot flood. One plant, to guard against such an occurrence, has adopted a clam shell bucket, by the use of which the accumulated rubbish is removed from the pit more quickly and less laboriously. This leaves but little to be done manually, and this little can be accomplished so quickly as to very greatly reduce the hazard.

To prevent the minor injuries which occur at the tapping hole some form of screen might be devised which would serve the same purpose as the screens at the cinder notch and tapping hole of a blast furnace.

Sparks and splashes.—Sparks and splashes are the cause of a large number of injuries in the open hearths but, as shown by the table, these injuries are usually of slight importance. During the period covered by the table, the frequency rates for this cause showed a slight tendency to decrease—from 17.4 cases per 1,000 workers in 1907 to 8.9 cases in 1913, although with a later increase to 14.1 cases in 1914. The severity rates, during the same period, increased rather markedly from 0.2 day per worker in 1907 to 0.5 day in 1913 and to 0.7 day in 1914—but these rates at most are too small to be significant.

As a preventive against the dangers from sparks and splashes in open hearths, two safeguarding methods could be employed much more extensively than has been done, namely, the use of good shoes and leggings and the use of eye protectors. Particularly, the use of goggles on the pouring platform would aid in cutting down the occasionally serious eye injuries.

Spills.—Since the worst of the spills occur in the operation of cranes and hoists they have been briefly referred to in the consideration of the latter subject. The occasion for their occurrence is as follows: The metal coming from the blast furnaces is placed in a mixer, so called because the product of different furnaces is mixed in it and a more uniform iron is thus provided for purification in the open hearths. The mixer is a bowl-shaped container, capable of holding from 250 to 1,000 tons. It is so constructed that it can be tilted to pour out the metal into the ladles which carry it to the furnaces. It is obvious that if the controlling mechanism fails, a very serious spill on a very large scale may take place.

Three methods are in use to prevent such an occurrence: (1) Counterweights at the back of the mixer by which the mixer automatically returns to a horizontal position if the controlling mechanism fails. This has the disadvantage of adding very greatly to the dead weight of the mixer; (2) an electrically operated dog which locks the mixer in position if the tilting gear goes wrong; and (3) a safety valve in the hydraulic tilting apparatus, held down by the pressure of the operator's foot and put in action by simply removing that pressure. In one plant a particular type of valve was devised after an accident which broke the handle by which the operating valves were changed, leaving the man in charge helpless to prevent continued motion. This special form of safety valve has so many points of excellence that a description is justified:

A mixer of hydraulic type is operated by two cylinders placed in opposition to each other under the bowl-shaped reservoir containing the metal. These are the pouring cylinder and the righting cylinder. A valve operated by a lever directs the water into one cylinder or the other at the will of the operator. If the valve leaks or can not be operated for any reason, it may become impossible to prevent the entrance of water to the pouring cylinder. The tilting will proceed under such conditions to the limit and the entire charge be spilled. The safety valve mentioned above meets this difficulty in the following manner: From the pipe supplying the pouring cylinder a branch pipe is led off to the sewer. In this branch pipe is a valve, counterweighted so that ordinarily it stands open. No pressure can be conveyed to the cylinder until the valve is closed. Beside the operator is a foot plate on the end of a rod, by which, when the foot plate is depressed, the valve is closed. In order to pour, the operator closes the valve by placing his foot on the plate. In an emergency, removal of the foot at once makes further tilting of the mixer impossible.

This device has several points of excellence: (1) It is in constant and necessary use and so must be kept in good order; (2) its action is controlled by the operator, but comes about automatically; (3) the action required is slight and would occur almost instinctively.

Explosions.—In computing the accident rates for explosions, ingot explosions were separated from all others in order to determine their real importance. It developed, as shown in the table, that ingot explosions, while of considerable frequency, have a very low severity rate. The severity rate, however, has not decreased in the period covered, and this means that they have been regarded as of too slight importance to merit adequate attention. This is unfortunate, as this form of injury can be practically eliminated. Accidents occur when a cover placed on top of the mold is removed, and can be prevented: (1) By the use of open-top molds without cover. This causes slightly more waste, but not enough to offset the benefit of reduction in accidents; (2) by regulations preventing the removal of cover until cooling has proceeded far enough to render explosion unlikely; (3) by screens from behind, which the uncapper can work.

Explosions in the open hearth, other than ingot explosions, are shown by the table to have constituted an extremely important cause of accidents in the early years. In 1907 the frequency rate was 8.4 cases per 1,000 workers; in 1913 it had decreased to 4.5 cases. The decrease in severity was from 15.2 days per worker in 1907 to 5.1 days in 1913. These decreases represent reductions of 46 per cent in frequency and 66 per cent in severity.

This very material reduction in severity is to be attributed almost wholly to improved methods, and not in any considerable measure to greater care on the part of the men. The character of the improved methods may be indicated by an illustration. A steel mill which produces special ingots of unusual size fills the molds by "bottom pouring." A tube leads down to the bottom of a pit in which the mold stands, and into this the metal is poured and rises in the mold. On top of the main mold a smaller mold, held in place by guy rods tightened by turnbuckles, is placed, the crack between the two molds being luted with clay and sand. When the metal in the large mold reaches the top, pouring is suspended and a small ladle of metal is brought by the crane to fill the small mold from above. This is usually done slowly, taking 15 to 20 minutes. On one occasion the ladle developed a "running stopper," that is, one which did not perfectly close the opening in the bottom of the ladle. This made perfect control impossible and the small mold was filled too rapidly. As a result when the small mold was nearly full an explosion occurred, forcing sheets of molten steel out of the joint and filling a considerable space with the flame of the gases. The junction of the two molds was about the height of a man's shoulder. One worker was instantly killed by the falling metal and several others inhaled the blazing gases and died from the pneumonia following the injuries.

Following this accident certain safeguarding methods were introduced which have proved efficacious in accidents of a somewhat similar character.

More common but less serious than the above are explosions in the slag and in the metal as it flows or is moved about. These smaller explosions can be guarded against by proper clothing and eye protectors. The larger ones must be prevented by better operative methods. It often happens that, when material is permitted to accumulate unreasonably, conditions favorable to explosion arise when prompt removal would prevent it altogether.

Gas flames.—Injury from this cause is fairly frequent but not severe. Control over it lies almost entirely in better mechanism and better method of operation. The victim is almost always a man whose duties call him near the furnace or gas producer, but who has little or no control over the conditions which endanger him.

Unclassified hot substances.—Hot water and steam are the most important in the group of unclassified hot substances. Their abatement is almost entirely a problem of structure and operative method.

HANDLING TOOLS AND OBJECTS.

This cause group, in the open hearths as in other departments, has high frequency and rather low severity rates. The changes in rates have been as follows: In frequency a decrease from 45.2 cases per 1,000 workers in 1907 to 23.2 cases in 1913, a reduction of 49 per cent; in severity, an increase from 0.3 day per worker in 1907 to 0.5 day in 1913.

Because of the very small size of the severity rates, the increase therein is of no particular significance. The marked reduction in the frequency rate, however, is interesting, and may be attributable in large part to the substitution of magnets on cranes for the hand labor formerly used in handling scrap. It is quite certain that were the old hand method used with the greatly increased tonnage handled in recent years the frequency rate reduction could not have occurred.

POWER VEHICLES.

Power vehicles in open hearths, as reference to the table will show, had a frequency rate of 16.7 cases per 1,000 workers in 1907 and 14.7 cases in 1913, a reduction of only 12 per cent. The severity rates were 11.1 days lost per worker in 1907 and 6.2 days in 1913, a reduction of 44 per cent. Comparing these with the corresponding rates for blast furnaces, it is interesting to note that those for the open hearths were very much the greater in both years as regards frequency, and, as regards severity, were about the same as those for blast furnaces in 1907 but very much higher in 1913.

From this comparison it must be concluded that the power vehicle problem is more serious in open hearths than in blast furnaces. It is desirable to inquire the reason. The problem is difficult of solution in proportion to the degree to which railway operations cross the other operations of the mill. In no other department is this the case to the same extent as in the open hearths. For the most part, in all other departments, the cars bringing and taking away material come to and depart from the mill without passing into or through it at places where other operations are in progress. The open hearth is very different in this respect. On the stocking floor proper, hot metal cars are moving; next the furnaces are the scrap car trains; into the storage space, outside the hot metal track, come regular railway cars with loads of raw material; on the pit side are regular cars to receive and carry away slag; and the ingot trains are moving constantly. With this amount of exposure it is scarcely remarkable that power vehicles are an important factor in accident causation in open hearths. Here personal care and caution must play a large part. The operation of these moving units by well trained and competent men is of great significance. Railway experience proves conclusively that appliances in the form of automatic couplers, proper steps, and grab irons must be furnished. Open hearth practice is not yet up to the highest possible standard in these respects. When it is made so, further reduction of severity from power vehicles should occur.

UNCLASSIFIED CAUSES.

This group of causes is responsible for the highest frequency rates of any of the groups, but its severity rates are relatively low. The group includes "falls of worker" and the high severity rates in certain years usually represent cases of a worker's falling from some part of the structure. While this hazard can not be compared with the similar danger in blast furnaces it is sometimes very important. The provision of railed walkways for all regular overhead operations, such as lamp trimming, is suggested as highly desirable.

Open hearths share with plate and sheet mills in having a considerable number of cases of heat exhaustion.[1] This has become materially less with the introduction of water cooled doors and jambs. By this arrangement a constant stream of cool water passes through the hollow iron door and through the iron jambs at its side. The effectiveness of these provisions appear in a difference of 33° in recorded temperatures in front of the furnaces in two open hearths, one of modern pattern and the other of the older type.[2] This difference is reflected in the lowered rate of heat exhaustion and must have a still more important bearing on general health.

ACCIDENT FREQUENCY, BY OCCUPATIONS AND CAUSES.

For certain distinctive occupations in the open hearth department, it has been possible to isolate the number of employees, and thus to compute accident frequency rates by occupations and causes. These rates are shown in the following table:

TABLE 37.—ACCIDENT FREQUENCY RATES IN OPEN HEARTHS, BY OCCUPATIONS AND CAUSES, 1905 TO 1914.

Cause.	Accident frequency rates (per 1,000 300-day workers).					
	Common labor.	Pit side workers.	Pouring platform workers.	Stocking floor workers.	Unclassified workers.	Total.
Working machines	4.1	0.5	....	1.5	3.7	2.2
Cranes and hoists	6.8	2.5	....	.5	1.7	2.5
Hot substances	90.3	37.5	41.9	36.3	41.3	48.6
Falling objects	104.1	20.0	5.2	29.9	33.7	42.3
Falls of worker	1.6	.7	....	1.2	2.8	1.3
Handling tools and objects	14.8	.4	....	2.1	25.0	9.2
Unclassified [a]	245.9	33.0	28.3	43.5	69.0	86.3
Total	467.7	94.7	75.5	114.9	176.5	192.4
Number of 300-day workers	*4,851*	*5,492*	*954*	*7,761*	*5,395*	*24,453*

[a] The unclassified group contains all cases not regarded as characteristic of this department.

The highest frequency rate (467.7 cases per 1,000 300-day workers) is found among the common laborers. This is true of a majority of the individual cause groups as well as for the total. As should be constantly emphasized, these high frequency rates for common labor are known to be accompanied by high severity although the exact severity rates can not be computed. It becomes of the utmost importance therefore to study with great care the conditions of such labor. It has been demonstrated that frequency of accident can be reduced very rapidly by methods which incite foremen to adequate instruction and oversight and which interest the men in exercising proper care. But, as regards severity, it must be insisted that faulty working conditions may very probably still remain and that these must be remedied to secure maximum results.

[1] See Table 31.

[2] See Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. III, p. 310.

Considering hot substances, common labor again has the highest rate (104.1 cases per 1,000 300-day workers), followed by pouring platform workers (41.9 cases) and pit men (37.5 cases). The conditions of work would suggest a considerable number of burns at the pouring platform, but of a less severe character than those suffered by the pit side workers.

ACCIDENT CAUSES IN THE BESSEMER DEPARTMENT.

Much of what has already been said regarding open hearths applies with equal force to the Bessemer department. This discussion will therefore be mainly confined to those points in which the Bessemer process has features of hazard not found in the open hearths.

The next table shows the frequency and severity rates for the principal accident causes in the Bessemer departments for which it was possible to obtain data over a series of years.

TABLE 38.—CAUSES OF ACCIDENTS IN BESSEMER DEPARTMENT, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines	4.1	3.9	....	1.3	3.0	....	2.3	1.7
Cranes and hoists	24.8	19.6	10.7	23.0	10.5	7.6	10.3	8.7
Hot substances	114.8	35.2	36.0	31.8	20.9	41.9	27.4	20.8
Handling tools and objects	13.4	33.2	25.3	40.8	19.4	6.3	19.4	5.2
Power vehicles	14.5	13.6	8.0	15.3	7.5	8.9	4.6	....
Unclassified [1]	230.6	160.4	114.7	139.0	77.7	100.2	61.7	29.5
Total	402.3	266.1	194.7	251.3	139.0	164.9	125.7	65.9
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	0.1	0.1	....	(2)	(2)	....	0.1	0.2
Cranes and hoists	1.0	35.3	0.1	0.8	0.3	0.3	.4	1.8
Hot substances	4.4	.7	.9	23.5	.6	.6	.6	.8
Handling tools and objects	.3	.3	.4	.6	5.5	.1	.2	2.0
Power vehicles	.4	.8	.3	.4	.2	.4	10.4	....
Unclassified [1]	13.1	20.6	26.2	14.1	1.2	3.6	1.3	17.6
Total	19.3	58.0	28.0	39.5	7.7	5.0	13.0	22.5
Number of 300-day workers	*967*	*511*	*750*	*784*	*669*	*788*	*875*	*576*

[1] The unclassified group contains all cases not regarded as characteristic of this department.
[2] Less than 0.05.

The irregularity in the severity rates may be due in considerable part to the small exposure upon which they are based. It has been the general practice of this report not to compute rates when the exposure obtainable is less than 1,000 300-day workers. This practice is departed from here because of the interest that attaches to this department.

In addition to such irregularity as may be due to the rather small basic exposure, it is also true that the hazards of the Bessemer department are essentially fluctuating. Events which can not be anticipated, such as explosions, are more common than in other departments. Improved structure has done and is doing a great deal but it still remains true that the Bessemer is what the safety men call a "bad actor."

Working machines are an almost negligible factor in this department. The converters themselves are not included as machines, since the accidents directly connected with them are nearly all properly placed under other heads, such as hot substances, falling bodies, etc.

Cranes and hoists appear as usual of high importance, both in frequency and severity.

Hot substances have very high frequency rates, but the severity rates are high in only a few years. The high frequency arises from the small particles of molten metal projected from the converters during a "blow." The decline in frequency to be noted is partly due to greater care in the clothing worn by the workmen but more to changed methods of operation which make it needless to work in certain localities when these particles are falling. The very high severity rate of 1910 (23.5 days) was due to a bad spill which caused two deaths.

The unclassified group includes falling objects, falls of worker, and several other causes. Of these, falling objects is of considerable importance in the Bessemer department but could not be conveniently isolated.

Formerly a rather frequent cause of serious accident from hot metal was the failure of the hydraulic hoisting apparatus. In plate 13 the ladle is shown above the mold ("B"). If, when in that position, leakage occurred from the hoisting cylinder the crane arm would sag down, the bottom of the ladle would catch on the top of the mold, and the ladle would be completely overturned. Such an occurrence is entirely prevented by the application of an automatic catch at point "A." The catch is so arranged that when in the position shown it engages with a lug on the pillar, having the form of an arc of a circle. When the crane is swung in either direction the catch remains engaged with the lug until the ladle is entirely clear of the molds. It then releases and the ladle can be lowered if necessary.

It has already been indicated that much danger results from what is called a "running stopper." This is a stopper defective in some way so that it will not perfectly fit the opening in the bottom of the ladle and prevent the outflow of the metal between pours. A simple installation in one Bessemer plant proved very effective in minimizing this danger. Two air hoists were installed above the pouring platform. Immediately upon the completion of the pouring of a ladle the stopper was hoisted out. If, on inspection, it appeared in good condition it remained suspended until the completion of another pouring and was then restored. If its condition was unsatisfactory the stopper was lowered to the platform and replaced by a fresh one kept constantly in reserve. This procedure had two advantages: (1) An inspection after each heat, and (2) the stopper, having a chance to cool before being restored, lasts longer than when in continuous service.

Under conditions formerly prevalent the scrap and pig thrown into the converter (to cool the metal before tilting the converter to discharge the heat into the ladle) was thrown directly into the converter from a platform. This exposed the men engaged to very severe heat and made it very likely that scrap would fall to the floor below. Many severe injuries arose from this cause. In the best recent construction the "scrappers" work behind a water-cooled screen and deliver the material into a chute, which effectually prevents its falling to the pit floor.

ACCIDENT CAUSES IN THE FOUNDRY DEPARTMENT.

The foundries included here are limited to those which form parts of large steel plants, the foundry data being accumulated somewhat incidentally along with the data for the more important departments.

The following table shows, by years, the frequency and severity rates for the more characteristic accident causes in these foundries:

TABLE 39.—CAUSES OF ACCIDENTS IN FOUNDRIES, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines	7.5	2.8	6.1	6.7	2.3	7.5	3.0	5.1
Cranes and hoists	34.1	25.0	59.9	32.8	22.9	47.3	19.2	27.4
Hot substances	42.6	36.2	39.6	35.3	27.4	23.7	24.2	10.3
Handling tools and objects	52.2	55.6	54.8	49.6	61.7	61.6	43.4	35.9
Power vehicles	....	....	2.0	.8	....	.9	2.0	1.7
Unclassified [1]	54.3	48.7	71.1	95.9	70.9	82.4	57.6	47.9
Total	190.6	168.3	233.5	221.2	185.1	223.5	149.5	128.2
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	0.4	(2)	0.1	(2)	0.2	0.7	(2)	(2)
Cranes and hoists	.8	0.6	1.7	1.0	10.7	19.4	0.5	0.3
Hot substances	.8	.8	.9	.6	.4	1.4	9.6	.2
Handling tools and objects	.6	.4	.5	.4	2.2	.7	1.5	2.6
Power vehicles	....	....	(2)	(2)	....	(2)	(2)	.1
Unclassified [1]	10.9	.6	2.2	2.2	11.5	1.0	1.2	.4
Total	13.6	2.5	5.5	4.4	24.9	23.1	12.8	3.7
Number of 300-day workers	*939*	*719*	*985*	*1,189*	*875*	*1,056*	*990*	*585*

[1] The unclassified group contains all cases not regarded as characteristic of this department.
[2] Less than 0.05.

As was noted to be the case with the Bessemer department, the yearly cause rates for foundries, shown in this table, are not based upon sufficient exposure to assure their being typical. But the body of material is sufficiently large to render the rates of very considerable interest.

CHAPTER V.

CAUSES OF ACCIDENTS IN ROLLING MILLS.

ACCIDENT CAUSES IN HEAVY ROLLING MILLS.

Accident rates, by principal causes, in the heavy rolling mills are shown in the following table for the period 1907 to 1914:

TABLE 40.—CAUSES OF ACCIDENTS IN HEAVY ROLLING MILLS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines[1]	16.7	12.0	13.3	9.9	11.4	8.1	9.2	7.3
Cranes and hoists	18.9	14.3	21.6	12.5	13.1	8.8	6.1	6.3
Hot substances[1]	16.0	11.9	14.4	11.9	10.1	11.2	8.9	7.4
Power vehicles	5.0	2.2	6.1	3.9	2.9	3.4	3.2	.9
Unclassified[2]	139.1	130.4	129.5	102.9	101.8	101.6	72.0	35.4
Total	195.8	170.8	184.9	141.1	139.3	133.1	99.4	57.3
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	2.5	3.3	2.5	4.4	1.4	0.4	0.4	0.4
Cranes and hoists	6.4	.4	4.7	.9	3.1	.4	.1	.2
Hot substances	2.2	.4	4.5	2.0	2.3	2.1	5.2	3.0
Power vehicles	.1	.1	.2	.2	.1	.5	.1	.3
Unclassified[2]	8.2	6.1	6.5	8.1	7.6	2.4	1.6	1.6
Total	19.4	10.3	18.4	15.5	14.4	5.6	7.5	5.4
Number of 300-day workers	*4,556*	*3,135*	*4,210*	*4,886*	*4,195*	*5,226*	*5,287*	*3,504*

[1] Further details under this item will be found in Table 105.
[2] The unclassified group contains all cases not regarded as characteristic of the department.

Examination of the table brings out an interesting fact as regards the importance of the unclassified cause group. This group, which includes those general causes which the rolling mills share with other departments, contributes more than one-half of the total frequency rate in each of the years. But in the case of the severity rates this situation is reversed, the unclassified group contributing the minor part of the total rate in almost all of the years and very much the minor part in the later years.

Tracing the course of the rates over the years shown, it will be noted that there has been a marked tendency to decline. The frequency rates for each of the cause groups is notably lower in 1913 than in 1907. This is also true of the severity rates, with the exception of the hot substance group, for which the rates were only 2.2

days lost per worker in 1907 as compared with 5.2 days in 1913 and with 3 days in 1914. Hot substances as a cause of severe accident have thus apparently been increasing in importance in the heavy rolling mills, while all other causes have been decreasing.

Careful study of the machinery of the heavy rolling mill indicates that the accidents in connection with the rolls themselves are among the more numerous and that they have remained practically constant during a number of years.[1] Objects flying from the machines caused injury much more frequently in the earlier than in the later years. Accessory machines used about the mills give rise to more accidents than any of the characteristic rolling machines, although the injuries from the former source are much less severe in character.

When hot substances are considered, it appears that during manipulation of the steel in the rolls injuries are not numerous. Such accidents arise usually before the hot steel has reached the rolls or after it has passed on to the hot beds.

This department does not appear to present particular points upon which safety effort may be centered. The improvement thus far effected appears to have been due rather to the steady application of generally accepted safety methods than to specific changes in method or structure. It is to be noted that the record is particularly good in the case of cranes and hoists.

In all heavy rolling the roll and transfer table have large gears (pl. 14) which when uncovered are a serious menace. In plate 14 a heavy iron cover is shown removed and lying on the floor. Below the gears is a cast-iron guard so molded as to form a reservoir for oil for each pair of gears. When the cover is in place, a complete inclosure is formed. The gears revolving in a bath of oil need attention in the matter of lubrication only at considerable intervals. Some millmen object to such guards on the ground that they interfere with inspection and repair. It is probable that the longer life of the gears, protected completely from dust and grit, more than offsets the extra time involved in removing the cover for inspection.

Those who object to the inclosing cover prefer a guard such as is shown at "B," plate 15. The side of this is hinged to the horizontal portion and can be turned back, exposing the gears for oiling, inspection, and repair.

Plate 15 also shows at "A" a bridge over the transfer tables. Before such bridges were provided even the necessary crossing from side to side of the tables was seriously dangerous for the experienced man, while the new or inexperienced man who had occasion to cross it was taking his life in his hand. Such means of transit can be very properly increased in many places.

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[1] See Table 105 for the analysis of the frequency rates of machines in heavy rolling mills.

PLATE 13.—LADLE CRANE IN BESSEMER PLANT, WITH SAFETY DOG ON HOIST.

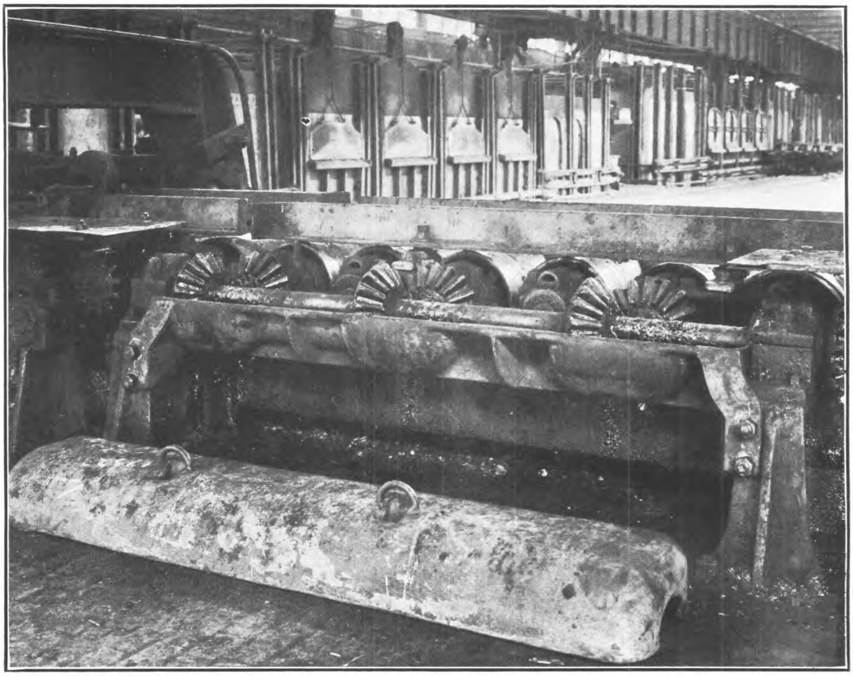

PLATE 14.—TRANSFER TABLE, WITH SHIELD FOR GEARS.

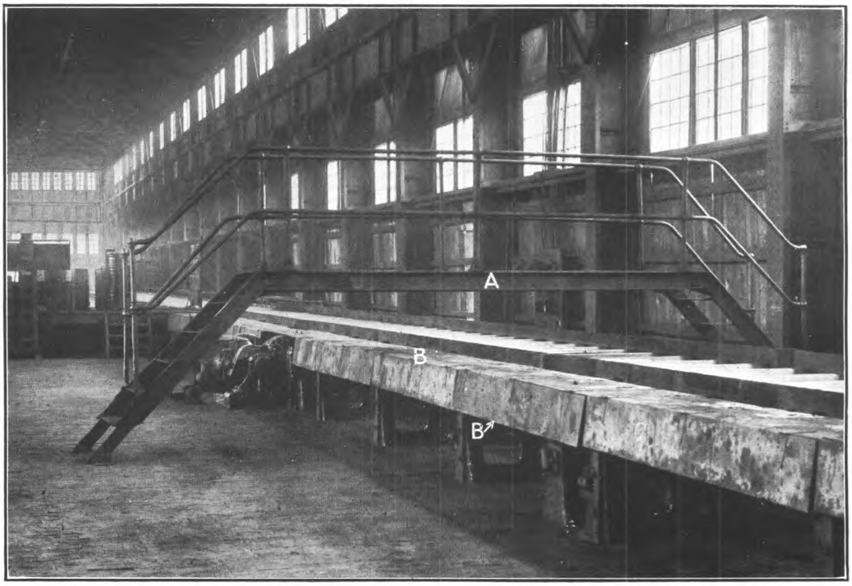

PLATE 15.—TRANSFER TABLE WITH GUARD FOR GEARS AND WITH BRIDGE.

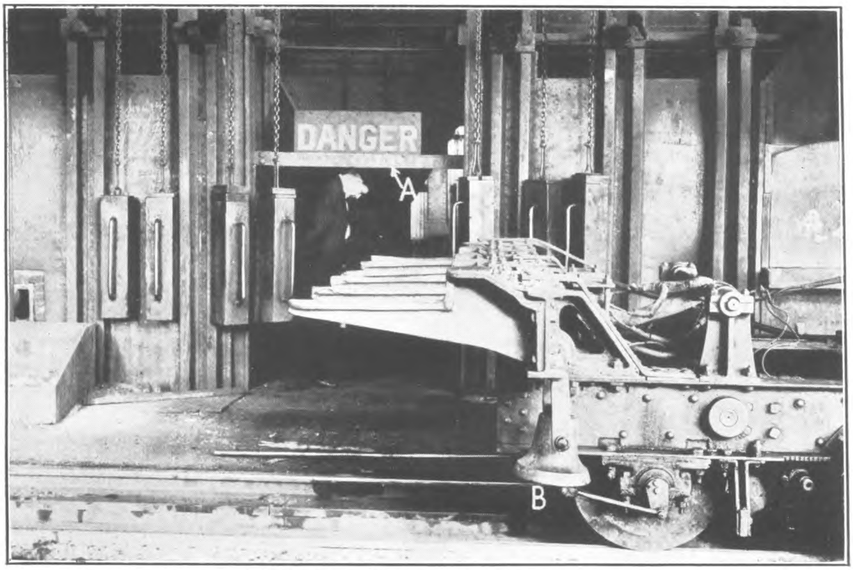

PLATE 16.—BLOOM DELIVERY CAR, WITH DANGER SIGN AND WARNING BELL.

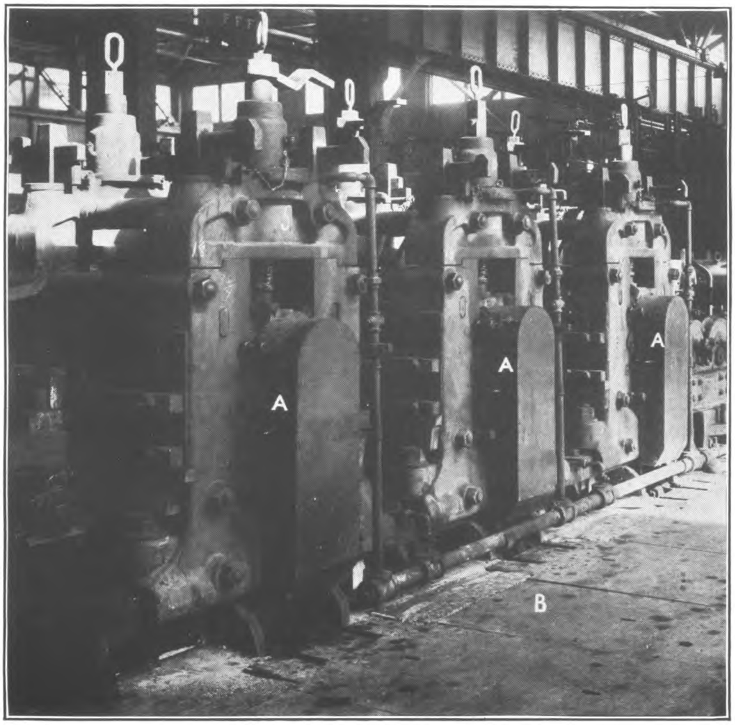

PLATE 17.—SHIELDS OVER ROLL WABBLERS.

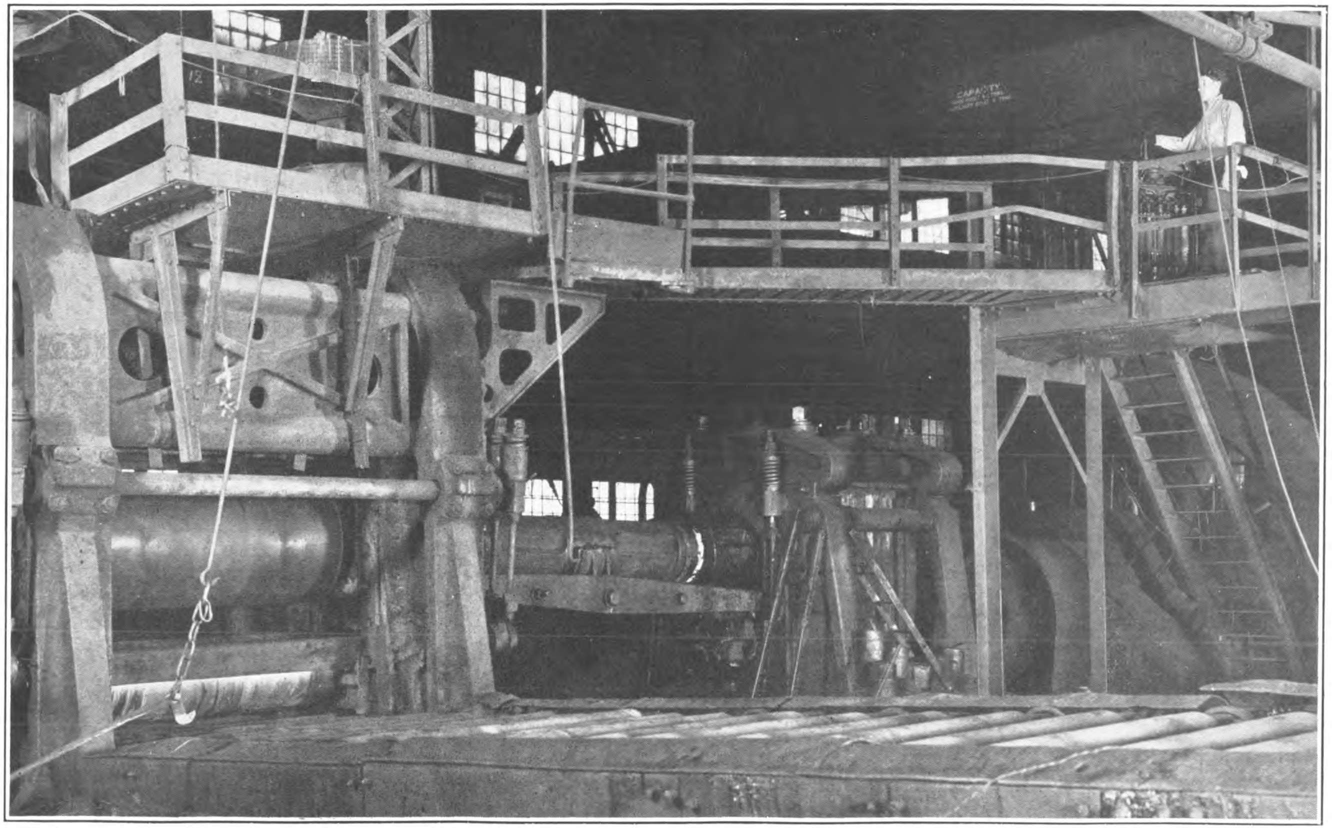

PLATE 18.—FORMER POSITION OF SCREW-DOWN PULPIT IN PLATE MILL.

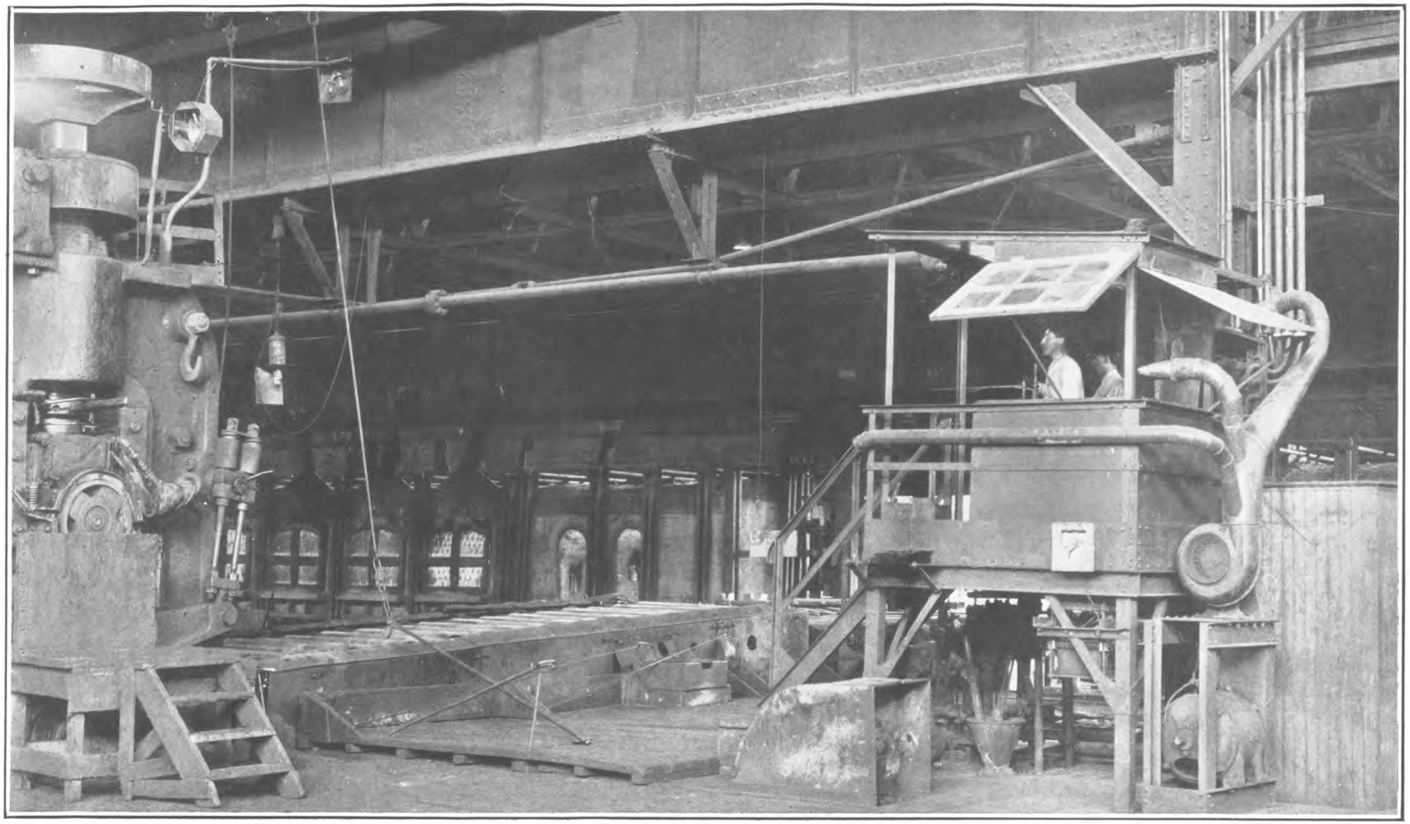

PLATE 19.—NEW POSITION OF SCREW-DOWN PULPIT IN PLATE MILL.

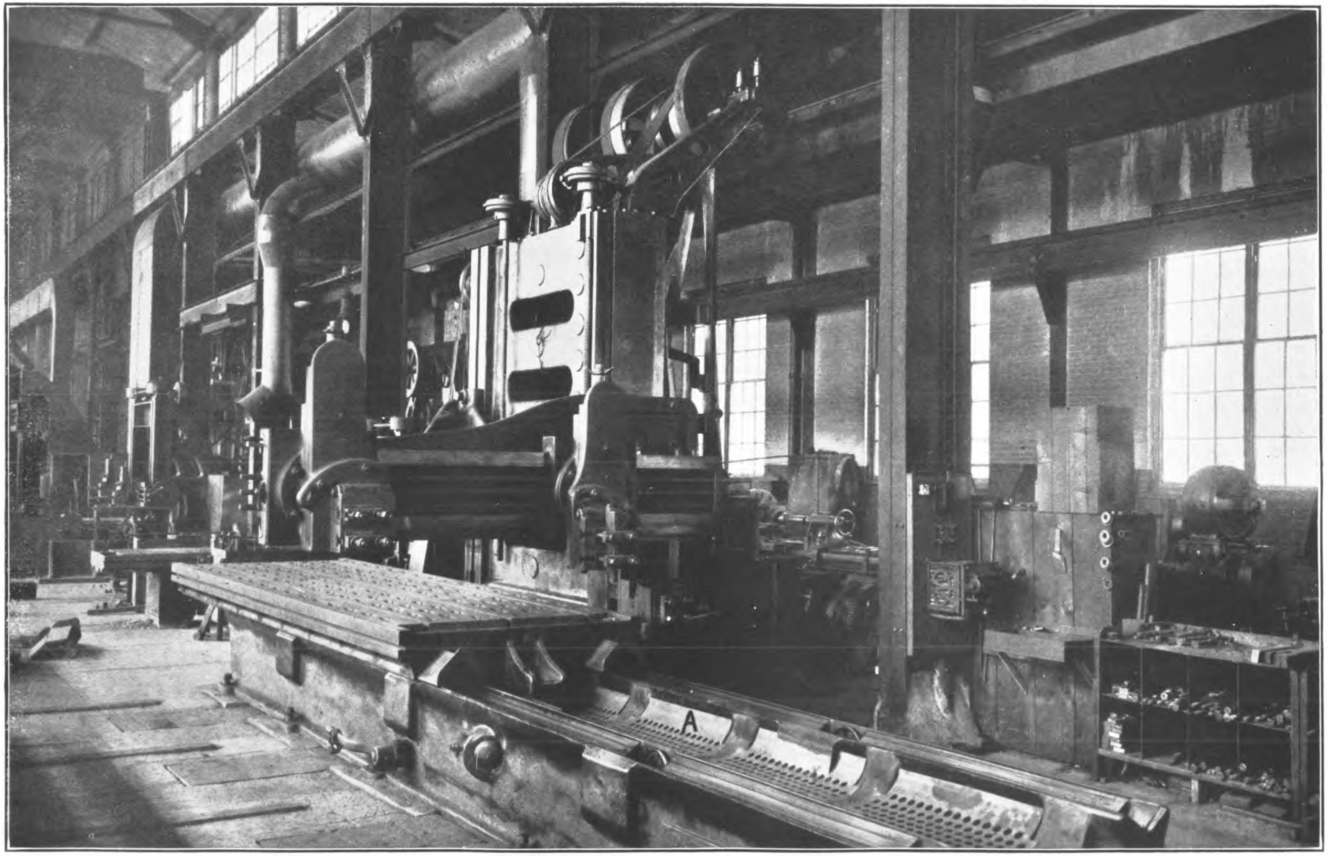

PLATE 20.—METAL PLANER, WITH SAFETY PLATES CLOSING OPENING IN BED.

Plate 16 shows at "A" a sign so placed that a man coming through the passageway is not likely to disregard it and step out upon the track. A further safeguard is the bell at "B" which rings automatically whenever the bloom car moves.

Plate 17 illustrates a feature which is now quite generally incorporated in the design of roll housings. At "A" are guards which screen the revolving roll wabblers.

ACCIDENT CAUSES IN TUBE MILLS.

The rates for the principal accident causes in the tube mills, for the years 1907 to 1914, are as follows:

TABLE 41.—CAUSES OF ACCIDENTS IN TUBE MILLS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914	1907 to 1910	1911 to 1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).									
Working machines [1]	48.8	44.8	43.6	31.8	35.5	19.7	10.5	2.6	42.3	17.3
Cranes and hoists	22.9	12.4	16.0	13.4	9.3	7.0	5.2	3.3	16.6	6.3
Hot substances	42.4	20.7	23.2	17.9	24.5	15.0	4.8	5.2	26.8	12.3
Power vehicles	.5	......	1.1	......	......	......	......	......	.4	......
Unclassified [2]	174.4	139.2	170.4	165.2	156.1	126.7	58.1	34.1	163.8	95.2
Total	289.0	217.1	254.3	228.2	225.4	168.4	78.6	45.2	249.9	131.1
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).									
Working machines [1]	1.8	1.0	8.1	5.9	0.6	5.7	0.2	0.3	4.3	1.9
Cranes and hoists	.5	.4	.5	.5	.1	4.3	.1	.6	.5	1.4
Hot substances	.6	.4	.4	.3	.5	.1	.2	(3)	.4	.2
Power vehicles	(3)	......	.1	......	......	......	......	......	(3)	......
Unclassified [2]	7.5	2.7	3.7	3.1	2.7	1.7	10.2	2.2	4.4	4.4
Total	10.4	4.5	12.7	9.9	3.9	11.8	10.6	3.1	9.6	7.9
Number of 300-day workers	*2,007*	*1,451*	*1,813*	*1,792*	*1,717*	*2,131*	*2,101*	*1,527*	*7,063*	*7,476*

[1] Further details under this item will be found in Table 105.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

This department offers a striking illustration of the weakness of the frequency rate alone as a measure of hazard. The operation of tube mills gives opportunity for a large number of minor injuries, while severe injuries are comparatively rare. As shown in the table, the earlier years have high frequency rates with relatively low severity rates. From year to year the frequency rates drop, toward the last of the period with extraordinary rapidity. During the same time severity shows much fluctuation without much decline. In fact a reduction in severity is hardly detectable, except by comparing the rates for the earlier four years combined with those for the later four years. This is done in the last two columns of Table 41, which show the cause rates for 1907 to 1910 in comparison with those for 1911 to 1914.

It will be noted that, between the two periods, the frequency rates for machine operation declined 59 per cent (from 42.3 to 17.3 cases), while severity rates declined 56 per cent (from 4.3 to 1.9 days). In this instance the reductions in frequency and severity are unusually close together. In contrast, it may be noted that cranes and hoists decline in frequency 62 per cent (from 16.6 to 6.3 cases), but rise in severity 180 per cent (from 0.5 to 1.4 days). This rise in severity, however, is mainly due to an unusually high severity in one year of the later four years. Aside from that year, the later period has distinctly lower severity.

Hot and corrosive substances decline in frequency 54 per cent (from 26.8 to 12.3 cases), and in severity 50 per cent (from 0.4 to 0.2 day). The miscellaneous group of other causes declines in frequency 42 per cent (from 163.8 to 95.2 cases), but in severity remains unchanged (at 4.4 days).

The total for all causes shows a decline in frequency of 47 per cent (from 249.9 to 131.1 cases), and in severity a decline of only 18 per cent (from 9.6 to 7.9 days).

These comparisons show clearly that a very definitely improved condition prevailed in the later of the four-year periods. It is equally clear that appeal to the frequency rates only would give a wrong idea regarding the nature and extent of the improvement.

The unclassified cause group is in need of special attention. Here, notwithstanding a very considerable drop in frequency, severity has maintained a nearly constant level. Table 42 reveals the fact that common labor has an extremely high frequency from these miscellaneous causes. Probably attention to certain phases of the working condition of such labor might produce desirable results.

A detailed analysis of the accidents resulting from machines in tube mills showed that the pipe threading and cutting machines contribute the largest number of injuries.[1] The pushers, by which the skelp is introduced into the furnace, also have a high frequency rate. Accidents at the rolls, while quite frequent in early years, had entirely disappeared by 1913 and 1914.

ACCIDENT FREQUENCY, BY OCCUPATIONS AND CAUSES.

For a few important occupational groups in the tube mills it has been possible to compute occupational rates by causes. These are shown in the following table. It was not possible to make similar computation for severity rates.

[1] See Table 105 for an analysis of frequency rates for machine accidents in the tube mills.

TABLE 42.—ACCIDENT FREQUENCY RATES IN TUBE MILLS, BY OCCUPATIONS AND CAUSES, 1907 TO 1914.

Cause.	Accident frequency rates (per 1,000 300-day workers).				
	Common labor.	Furnace crews.[1]	Finishing crews.[2]	Other occupations.[3]	Total.
Working machines	61.7	12.7	17.3	35.6	29.4
Cranes and hoists	56.0	1.6	.2	7.7	11.3
Hot substances	69.7	13.7	.7	16.9	19.3
Power vehicles	.5	....	....	.4	.2
Unclassified	473.4	32.3	43.2	113.6	128.6
Total	661.3	60.3	60.5	174.2	188.9
Number of 300-day workers	*2,123*	*3,066*	*4,150*	*5,200*	*14,539*

[1] Includes ballers, bar pullers, benders, heaters, hook runners, pushers, rollers, tong men, take-offs, turn-downs, welders, etc.
[2] Includes bundlers, pipe threaders, pipe testers, weighers, etc.
[3] Includes crane hookers, cranemen, mechanics, workers in socket and galvanizing shops, etc.

This occupational table does not demand special comment. But attention may be called to the very high frequency rates among common laborers. This might be of small significance were it not known, although exact data is lacking, that the severity rates among such labor are also high.

ACCIDENT CAUSES IN PLATE MILLS.

The accident rates in plate mills, by causes and by years, are as follows:

TABLE 43.—CAUSES OF ACCIDENTS IN PLATE MILLS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines [1]	20.9	17.1	12.9	14.4	14.6	11.5	9.9	4.4
Cranes and hoists	40.7	19.6	32.4	34.7	21.3	29.1	17.9	10.2
Hot substances [1]	20.9	17.1	20.2	16.0	14.0	16.6	16.4	7.3
Power vehicles	5.2	1.7	6.7	5.3	3.6	5.5	5.0	.7
Unclassified [2]	253.3	174.8	180.5	147.4	134.9	165.7	130.1	66.0
Total	341.0	230.2	252.8	217.9	188.4	228.4	179.3	88.5
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	7.4	0.5	0.3	1.0	0.2	1.7	0.6	0.1
Cranes and hoists	.9	.7	6.0	10.6	.3	1.1	5.1	.3
Hot substances	14.3	.2	.2	.2	.2	.2	.3	.1
Power vehicles	.3	(3)	.1	5.0	.1	.1	4.6	(3)
Unclassified [2]	7.7	9.8	2.5	3.6	3.6	7.5	1.9	1.6
Total	30.7	11.2	9.1	20.5	4.4	10.6	12.5	2.1
Number of 300-day workers	*1,915*	*1,173*	*1,634*	*1,872*	*1,645*	*1,992*	*2,013*	*1,379*

[1] Further details under this item will be found in Table 105.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

Working machines show from 1907 to 1913 a decline in frequency rates of 53 per cent (from 20.9 to 9.9 cases), and in severity a decline of 92 per cent (from 7.4 to 0.6 days). Between the same years cranes and hoists decline 56 per cent in frequency (from 40.7 to 17.9 cases) but rise in severity from 0.9 day to 5.1 days from the earlier to the later year, although, if the experience is considered in four-year periods, the earlier four years show much greater severity than the later four. Hot substances have lower rates in 1913 than in 1907—in frequency by 22 per cent (20.9 as against 16.4 cases), in severity by 98 per cent (14.3 as against 0.3 days). Power vehicles have about the same frequency rate in 1913 as in 1907, and while the severity rate is higher in 1913 than in 1907, the average for the later four-year period is just about the same as for the first four years. The unclassified cause group shows a marked reduction in both frequency and severity rates.[1]

The most promising field for safety study in the plate mills appears to be the operation of shears and the protection from flying objects which are largely due to shears.

It has elsewhere been noted that plate mills show rather frequent cases of exhaustion produced by heat. This is due to the extended area of radiation presented by the plates. The most important safeguard is a supply of water of good quality and of not too low a temperature for drinking purposes. Besides this, attention can be given to the position of the workers, to shielding them by means of water-cooled or other screens, and to furnishing them with a supply of fresh air. This latter serves both for the relief of the men and to carry away heated air. The plates (18 and 19) show a rearrangement in one mill which contributed greatly to the comfort of the man in the "pulpit," increased his efficiency, and doubtless conserved his health. Originally his "pulpit" was almost directly over the roll table along which the red-hot plates were constantly passing (Pl. 18). In the rearrangement of the mill he was shifted to a position removed from the table and a fan was installed, driving its air current from the man toward the heated plates (Pl. 19). The improvement was very marked.

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[1] A further analysis of frequency rates for machines and hot substances in plate mills is given in Table 105.

ACCIDENT CAUSES IN SHEET MILLS.

The accident rates for sheet mills are shown, by principal causes and by years, in the following table:

TABLE 44.—CAUSES OF ACCIDENTS IN SHEET MILLS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines [1]	13.1	15.9	11.0	12.9	19.3	17.8	19.7	18.4
Hot substances [1]	21.7	11.3	8.5	4.9	4.5	7.5	3.0	6.4
Handling tools and objects [1]	39.3	37.9	31.7	14.0	30.8	55.7	37.5	18.4
Heat	....	....	1.7	2.7	3.7	1.0	.7	1.6
Unclassified [2]	60.2	55.4	49.5	37.9	50.6	65.3	53.5	48.3
Total	134.3	120.5	102.3	72.4	108.9	147.4	114.5	93.4
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	0.4	0.3	4.4	1.6	4.0	1.7	2.8	0.6
Hot substances	.2	.1	.1	.1	.1	.1	.1	.1
Handling tools and objects	.3	.3	.6	.6	.5	.8	.6	.2
Heat	....	....	(3)	3.4	3.7	(3)	(3)	(3)
Unclassified [2]	12.3	2.1	13.5	11.4	8.8	4.7	5.0	5.6
Total	13.2	2.8	18.5	17.2	17.0	7.5	8.5	6.5
Number of 300-day workers	*2,211*	*1,951*	*2,366*	*2,637*	*2,438*	*2,925*	*2,691*	*1,905*

[1] Further details under this item will be found in Table 105.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

Table 44 shows that these mills have relatively low rates, both frequency and severity. As a whole, they present the very unusual condition of a tendency to rising frequency rates while severity rates are declining. This situation is of sufficient interest to justify particular attention.

Reference to Table 45 will show that the hot-mill crews have a frequency rate very nearly the same as the remainder of the workers. The accidents to hot-mill men will very largely occur in connection with the characteristic machines of the mills. On the other hand, the miscellaneous employees will furnish nearly all the cases which fall into the unclassified group of causes.

An examination, therefore, of the experience for working machines and unclassified causes will give a fair idea of the trend of events in the two occupational groups.

From the rates given in Table 44 it will be seen that working machines—operated by the hot-mill crew—show for the entire period a definite tendency to rise both in frequency rates and in severity rates. At the same time the rates for the unclassified group of causes—contributed to most largely by the miscellaneous employees—

go down as definitely. The combination of these opposing tendencies produces the total result, referred to earlier as unusual, of rising frequency rates and decreasing severity rates.

How has it happened that an important group of workers have had actually rising rates during this period of general accident reduction? It may be replied that the rates, being relatively low as compared with other mills making different products, have not attracted the attention which they deserved. Further, the hot-mill crew having a rising rate was combined with a group of workers having a somewhat declining rate and the real condition was obscured by this combination, sheet mills as a whole showing a declining rate for the five years 1910 to 1914. Also, it is not possible to disconnect this definite rise in the accident rate of hot-mill crews as represented by these mills from the great increase in tonnage which has occurred since 1909. Accident rates, both frequency and severity, rising parallel with this growing tonnage force the conclusion that this increased product has been secured at some cost of increasing hazard. Whether the increase is of serious moment can only be determined by further study. It certainly deserves the most careful consideration of safety men who have charge of such mills.

The following table shows the frequency rates, by causes, for two occupational groups in the sheet mills—the hot-mill crew on the one hand, and all other workers on the other hand. The importance of this separation has already been pointed out.

TABLE 45.—ACCIDENT FREQUENCY RATES IN SHEET MILLS, BY OCCUPATIONS AND CAUSES, 1907 TO 1914.

Cause.	Hot-mill crews.	Other occupations.	Total.
Working machines	23.1	13.7	17.6
Hot substances	3.3	6.6	5.2
Handling tools and objects	39.0	28.3	32.7
Heat	3.3	.3	1.5
Unclassified	37.1	60.6	50.9
Total	105.8	109.5	107.9
Number of 300-day workers	*5,200*	*7,391*	*12,591*

CHAPTER VI.

CAUSES OF ACCIDENTS IN THE MECHANICAL, FABRICATING, AND YARD DEPARTMENTS.

ACCIDENT CAUSES IN THE MECHANICAL DEPARTMENT.

The accident rates for the mechanical department, by principal causes and years, are as follows:

TABLE 46.—CAUSES OF ACCIDENTS IN THE MECHANICAL DEPARTMENT, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines [1]	44.5	40.8	44.0	30.1	30.8	25.4	10.1	13.2
Cranes and hoists	16.9	13.6	10.1	12.1	6.5	4.7	5.1	6.0
Hot substances	13.4	7.4	8.1	9.9	14.9	8.9	10.5	5.4
Unclassified [2]	177.4	212.5	168.4	132.7	93.3	83.8	84.5	81.8
Total	252.2	274.2	230.7	184.9	145.5	122.8	110.2	106.5
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines [1]	1.0	1.6	1.1	0.6	0.7	1.1	0.2	1.0
Cranes and hoists	.4	5.9	.1	.2	.2	.3	.2	1.6
Hot substances	.2	5.7	4.6	.1	.1	.1	3.7	.1
Unclassified [2]	10.4	13.8	13.3	14.3	9.9	5.9	9.1	2.1
Total	11.9	27.0	19.1	15.3	11.0	7.3	13.2	4.7
Number of 300-day workers	*2,542*	*1,619*	*1,977*	*2,223*	*2,144*	*2,362*	*2,569*	*1,662*

[1] Further details under this item will be found in Table 106.
[2] The unclassified group includes all cases not regarded as characteristic of the department.

The characteristic hazard of mechanical departments is the working machine and it is particularly desirable to determine its importance as compared with other causes. Inspection of the various years covered by the table shows that both the frequency rates and the severity rates for working machines are much less than the rates of the unclassified group which contains causes common to this and other departments. This indicates clearly that the working machine is not, even in the department where it is characteristic, a hazard in any degree equal to the common dangers of industry. It is such facts as these which have given rise to the idea that "mechanical safeguarding" is a relatively unimportant matter. If attention is directed solely to working machines the idea is correct. When, however, the question of physical conditions is considered on a broader basis, as is later done (Chapter VIII), a much modified conclusion will be found to be necessary.

ACCIDENT CAUSES IN THE FABRICATING SHOPS.

The accident rates for fabricating, by principal causes and years, are shown in the following table:

TABLE 47.—CAUSES OF ACCIDENTS IN THE FABRICATING SHOPS, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Working machines [1]	42.3	29.0	48.0	48.2	58.1	74.7	63.6	37.0
Cranes and hoists	36.0	30.1	49.7	39.5	29.5	37.1	43.5	29.0
Hot substances	5.8	3.4	2.3	6.3	7.7	10.6	8.8	3.4
Unclassified [2]	198.9	121.7	169.5	190.0	202.0	191.9	174.1	129.1
Total	283.0	184.3	269.5	284.0	297.3	314.4	290.0	198.4
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Working machines	1.4	5.6	0.8	1.3	0.6	1.2	1.1	0.5
Cranes and hoists	13.8	7.4	16.0	14.0	5.7	10.8	.8	6.2
Hot substances	(3)	(3)	(3)	(3)	(3)	.2	.1	(3)
Unclassified [2]	20.3	3.8	11.7	11.2	2.4	8.7	6.5	2.9
Total	35.4	16.7	28.5	26.5	8.8	20.8	8.5	9.7
Number of 300-day workers	*2,081*	*1,758*	*1,770*	*2,074*	*2,203*	*2,074*	*2,045*	*1,759*

[1] Further details under this item will be found in Table 106.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

The working machine in this, as in the mechanical department, is a characteristic hazard, and it is slightly more important in fabricating, as comparison of the severity rates of this with the preceding table will show. This is due to the greater use of reamers, riveters, and punches, whose hazard exceeds that, for example, of lathes and planers. But the more serious dangers of fabrication are related to the constant use of the crane and to the common hazards which it shares with other departments. So frequent is the use of the crane in connection with the processes of fabrication that it might almost be regarded as one of the productive machines.

Working machines do not exhibit any tendency to declining rates in these shops, but cranes and unclassified causes show a steady decline.

In Table 106 will be found frequency rates for the individual machines used in the mechanical and fabricating departments.

ACCIDENT REDUCTION METHODS AMONG MECHANICS AND FABRICATORS.

The relatively rather slight importance of working machines in both the mechanical and fabricating shops has been pointed out. While as part of the general danger of the shops such machines are of small significance, it must not hastily be assumed that the individual

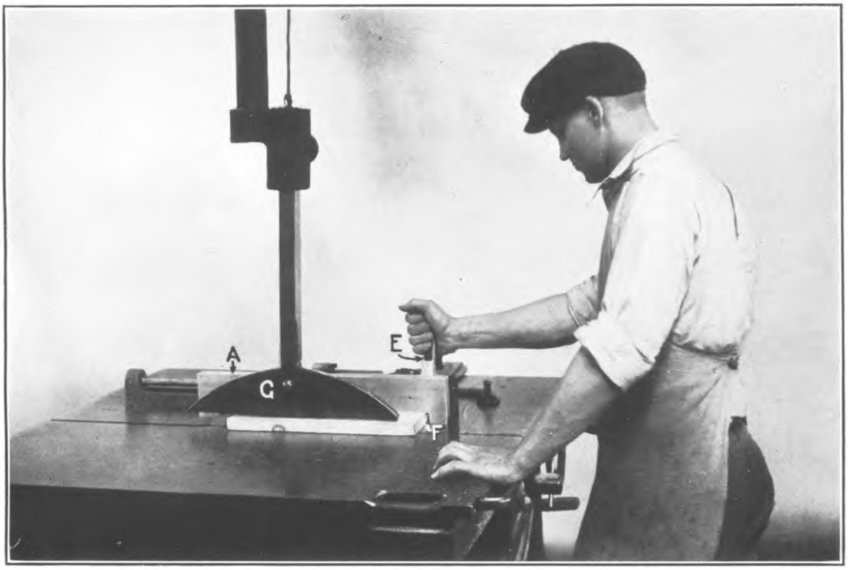


PLATE 21.—CIRCULAR SAW, WITH GUIDE PLATE AND GUARD.

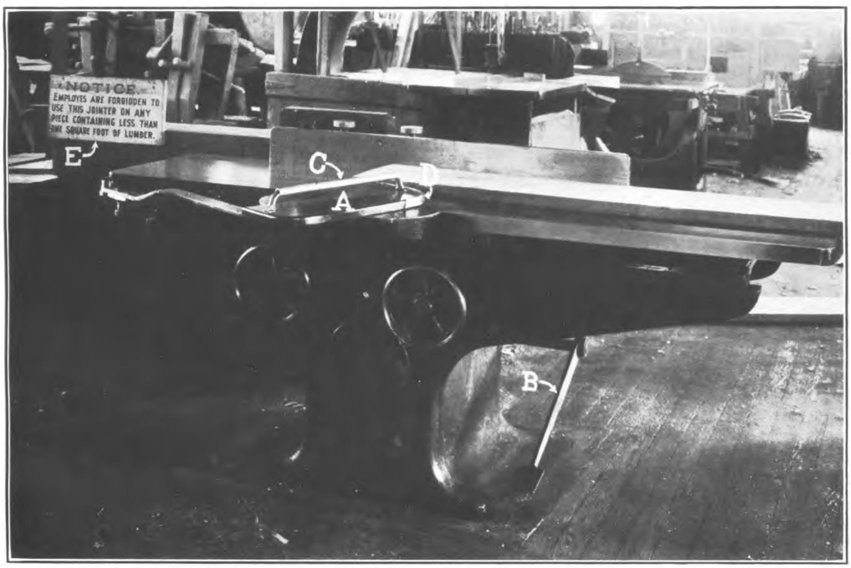


PLATE 22.—SHIELD OVER REVOLVING KNIFE OF WOOD PLANER.

PLATE 23.—CLAMP HOOKS FOR CARRYING PLATES.

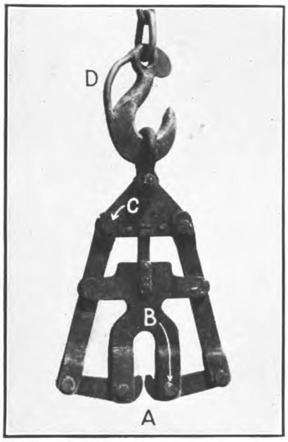


PLATE 24.—CLAMP FOR HANDLING PLATES IN VERTICAL POSITION.

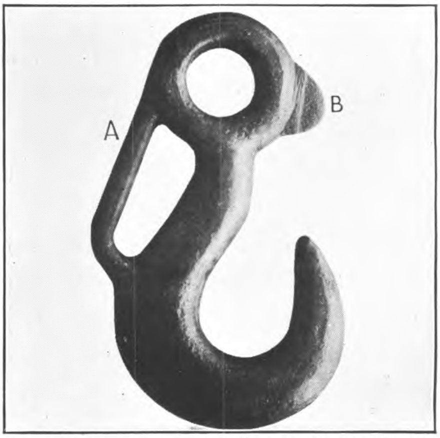


PLATE 25.—HOOK WITH SOLID FORGED HANDLE.

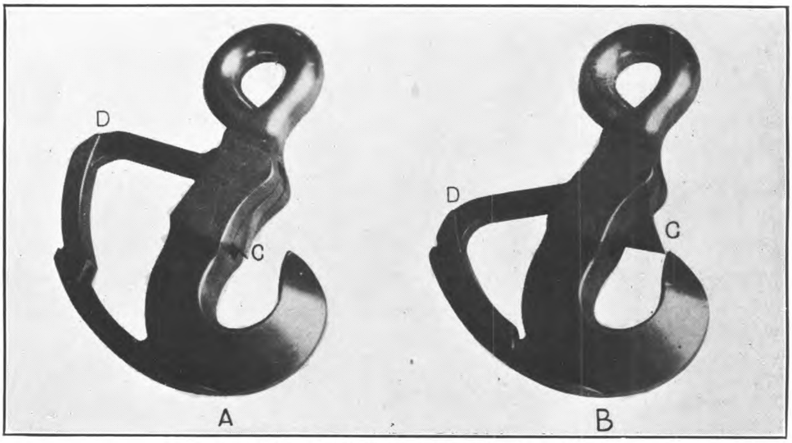


PLATE 26.—LOCKING SAFETY HOOKS.

operator is not exposed to a considerable degree of danger, although, unfortunately, occupational rates which would definitely determine this point can not yet be prepared.

Among working machines of various kinds, the punches, reamers, and riveters contribute most to the accident hazard. In this connection the improvement which promises most is an electrically actuated reamer. Heretofore compressed air has been the motive power. A reamer so actuated is very likely to become unmanageable and may cause serious injury. The electrically propelled reamer runs steadily and without the jerks and jars inseparable from the older type.

Numerous attempts have been made to devise a safety chuck for drills which would hold the drill rigid only when actually pressing against the work. Some of these devices are very promising, but have not yet come into general use. The avoidance of drill accidents remains a matter of personal care.

Lathes as now furnished by the makers—with gears entirely inclosed and with changes of speed accomplished by gear shifting or, when cone pulleys are employed, by a proper belt shifter—present few points of danger.

Grinding wheels are now nearly all inclosed in hoods which hold the fragments if they explode. With goggles or eye screens to protect the eyes such wheels should be comparatively harmless.

The only working machine which has a record of a number of deaths is the metal planer. These deaths, as far as could be ascertained, arose from failure to close the openings in the bed of the machine on which the platform moves back and forth. The cause of all deaths recorded is similar to that in the following example: A workman reaching for a tool in the space in the bed slipped and fell forward into the opening. He was caught and crushed by the moving platform. Plate 20 ("A") shows a simple method of closing these openings, a precaution which would have prevented the accident cited. There seems no reason why this particular death hazard should anywhere remain.

In collateral branches of the mechanical and fabricating shops, such as carpenter and pattern shops, it is still possible to find saws and wood planers not provided with any of the safeguards which have proved effective. Plates 21 and 22 illustrate some of these devices.

Cranes and hoists show an accident rate reduction in both mechanical and fabricating shops, but are still contributing serious injuries frequently enough to demand further attention. Adequate strength of chains and operating rules tending to prevent overstrain have not yet been sufficiently considered. It is probable that safety hooks of various types (plates 23, 24, 25, and 26) deserve a very much wider use than has thus far been accorded them.

ACCIDENT CAUSES IN THE YARD DEPARTMENT.

The accident rates for the yard department, computed for principal causes and by years, are as follows:

TABLE 48.—CAUSES OF ACCIDENTS IN YARD DEPARTMENT, BY YEARS, 1907 TO 1914.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Cranes and hoists	19.5	19.7	17.5	7.0	5.5	12.0	6.5	5.2
Hot substances	8.4	14.5	12.2	5.6	5.0	4.3	3.3	1.5
Falling objects	31.7	46.6	27.5	32.8	24.9	20.2	10.9	8.1
Power vehicles [1]	41.3	15.8	23.3	37.0	23.8	33.7	20.0	22.1
Unclassified [2]	99.3	95.3	105.8	62.8	49.7	51.5	31.3	35.4
Total	200.2	191.9	186.1	145.3	108.8	121.8	72.0	72.3
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Cranes and hoists	1.5	0.5	5.2	0.2	0.2	5.3	0.1	0.7
Hot substances	3.6	.9	.3	.4	.1	.1	[3]	[3]
Falling objects	4.0	6.7	.5	.5	.7	1.0	.2	.4
Power vehicles	8.9	1.4	24.4	9.9	10.5	4.1	1.4	1.1
Unclassified [2]	8.4	2.2	1.9	2.2	1.4	.8	.8	7.3
Total	26.3	11.8	32.3	13.1	12.8	11.4	2.6	9.5
Number of 300-day workers	*2,618*	*1,522*	*1,891*	*2,134*	*1,810*	*2,078*	*2,751*	*1,356*

[1] Further details under this item will be found in Table 107.
[2] The unclassified group includes all cases not regarded as characteristic of the department.
[3] Less than 0.05.

Of the cause groups isolated for this department none seems to call for particular comment except the "power vehicle" group. The "unclassified" and "falling objects" groups both have much higher frequency rates, but the severity rate for power vehicles is very much higher than any of the others in almost all of the years covered.

Comparing 1907 with 1913, frequency from power vehicles declined 51 per cent (from 41.3 to 20 cases per 1,000 workers), and severity declined 84 per cent (from 8.9 to 1.4 days per worker). Possibly a fairer comparison is by four-year periods, i. e., of the years 1907 to 1910 with the years 1911 to 1914. This shows frequency declining 15 per cent and severity 61 per cent. Both these methods of comparison are distinctly reassuring since they show that the main hazard of yard operations, the operation of locomotives and cars, has been brought under control to a very considerable degree. This is the more cheering inasmuch as in the earlier report on accidents in the iron and steel industry, published in 1913, it was found that no appreciable improvement in the yard department had occurred up to that time.[1]

Among the accidents due to power vehicles, the coupling and uncoupling of cars was the immediate cause of the largest number

[1] Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, p. 98.

PLATE 27.—YARD TRESTLE, WITH VARIOUS SAFETY DEVICES.

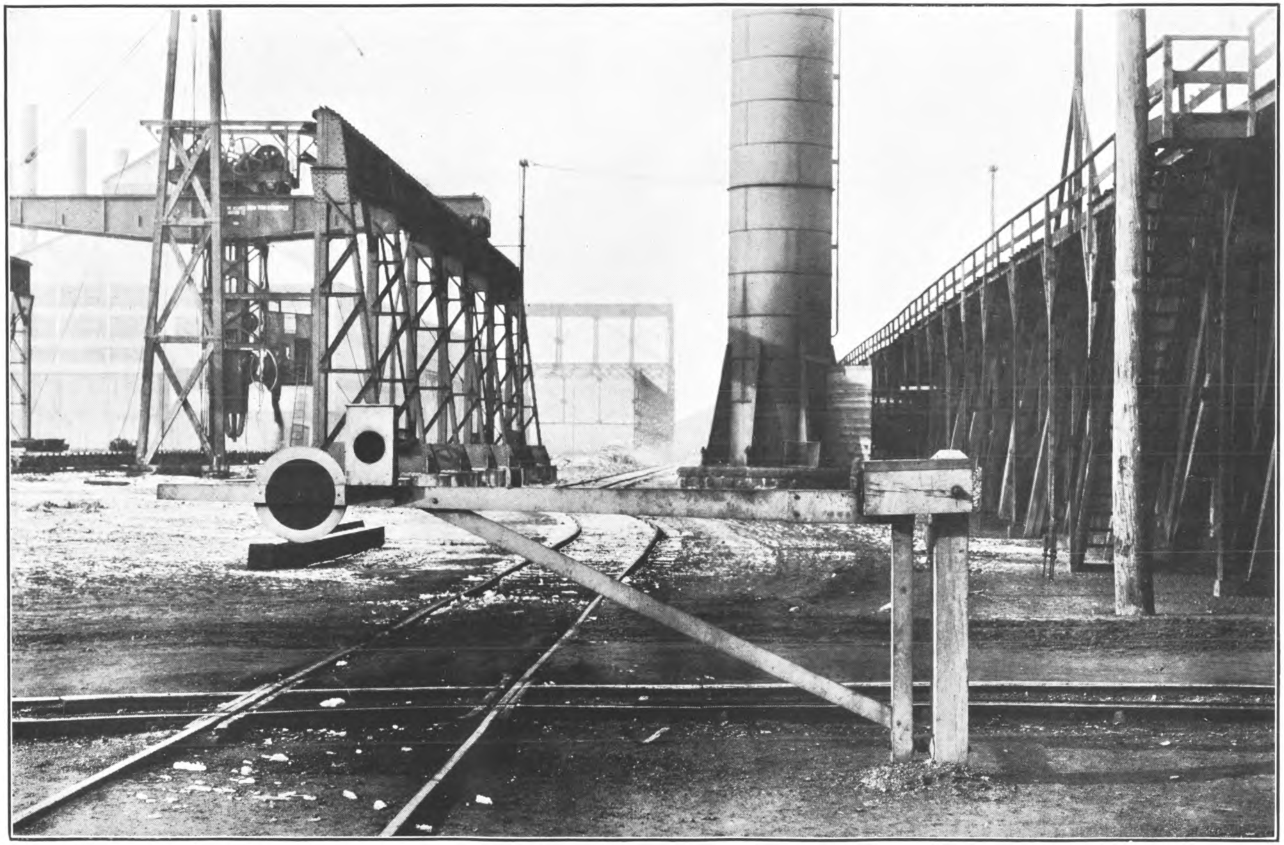


PLATE 28.—SAFETY GATE FOR CROSSING OF TRACKS.

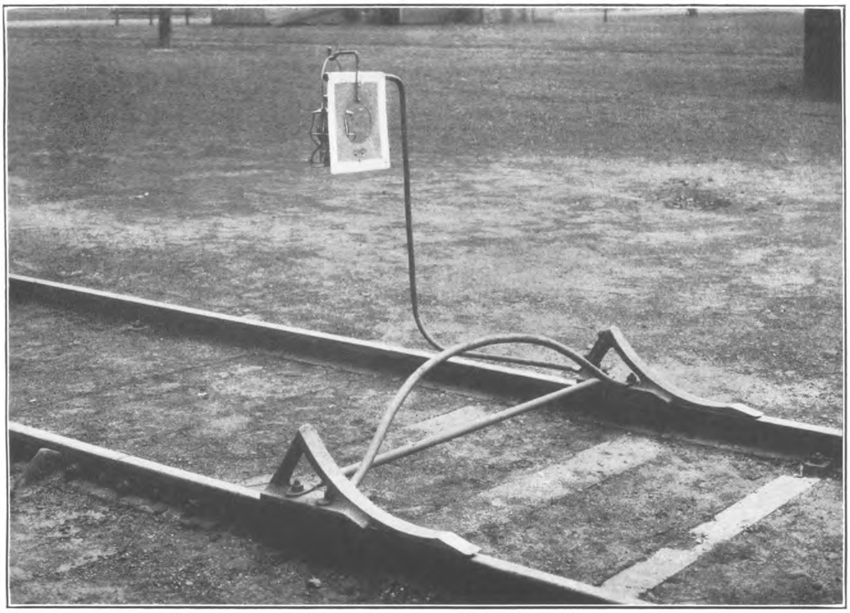


PLATE 29.—SKIDDER WITH TARGET ATTACHMENT.

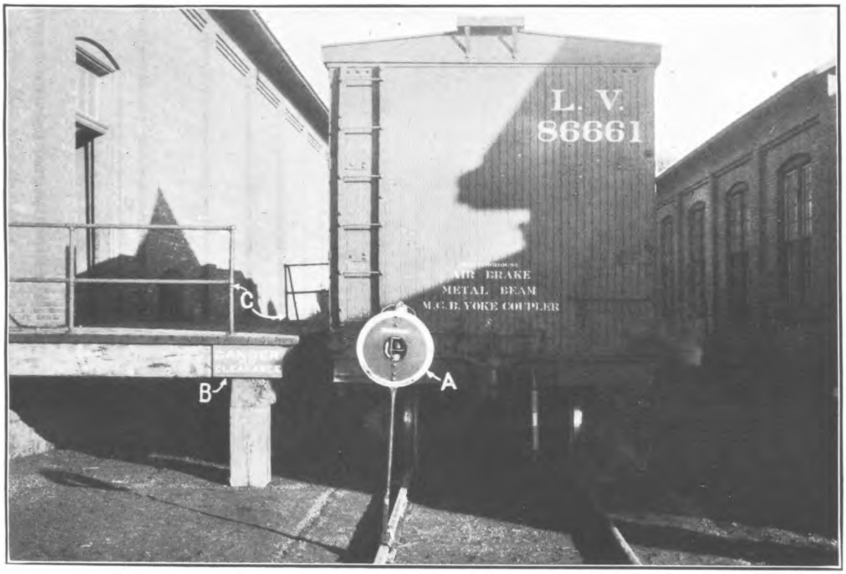


PLATE 30.—TARGET SIGNAL, USABLE DAY OR NIGHT.

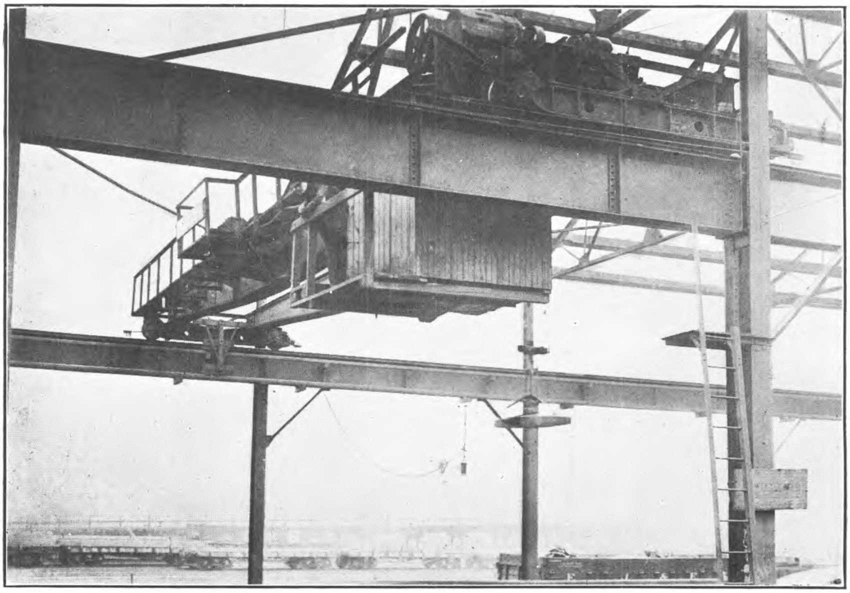


PLATE 31.—RAILED CRANE BRIDGE FOOTWALKS.

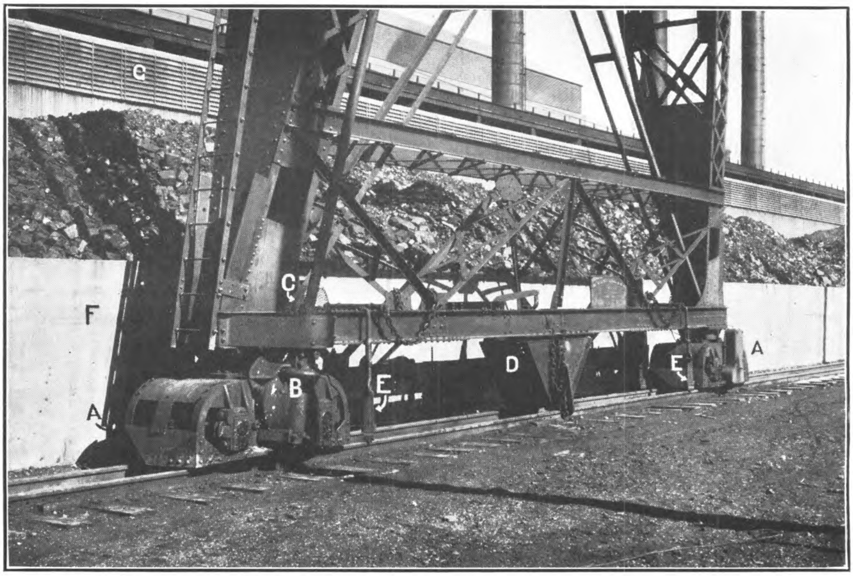


PLATE 32.—GANTRY CRANE, WITH WHEEL FENDERS, GEAR GUARDS, AND RAIL CLAMPS.

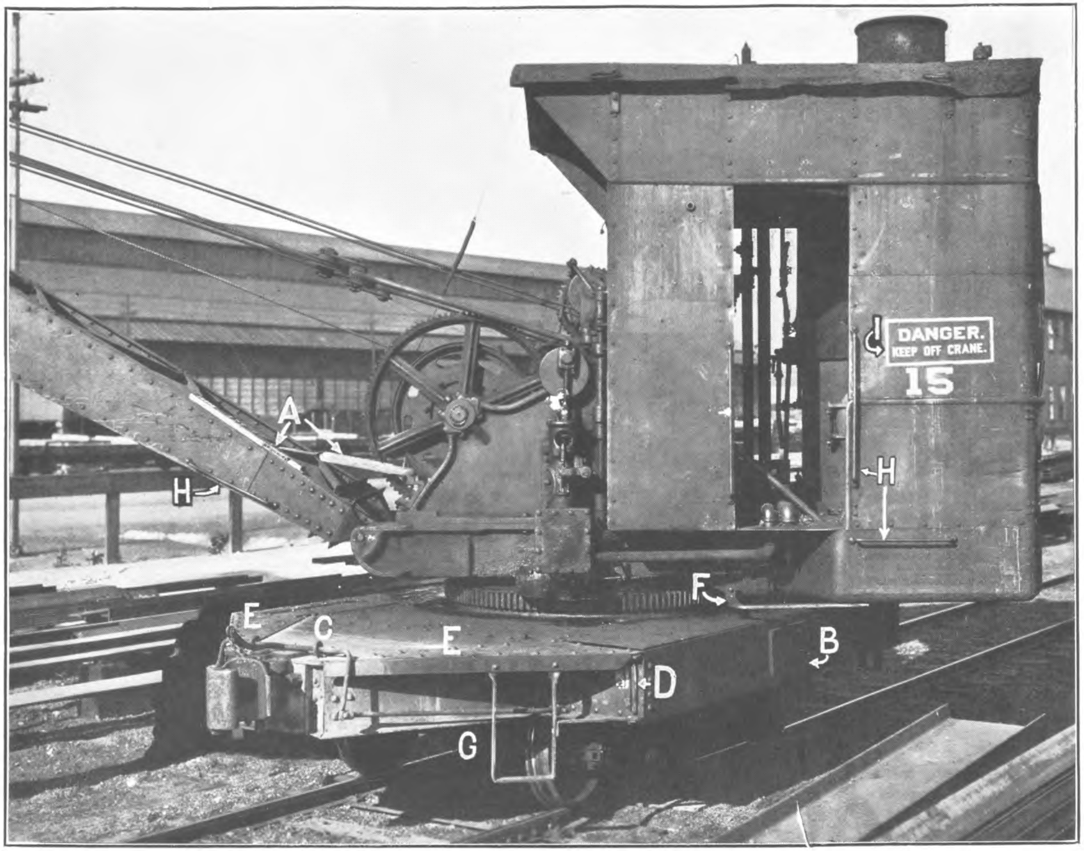


PLATE 33.—LOCOMOTIVE CRANE, WITH SAFETY DEVICES.

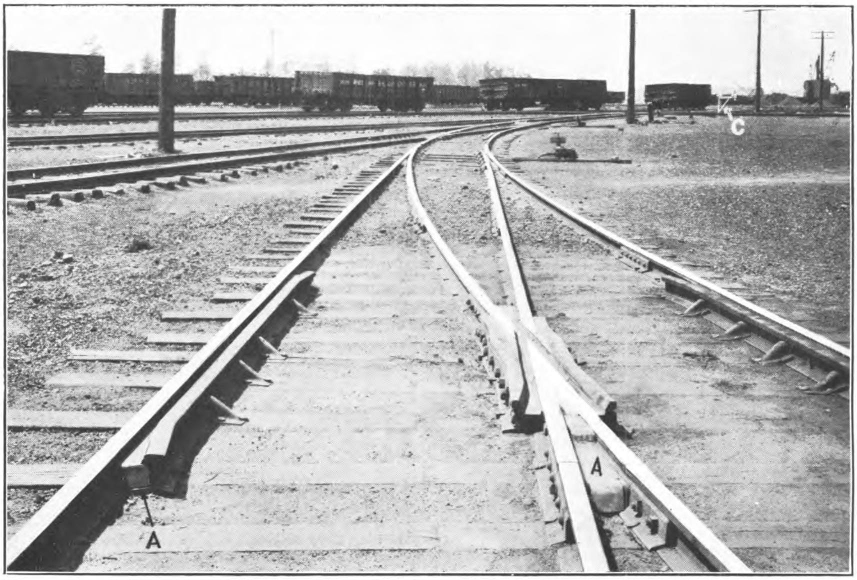


PLATE 34.—GUARDS IN FROG AND GUARD RAIL.

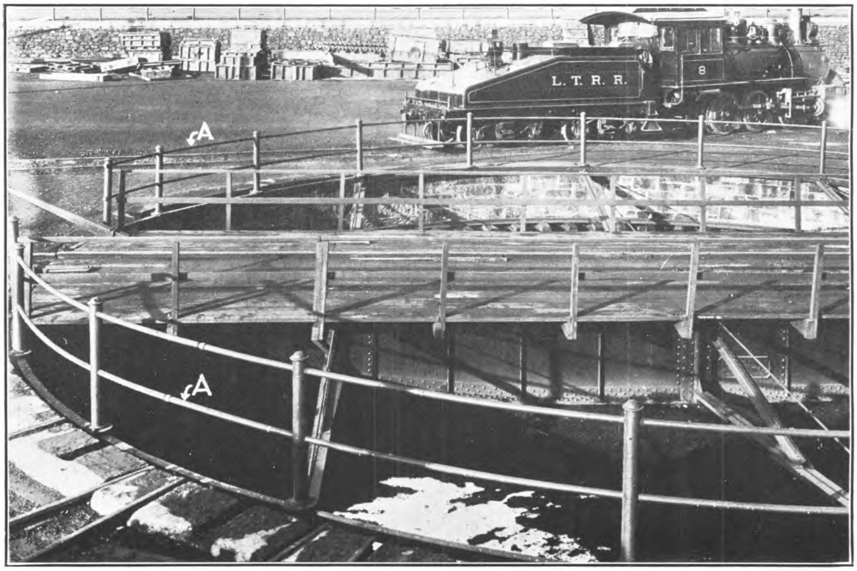


PLATE 35.—GUARD FOR TURNTABLE PIT.

of injuries. But the most significant cause of serious injury was that of being run over by moving cars and engines. There was one fatality in connection with coupling while there were five due to being run over. Since four of the five fatalities occurred during the earlier four-year period, it is evident that a considerable part of the reduction in the severity rates of power vehicles, as shown in the above table, is due to improved conditions in the yard operations which reduced the number of cases of workers being run down.

An analysis of the accidents due to power vehicles is contained in Table 107.

SAFETY METHODS IN YARDS.

It is evident from the above data that yard operations are being brought under the influence of safety activity to a very considerable degree in the mills here represented. There is no reason why this improvement should not extend to the entire industry.

The great, and to a considerable extent unavoidable, hazard of yard operation is the grade crossing. This must be treated whenever possible as the same problem is being met in city transportation. A well-guarded yard trestle (pl. 27) when usable is a very great safety factor. Next in importance and much more generally available is convenient and permanent signal apparatus. A signal which must be sought out and put in place by the switchman is very much less desirable than one located at the point of danger and needing only to be adjusted. (Pl. 28). There are, of course, numerous cases where signals are necessarily located temporarily. These should be of some standard form and provided with satisfactory means of attaching them so that they can be moved only by intent and effort. (Pls. 29 and 30.)

Having abolished grade crossings as fully as possible, established clearances, and adopted some permanent scheme of signaling, the safety man will turn his attention to automatic couplers and the adequate equipment of his overhead (pl. 31), gantry (pl. 32), and locomotive cranes (pl. 33).

The locomotive crane (pl. 33) may be considered as a type of yard apparatus which has received attention from the safety man and which is now being produced with many of his ideas incorporated in the design. As a traveling machine, this apparatus has some of the dangers arising from ordinary engines. For example, if it is not provided with an automatic coupler ("E"), but is coupled by ordinary link and pin, it may add to the large group of cases due to coupling and uncoupling. Without a proper grab iron ("H") the craneman may get a serious fall in attempting to enter his cab. It is, however, chiefly as a hoisting apparatus that danger arises. This comes more often than in any other way from an effort to hoist beyond capacity, thus causing the machine to tip over. At "B" is a plate on which, in letters which can not be effaced, the capacity of the crane is shown. At "A" is an indicator from which the crane-man may read safe loads in varying positions of the boom. In addition a device may be applied which rings an alarm if tipping should begin. All these means of safe operation have developed under the stress of experience. These or equivalent safeguards are now very generally embodied in the crane designs offered by the best makers.

After attention to these items of yard apparatus the guarding of frogs and turntable pits, as shown in plates 34 and 35, would be proper to undertake. If the switches are of the old type with a heavy ball on the end of a lever operating at right angles to the track they should be replaced by a type in which the lever operates parallel with the track, since cases arising from switches are numerous enough to need serious attention.

CHAPTER VII.

THE HUMAN FACTOR IN ACCIDENT OCCURRENCE.

The discussion of accident causes in the preceding chapters has been limited to what may be called the physical causes, i. e., the machine, the structure, the impersonal thing which is immediately responsible for the injury to the worker. Attention will now be turned to the personal factor—the worker himself—as a contributing element in accident occurrence.

The worker, just because he is an ordinary human being, is subject to certain influences which may seriously increase the likelihood of his being injured. This human factor is manifested in many ways. It manifests itself principally perhaps in the higher accident rates of the inexperienced worker—the worker who, either through youth or through recent entrance into industry, is lacking in the training which teaches him control and caution. It also shows itself in the higher accident rates of men working under unfavorable conditions, such as at night, or when physically unfit, or in extremes of heat and cold.

Thus, the worker, through some lack or defect or through the influence of unfavorable surroundings, may contribute to the accident which causes him injury, and as such may be regarded himself as a cause. But, as will appear in Chapter VIII, he is rarely more than a contributing cause. Very often, and especially so in the case of the more serious accidents, there is some defect of machine or structure or operative method without which the accident would not have occurred, notwithstanding the actions of the man.

INFLUENCE OF INEXPERIENCE UPON ACCIDENTS.

The fact that the inexperienced man is especially subject to accident may be demonstrated from a number of sources. The following table, showing accident rates according to length of service, is of particular interest upon this point.

TABLE 49.—ACCIDENT FREQUENCY RATES ACCORDING TO PERIOD OF WORKERS' EMPLOYMENT IN A LARGE STEEL PLANT.

[Based on data for January-May, 1916.]

Length of service.	Number of 300-day workers.	Cases of accident.	Accident frequency rates per 1,000 300-day workers.
6 months and under	512	57	111.3
Over 6 months and not over 1 year	278	29	104.3
Over 1 year and not over 3 years	357	31	86.8
Over 3 years and not over 5 years	637	27	42.4
Over 5 years and not over 10 years	814	16	19.7
Over 10 years and not over 15 years	470	4	8.5
Over 15 years	459		
Total	3,527	164	46.5

The table indicates clearly an extremely rapid decline in accident frequency with increased experience on the part of the worker. For those who had been employed 6 months or less the frequency rate was 111.3 cases per 1,000 workers. This dropped to 104.3 cases for those with 6 months' to 1 year's experience. Thereafter the rate declined very rapidly, and among those who had been employed more than 15 years no accidents occurred during the period covered.

These figures are so striking that, notwithstanding the comparatively small number of workers concerned, they would seem to be conclusive as to the close relationship between inexperience and high accident rates. This conclusion, moreover, is supported by other tabulations, presented later, based on the age of the worker and the degree of his ability to speak English.

That the "green" man is particularly subject to accident has been recognized to some extent and in a number of plants special efforts have been made to train and caution him. But the full effect of this factor has not been perceived. Careful analysis indicates that inexperience plays a very important part in accident occurrence and suggests that it may be an extremely influential factor in the increase in accident rates which almost invariably accompanies an increase in business activity.

That accident rates do increase in periods of business activity is evidenced by numerous tabulations in this report. Thus the recovery from the industrial depression of 1908 was accompanied in practically all plants covered by this study by a marked rise in accident rates. This experience occurred so regularly that there is clearly some close connection between increased activity and increasing accident rates.

What is this connection? Why should increasing plant activity mean higher accident rates? Two possible reasons suggest themselves. The first is that the rising accident rates may be due to "speeding up"—i. e., to the greater intensity and stress of the work placed upon the individual workman. The evidence of laboratory test and mill experience is to the effect that sudden increments of speed are accompanied by greater accident frequency. That such speeding up may have occurred in the steel plants covered during periods of business activity is suggested by the fact that at such periods the output per worker employed shows an increase. But increased per capita output does not absolutely prove increased individual exertion, as the output increase might be due to modifications of equipment and methods which would tend to lessen rather than increase the individual's effort. But even granting that speeding up does occur in a period of plant activity, and it is probable that it does occur in some degree, it is still questionable whether it is sufficient to account for the sharply rising accident rates.

The second reason which suggests itself as possibly a cause of the rising accident rates in times of increasing business activity is the influence of the new men added to the working force. At such a time the working force is necessarily added to, a process which may be referred to as "labor recruiting." Among those recruited there is necessarily a more or less considerable element of inexperienced men. Because of their inexperience these men are, as has been noted above, especially subject to accident, and their presence in the plant would tend in itself to swell the accident frequency rate. This factor could easily be one of very great importance. Indeed, careful analysis of the experience of several plants leads to the belief that it is this factor of inexperience, introduced into a plant at a time of heavy labor recruiting, which is primarily responsible for the rising accident rates following a period of depression.

The results of the present studies of this subject can best be shown in chart form. The three charts submitted (charts 11, 12, 13) have been prepared from the records of important steel plants.[1] They constitute a basis for extremely interesting deductions, although not necessarily final ones, regarding the relationship of industrial activity and accident occurrence.

Chart 11 shows for one large plant (Plant A) the course of (1) accident frequency rates, (2) labor recruiting rates, (3) total employment, and (4) output per worker over a period of six years. The importance of understanding clearly the significance of these terms justifies a repetition of their definitions:

(1) Accident frequency rates, as earlier explained, represent the number of accident cases per 1,000 300-day workers employed during a given period, which period in the case of these charts is a full year.

(2) Labor recruiting rates, in similar fashion, represent the number of cases of new men hired during the year per each 1,000 300-day workers employed during that year. Thus if the total employment of a plant during a year was 10,000 300-day workers, and during that period 2,000 new men had been taken on, the labor recruiting rate would be 200 per 1,000 workers. It would be of especial interest to isolate the entirely inexperienced men among those taken on, but this is impractical and it is not necessary for the present purpose, as any group of new men always includes a proportion of entirely inexperienced workers.

[1] The data upon which these charts are based appear in Appendix J.

CHART 11.—RELATION OF LABOR RECRUITING, EMPLOYMENT, AND OUTPUT TO ACCIDENT OCCURRENCE, 1908 TO 1914: PLANT A.

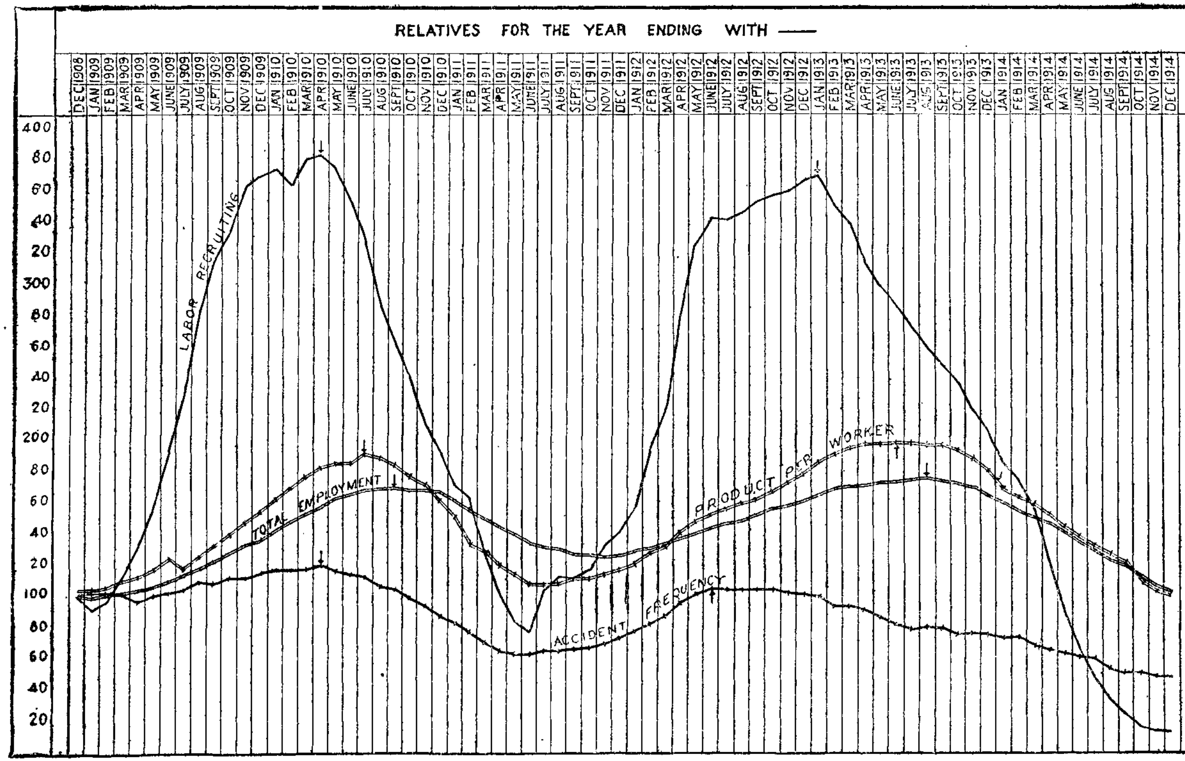


CHART 12.—RELATION OF LABOR RECRUITING, EMPLOYMENT, AND OUTPUT TO ACCIDENT OCCURRENCE, 1908 TO 1914: PLANT B.

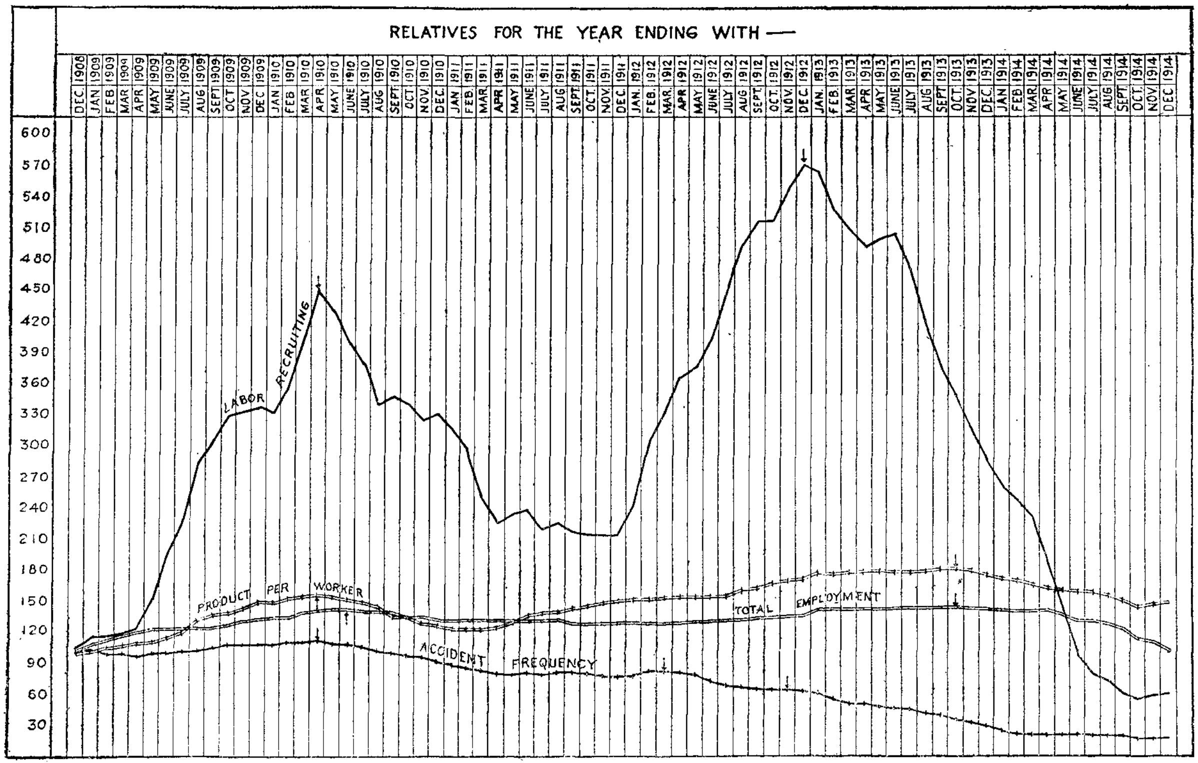
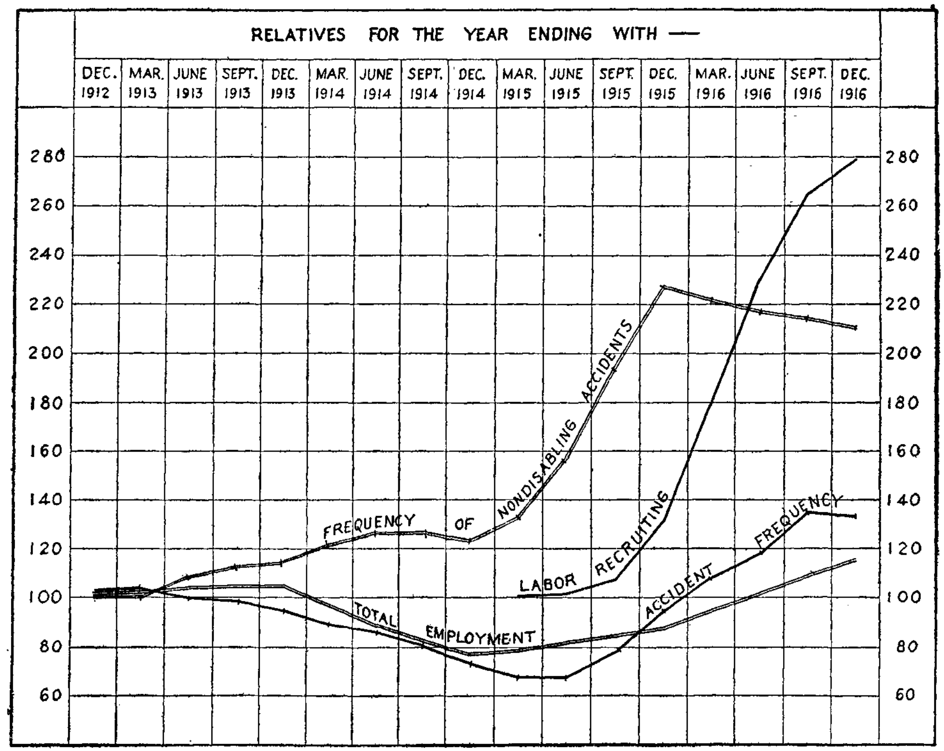


CHART 13.—RELATION OF LABOR RECRUITING, EMPLOYMENT, AND OUTPUT TO ACCIDENT OCCURRENCE, 1912 TO 1916: PLANT C.



(3) Total employment represents the total number of 300-day workers employed during the year. This item may be taken as indicating fairly closely the course of industrial activity. Almost always when business increases employment increases, and when business decreases employment decreases.

(4) Output per worker represents the average output per 300-day worker, and is obtained by dividing total product by total employment. Increase in output per worker means either speeding up or the introduction of more productive methods, usually the former, inasmuch as productive methods ordinarily change very slowly.

The course of each of these four items over a period of some six years is plotted on the chart in a series of relative numbers, the year ending December, 1908, being taken as 100. In order to avoid the violent fluctuations which occur when the month is taken as a base, the curves have been "smoothed." The points in each column represent the data not for the individual month, but for the year ending with the month indicated at the head of the column. The "smoothing" process here used is described in full in Chapter XII. All the curves are drawn on the same scale.

With these explanations in mind the meaning of the chart may now be examined. The first point to be noted is that, as indicated by the course of the employment curve, the years covered include two periods of industrial activity, in 1910 and 1913, respectively, with corresponding periods of relative depression. The other three curves follow, in a general way, the employment curves, but the movements are by no means the same. Especially to be noted is the fact that the labor recruiting curve and the accident curve parallel each other with striking closeness. As one changes the other changes at, or almost at, the same time. The curves of employment and per capita product, on the other hand, change in their upward and downward swings at distinctly later times than do those for labor recruiting and accidents.

These facts would seem to indicate very clearly that, for the plant and period covered, the element of inexperience as measured by the labor recruiting rate had a much greater influence upon accident rates than did any speeding up of the worker that may be suggested by increased output per capita. The falling accident rate, with increasing output per capita (such as occurs, for instance, in the years ending in May and June, 1910, and January to June, 1913), might, indeed, be interpreted as meaning that increased intensity of labor has no tendency to increase accident rates. But such a conclusion is not warranted, since it is obvious that without the rising output per capita accident rates might have declined more rapidly than they did. The effect of increased speed of labor upon accident occurrence must be determined by studies in other directions.

An interesting sidelight is thrown on the relationship of inexperience and accident rates, as disclosed in this chart, by tracing the accident curve in its two upward swings. It will be noted that the upward swing in the second period, beginning in June, 1911, is much sharper and more nearly parallel to the labor recruiting curve than is the first upward swing beginning in 1909. Examination of Table 38, showing the character of the labor force as regards their familiarity with the English language, offers a possible explanation of this difference. It appears from these tables that the earlier period of labor recruiting represented a much larger proportion of English speaking workmen, who it may be inferred were of greater industrial experience, though new to the establishment, than were the non-English speakers. The second period of labor recruiting included a larger proportion of non-English speakers, who, relatively less experienced, would contribute more to the accident rate. This fact would seem to explain the different behavior of the accident curve at the two periods mentioned. But all such variations should be interpreted with considerable caution. In other words, the degree in which coincidence implies causal relation can be determined only after full knowledge and careful critical examination of the facts.

The data upon which chart 11 is based are shown in Table 110 except the monthly production, which was furnished as confidential and can not be published.

The experience of a second large steel plant (Plant B) is projected in chart 12, in the same form and for the same six-year period as that for Plant A in chart 11.

It will be noted here, as in chart 11, that the years covered represent two distinct periods of plant activity.

At the crest of the first upward movement (occurring in the year ending April, 1910), labor recruiting, product, and accident frequency reach their zenith together. At the succeeding period of depression (roughly the year 1911) there is a considerable period in which the curves for recruiting, employment, and accident frequency run an almost parallel course. During this period the product curve was rising rather rapidly, but this is known to be related to changes in the equipment of the mill rather than to any increase in personal activity.

When in the latter part of 1911 labor recruiting begins to go up there is a sharp but temporary rise in accident frequency. When labor recruiting reaches its highest point (in the year ending with December, 1912) there is a further slight upward tendency of accident frequency. During this second period of increasing activity the curves for employment and product reach their high points much later than accidents and labor recruiting.

This experience is in its essentials in substantial agreement with that shown for Plant A in chart 11. It is, however, much less emphatic in relating labor recruiting with accident frequency. When, as at the first period of activity, two possible factors of accident increase—i. e., product per capita and labor recruiting—culminate together, it is impossible to determine which may have been the more influential. During the second period of activity, while labor recruiting is apparently the dominant factor, its influence upon the accident curve is much less marked than during the first period and during both periods shown in chart 11. There seems to be a perfectly good reason for this. At almost the same time that labor recruiting in Plant B increased so rapidly in the early part of 1912, special efforts at accident prevention were inaugurated, including the award of a bonus to each foreman who improved his accident record (March, 1912). The effect of this special effort, particularly the bonus to the foreman, was to induce great care in the instruction of new men regarding the dangers of their occupations and the proper way of avoiding them. The foremen were also led to give unusual attention to the distribution of these men, putting a new man along with a more experienced worker and so gradually introducing him to the responsibilities of his job. The result of this was shortly to check the rise in accident rates, which began in January, 1912, at the same time that labor recruiting began to increase.

The possibility here indicated of controlling the tendency to increased accident rates with rising labor recruiting is most important. Instead of regarding the increase as an inevitable exhibition of the laws of nature, the safety man must learn to intensify his efforts in proportion to the influx of inexperienced workmen. It would be too much to say that the record made by this plant can always be duplicated, but it may be said with entire confidence that similar intensification of effort will produce definite results.

Table 111 shows the data on which chart 12 is based, except the monthly production, which was furnished as confidential and can not be published.

The experience of a third large plant (Plant C) for a four-year period, 1912 to 1916, is projected in chart 13.[1] The general form of this chart is the same as the two preceding, but the character of the material available necessitated some slight changes in presentation. First, the records for this plant were on a quarterly instead of a monthly basis and this division had to be followed in the chart. Second, no record of output could be obtained. Third, labor recruiting rates could be traced for only about half the period covered. On the other hand, this plant had a full record of nondisabling

[1] The data upon which this chart is based appear in Table 112.

accidents as well as of those causing disablement, and the presentation of these by separate curves offers some interesting comparisons.

In the plant represented by this chart the early portion of the period covered discloses a declining employment and a declining accident frequency rate for disabling cases. At the same time the rate for nondisabling cases was rising, due, in all probability, not to any actual increase in such cases but to increasing insistence upon the reporting and care of slight injuries.

It was not possible to trace labor recruiting back of the year ending with March, 1915. At about that time active recruiting began. Immediately the rate for nondisabling accidents showed a very marked increase, and shortly the rate for disabling accidents began to show the same tendency.

The rapidity of the rise in accident rates drew the attention of the plant executives, and various special efforts at control were inaugurated. These were having some degree of success before the end of the period in spite of the fact that labor recruiting was still proceeding with scarcely diminished activity.

SELECTIVE DISCHARGE.

The lessened accident rates of periods of depression have been attributed above to the decrease in the introduction of new men, together, perhaps, with lessened industrial tension. There is another factor operative to which it is desirable to call attention. It may be called "selective discharge." Whenever depression sets in all the men are naturally desirous of retaining their jobs. The employer therefore exercises selection in deciding whom he will let go. The skillful and mature man will naturally be retained while the younger, less skillful, and less experienced man will be laid off. The effect of this process is to raise the average quality of the working force and thus to influence favorably the accident rate.

GEOGRAPHIC LOCATION AS A POSSIBLE FACTOR.

Comparison of the accident rates of different plants reveals the fact that some, in which safety work of the highest quality is being done, have constantly higher rates than others in which the safety work is apparently of a lower quality. A probable explanation of this is that the high rates of the former plants may be influenced by the fact that they are so located geographically as to constitute ports of entry, as it were, for new immigrant labor. Their records indicated a higher proportion of men entirely without experience in the industry, although in some cases their labor turnover was less than in other plants which had attained to lower accident rates.

If this indication should prove upon closer scrutiny to be constant, it would afford an explanation of the striking contradiction noted above. At present such an explanation can not be established conclusively, but it may be suggested as possible and in justice to some very efficient safety men who may be doing their work under an extra handicap.[1]

INFLUENCE OF AGE UPON ACCIDENTS.

It is very difficult to determine the influence of the worker's age upon accident occurrence because of the fact that the work done by persons of different age groups may not be uniform. If the work done is not uniform, a higher accident rate for those of one age group may be due not at all to the factor of age but simply to the higher hazards of their particular tasks. The information available upon this subject is not conclusive, but an analysis of such as could be obtained brings out some points of interest.

An important body of data regarding age as related to accident frequency was presented in the earlier report of the bureau upon accidents in the iron and steel industry.[2] The table is reproduced, in substance, below. It shows the accident frequency rates over a period of five years for a total of 33,511 300-day workers employed in a large steel plant. In this case it was not possible to compute severity rates.

TABLE 50.—FREQUENCY OF ACCIDENTS IN A LARGE STEEL PLANT ACCORDING TO AGE GROUPS, 1906 TO 1910, BY YEARS.

Age groups.	1906	1907	1908	1909	1910	Total (5 years).
Number of 300-day workers:						
Under 20 years	475	384	198	261	390	1,708
20 to 29 years	3,875	3,810	2,214	3,343	3,264	16,506
30 to 39 years	2,047	2,256	1,212	1,697	2,271	9,513
40 years and over	1,097	1,135	921	914	1,717	5,784
Total	7,494	7,585	4,575	6,215	7,642	33,511
Number of accident cases:						
Under 20 years	52	56	8	30	27	173
20 to 29 years	760	694	364	577	527	2,922
30 to 39 years	382	374	183	304	298	1,541
40 years and over	156	170	89	143	115	673
Total	1,350	1,294	644	1,054	967	5,309
Accident frequency rates (per 1,000 300-day workers):						
Under 20 years	109.5	145.8	40.4	114.9	69.2	101.3
20 to 29 years	196.1	182.2	164.4	172.6	161.5	177.0
30 to 39 years	186.1	165.8	147.3	179.1	131.2	162.0
40 years and over	142.2	149.8	96.6	156.5	70.0	116.4
Total	181.1	170.6	140.8	169.6	126.5	158.4

The first point to be noted in the table is that the decline in accident frequency rates which took place between the beginning and

[1] For racial distribution of steel workers see Report on Conditions of Employment in the Iron and Steel Industry in the United States, (S. Doc. No. 110, 62d Cong., 1st sess.) Vol. III, p. 83 et seq.

[2] Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, p. 159.

end of the period covered occurred in each of the age groups as well as in the total.

The second point to be noted is that for the combined five-year period, and also for each of the individual years, except 1909, the age group 20 to 29 showed the highest accident frequency. Next highest to the 20 to 29 age group in accident frequency is the 30 to 39 group, with the 40 and over group next in order and the under 20 group lowest of the four. In order to understand the significance of this order it is necessary to consider the occupational status of each of the age groups. The group under 20 is that engaged in the least hazardous work. Most of those who belong to it are door boys and lever operators. Those of 40 and over have to a certain degree passed out of the danger zone. Many of those who have passed but little over the boundary line are still to be found in the dangerous occupations, and probably on this account the accident rate is higher than that for those under 20. But the differences which exist in the work of these two groups are so considerable that it is impossible to judge whether the factor of age is at all a significant one. If the groups could be placed under nearly identical occupational conditions, the rates might be changed, or even reversed.

The two age groups, 20 to 29 and 30 to 39, include by far the larger proportion of the steel workers. From statistics showing the age distribution in the various departments [1] and from careful observation the dangers to men in the older age group appear to be as great as those encountered by the younger. In fact inquiry shows that those who are particularly exposed to the special hazards, such as arise in the moving of molten metal, have very commonly reached their present position by a prolonged apprenticeship and are very apt to be men above 30. It is a reasonable conclusion therefore that danger in the younger age group is not greater than in the older. It appears that the 20 to 29 age group has the higher rate in each year except one, and that for the whole period the rate is decidedly higher for this group.

It becomes, then, appropriate to inquire the reason for this higher rate, since apparently it can not be attributed to more dangerous occupations. The probable causes may be summed up as inexperience and immaturity. The stream of immigration which largely furnishes the working force for the steel mills is most largely young men between 20 and 30. Such immigrant youth as come under the age of 20 do not as a rule get into the steel mills, the places open to persons of that age being largely monopolized by the American born. If the immigrant does not at once upon his arrival find his way into

[1] Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. III, p. 99.

a steel mill he is not likely to do so at a later period. This decade, 20 to 29, is then the great recruiting period for the steel industry. Those of the group 30 to 39 are relatively experienced men who entered the works earlier or, in the rare instances where they are recently arrived immigrants, they have a degree of maturity which is not true of those between 20 and 29. The great factor is undoubtedly that of inexperience. These young men come directly from an agricultural life and are exposed upon their entrance into the activities of the steel mill to all the dangers which inevitably beset beginners.

The experience of a second large steel plant, as regards the relation of age and accident, is given in the next table. In this, as in the plant just discussed, the accident reduction which had taken place over a period of years had affected all age groups. But as it does not seem necessary further to establish this point, the data for the several years are combined in order to get as large an exposure as possible. Accident severity rates, as well as frequency rates, are given in detail.

TABLE 51.—FREQUENCY AND SEVERITY OF ACCIDENTS IN A LARGE STEEL PLANT, ACCORDING TO AGE GROUPS, 1907 TO 1914.

Age group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Under 20	949	1.1	7.4	554.3	562.8	9.5	3.4	7.7	20.6
20 to 29	16,443	.7	3.4	230.1	234.2	6.0	1.8	3.5	11.3
30 to 39	14,417	.7	2.4	175.6	178.7	6.2	.9	2.9	10.0
40 and over	11,124	.5	2.8	128.5	131.8	4.9	1.2	2.6	8.7
Total	42,933	.7	3.0	192.6	196.3	5.9	1.4	3.1	10.4

The accident rates of this table conform very closely to those of the preceding table with the exception of the rates for the age group under 20. For this group the accident rates are here extremely high, in sharp contrast with the experience shown in the first table. This is due, in part, to the practice of this plant of employing young men along with older men in occupations likely to produce many cases of short-term disability. But at best the group is of too small size (949 300-day workers) to permit of conclusive deductions. Its smallness of size would be reflected especially in the severity rate, since, in small groups, a single fatality influences the severity rate materially. More significant is the fact that this group has the highest severity rate for both permanent and temporary disability. Clearly, when such youths do engage in the same work as more experienced workers, their hazards are very serious.

It is very possible that the workers under 20, being a small group among a much larger group of older workers, and furnishing only a limited number of accidents, have never had their high accident rates observed. The condition disclosed by this tabulation, therefore, suggests the desirability of every plant's making, from time to time, a critical examination of the working force by age groups.

The next table presents the accident experience of a tube mill by age groups. The age group under 20 is omitted, as the number of persons therein was too small to justify the computation of rates.

TABLE 52.—FREQUENCY AND SEVERITY OF ACCIDENTS IN A TUBE MILL, ACCORDING TO AGE GROUPS, 1907 TO 1914.

[Employees under 20 years of age are not included, because the number is too small to justify computation of rates.]

Age group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
20 to 29	6,351	0.3	3.1	207.2	210.6	2.8	1.7	3.1	8.2
30 to 39	4,977	.2	2.2	150.7	153.1	1.8	1.0	2.4	5.2
40 and over	2,965	1.0	1.7	101.9	104.6	9.1	.9	1.9	11.9
Total	14,293	.4	2.5	165.7	168.6	3.8	1.3	2.6	7.7

The relations of these age groups as regards accident frequency, it will be noted, are the same as in the two preceding tables. As regards severity, however, age group 40 and over has the leading place, due entirely to the high death rate.

INABILITY TO SPEAK ENGLISH, AS RELATED TO ACCIDENTS.

Of all inexperienced workers the man most handicapped would seem to be the one who is not only without knowledge of his task, but is unable to communicate freely with those who direct him. When one large company began to study carefully their working conditions they found it not infrequently the case that a foreman was in charge of a gang with no member of which could he communicate either directly or by an interpreter. Still more common was it to find individual men who were thus barred from communication with their immediate superior. This was at once recognized as a dangerous condition and the rule was issued that gangs should be formed in such a manner that each man should be able to communicate with his foreman directly or by interpreter.

The following table contrasts accident rates of (1) American-born workers, (2) English-speaking foreign-born workers, and (3) non-English-speaking foreign-born workers, over a period of 8 years, 1906 to 1913, in the only plant for which full data could be obtained:

TABLE 53.—INABILITY TO SPEAK ENGLISH AS RELATED TO ACCIDENTS: EXPERIENCE OF A LARGE STEEL PLANT, 1906 TO 1913.

Group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1906.									
American born	1,370	5.8	5.8	143.1	154.7	52.6	5.0	2.1	59.7
English speaking foreign born	1,906	6.8	5.8	109.7	122.3	61.4	2.3	1.9	65.6
Non-English speaking foreign born	4,218	4.3	5.7	233.0	243.0	38.4	3.2	3.5	45.1
Total	7,494	5.2	5.7	185.2	196.6	46.8	4.3	2.9	54.0
1907.									
American born	1,719	3.5	2.3	111.1	116.9	31.4	2.5	2.1	36.0
English speaking foreign born	2,267	3.1	4.0	155.7	162.8	27.8	7.0	2.8	37.6
Non-English speaking foreign born	3,599	3.3	7.5	204.5	215.3	30.0	5.5	4.3	39.8
Total	7,858	3.2	5.1	162.9	171.2	28.6	6.2	3.2	38.0
1908.									
American born	1,188	.8	5.1	77.4	83.3	7.6	2.3	1.4	11.3
English speaking foreign born	1,689	3.0	4.7	94.1	101.8	26.6	2.6	1.7	30.9
Non-English speaking foreign born	1,698	3.5	7.1	182.6	193.2	31.8	6.4	3.7	41.9
Total	4,575	2.6	5.7	122.6	130.9	23.6	3.9	2.4	29.9
1909.									
American born	1,453	1.4	.7	95.7	97.8	12.4	.1	1.5	14.0
English speaking foreign born	2,027	3.5	3.9	123.3	130.7	31.1	1.9	3.0	36.0
Non-English speaking foreign born	2,735	1.5	2.6	200.0	204.1	13.2	3.2	3.2	19.6
Total	6,215	2.1	2.6	150.6	155.3	18.8	2.1	2.7	23.6
1910.									
American born	1,843	1.1	.5	67.3	68.9	9.8	.6	1.0	11.4
English speaking foreign born	3,283	.6	1.8	49.0	51.4	5.5	1.5	.7	7.7
Non-English speaking foreign born	2,516	3.2	9.1	224.6	236.9	28.6	4.2	4.1	36.9
Total	7,642	1.6	3.9	111.1	116.6	14.1	3.2	1.9	19.2
1911.									
American born	1,369	2.9	2.9	71.6	77.4	26.3	1.2	1.2	28.7
English speaking foreign born	2,446	1.6	3.3	80.1	85.0	14.7	3.5	2.4	20.6
Non-English speaking foreign born	1,959	.5	4.6	157.7	162.8	4.6	4.2	3.2	12.0
Total	5,774	1.6	3.6	104.4	109.6	14.0	2.5	2.0	18.5
1912.									
American born	1,863	....	3.2	83.2	86.4	....	1.7	1.5	3.2
English speaking foreign born	2,656	.4	7.2	81.3	88.9	3.4	5.9	1.8	11.1
Non-English speaking foreign born	2,877	1.4	8.0	240.2	249.6	12.5	7.1	4.4	24.0
Total	7,396	.7	6.5	142.6	149.8	6.1	5.3	2.7	14.1
1913.									
American born	1,782	1.7	2.8	52.1	56.6	15.2	.7	1.1	17.0
English speaking foreign born	2,472	2.0	2.0	76.9	80.9	18.2	1.7	1.4	21.3
Non-English speaking foreign born	2,877	1.4	8.0	240.2	249.6	12.5	7.1	4.4	24.0
Total	7,562	1.9	4.6	106.3	112.8	16.7	2.2	2.3	21.2
TOTAL OF 8 YEARS.									
American born	12,587	2.1	2.8	85.8	90.7	18.6	1.7	1.5	21.8
English speaking foreign born	18,746	2.3	3.9	92.5	98.7	21.1	3.3	2.0	26.4
Non-Engish speaking foreign born	22,910	2.6	6.5	203.5	212.6	23.2	3.5	2.8	29.5
Total	54,243	2.4	4.8	137.8	145.0	21.4	3.2	2.6	27.2

It is very noteworthy that in all the years covered by this table the non-English speakers not only had the highest frequency rate but show little, if any, improvement from year to year. As regards

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severity, the non-English speakers show the highest rates in 5 years out of the 8 covered, and show much less degree of improvement over the period than do the English speakers.

Examining the combined data for the 8 years, it will be noted that the non-English speakers have a frequency rate 2.3 times that of the American born (212.6, as against 90.7 cases per 1,000 300-day workers) and a severity rate 1.4 times as high as that of the American born (29.5 against 21.8 days lost per worker).

DAY AND NIGHT ACCIDENT RATES.

The impression that the night turn is less dangerous than the day turn has been quite prevalent among safety men. This impression has been the result apparently of limiting attention to the comparative number of accidents rather than to comparative accident rates. The number of accidents on the night turn is almost invariably much the smaller, because very much fewer men are employed by night than by day.

As a matter of fact, the question as to the comparative hazards of night and day employment is still undetermined. But in the iron and steel industry there is a definite tendency toward higher accident rates at night. The following statement summarizes all the material upon this subject obtained in the course of the present investigation, together with such data as are available from other sources:

Higher rates at night have been found to exist in the following cases:	
United States. Steel plant with average employment of	8,000
United States. Steel plant with average employment of	5,000
United States. Machine building plant with average employment of	15,000
United States. Plant producing electrical apparatus, with average employment of	17,000
Germany. Iron and steel industries in Dusseldorf district, with average employment of	61,719
Germany. Machine building in Dusseldorf district, with average employment of	3,546
Higher rates by day have been found to exist in the following cases:	
United States. Steel plant with average employment of	6,000
Germany. Miscellaneous industries in Dusseldorf district, with average employment of	24,022

There are several factors bearing on the subject of night accident hazards, some operating in one direction, some in the other. They may be stated as follows:

(*a*) Tending to lower the rates at night—

(1) Smaller proportion of relatively inexperienced and unskilled men.

(2) Less congestion.

(3) Less transportation of material.

(4) Tendency not to undertake difficult repairs.

(*b*) Tending to raise the rates at night—
- (1) Imperfect lighting.
- (2) Unsatisfactory physical and mental condition of the worker.
- (3) Less rigorous supervision.

Apparently up to the present time the forces tending to higher rates have had the greater influence. As illustrations are offered it will become evident that in the progress of time the disparity between night and day rates has become less and that in some cases a condition of lower rates at night has been reached.

Of the factors tending to high night rates imperfect lighting has naturally received the larger share of attention. This is a matter of efficient operation and illuminating engineers are showing very conclusively that adequate provision in this respect will immediately return more than its cost in greater output.

Undoubtedly the most difficult problem is that of the worker's condition at night. This is related in no small measure to the difficulty of securing adequate recuperation by proper sleep. The experience of British munition factories shows that continuous night work seriously impairs the efficiency of the workers.[1] The light and noise of daytime and the heat of summer conspire to render sleep in day hours unrefreshing. This discomfort may easily lead to efforts for relief in themselves injurious.

EXAMPLES OF NIGHT AND DAY RATES—PLANT A.

The experience of a large steel plant is shown in the following charts. These give separately, for the day turn and the night turn, the frequency and severity rates over a period of years and by departments.

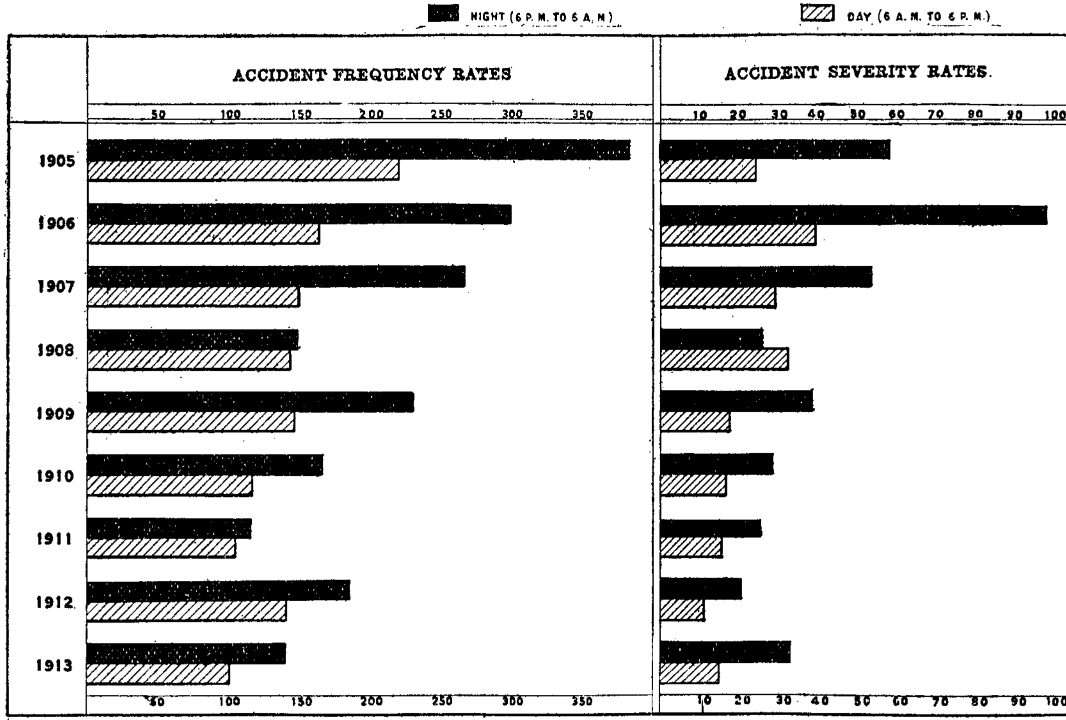
In the years studied in this plant the frequency rates for night were in excess in each year and the rates for severity in excess in each year but one. The night rates decrease more rapidly than those for the day. This gradual approximation is more regular in the severity rates than in those for frequency. Improved lighting has been suggested as a cause. This must have had great influence but can hardly be the complete explanation. The improvements in lighting were made at particular periods with intervals of uniformity between. If lighting were the controlling factor it would naturally be expected that some rather pronounced change would appear at the time of lighting improvement. Since the decline in rates is fairly constant some constant cause may be suspected. The use of alcohol as a possible influence is discussed later in this chapter.

When the experience of this plant is considered from a departmental standpoint some interesting deductions are possible. The

[1] Health of Munition Workers Committee (Ministry of Munitions). Interim report on Industrial Efficiency and Fatigue. (1917) pp. 26, et seq.

CHART 14.—NIGHT AND DAY RATES IN A LARGE STEEL PLANT, BY YEARS.

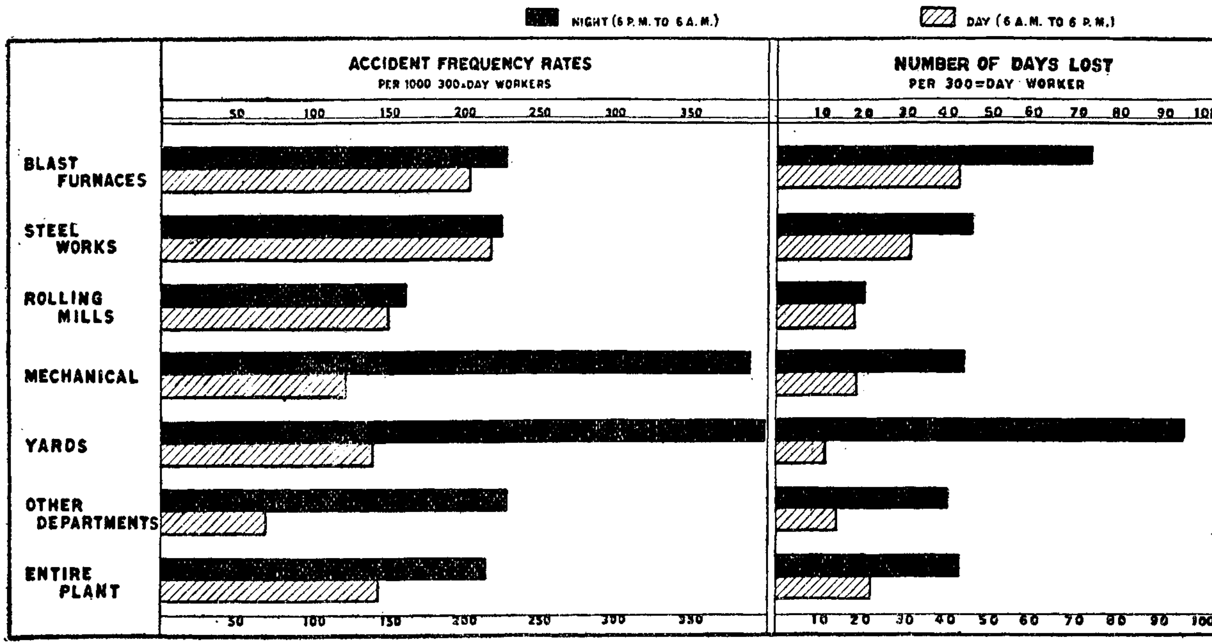
[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



Year	Frequency rates.	Severity rates.	Number 300-day workers
1905	385	58.1	1,544
	219	24.5	4,062
1906	299	97.4	1,801
	163	40.0	5.693
1907	265	53.9	1,897
	149	29.4	5.688
1908	147	26.0	1,129
	142	32.1	3,446
1909	229	38.6	1.647
	146	17.5	4.568
1910	165	28.2	1,998
	116	16.8	5.644
1911	116	25.8	1,559
	104	15.6	4,215
1912	184	21.3	2,094
	139	11.5	5,302
1913	139	32.8	2,003
	101	15.4	5,559

CHART 15.—NIGHT AND DAY ACCIDENT RATES IN A LARGE STEEL PLANT, BY DEPARTMENTS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



	ACCIDENT FREQUENCY RATES	DAYS LOST PER 300-DAY WORKER	NUMBER 300-DAY WORKERS
BLAST FURNACES	229	74.6	2.879
	204	42.6	6.413
STEEL WORKS	224	46.2	3.638
	218	30.5	5.045
ROLLING MILLS	160	21.1	6.516
	150	18.1	10.789
MECHANICAL	389	44.3	556
	122	19.1	7.767
YARDS	399	95.4	874
	139	11 7	5.083
OTHER DEPARTMENTS	227	40.4	1 209
	69	14.8	9.680
ENTIRE PLANT	214	43.2	13.672
	142	22.2	44,977

mechanical and yard departments call for particular notice in this respect. The high frequency rates at night among mechanics is doubtless the result of two factors: (1) The night force is almost entirely engaged in what is called field work. Shop work on lathe and planer is not undertaken as a rule at night, except in cases of extreme urgency. The force is kept on duty mainly for imperative repairs needed to keep the mills running, and consequently demanding all possible speed. (2) The lighting factor. Often the repairs must be made in places which do not call for careful lighting on operative grounds. Some hurriedly improvised lighting must be supplied. The probability that it will be unsatisfactory is very great. This need for emergency lighting may be a point to which lighting engineers should give further attention.

The extremely high night accident rates in yard operations must be very largely due to the difference in lighting. The moving of cars, the loading and unloading, and the shifting of materials which go on at night must be very much dependent for their safety upon lighting which enables the worker to avoid the obstacle over which he may stumble and to place properly the objects which he handles.

EXAMPLES OF NIGHT AND DAY RATES—PLANT B.

The following table shows, by years, the night and day accident rates of a large steel plant:

TABLE 54.—NIGHT AND DAY ACCIDENT RATES IN A LARGE STEEL PLANT, 1907 TO 1914, BY YEARS.

Period.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907:									
Night	2,079	1.4	2.9	285.7	290.0	13.0	1.4	5.4	19.8
Day	4,036	.2	1.7	285.1	287.0	2.2	1.0	4.7	7.9
1908:									
Night	1,435	....	6.3	170.7	177.0	....	1.1	3.3	4.4
Day	2,786	.7	3.2	202.4	206.3	6.5	1.5	3.8	11.8
1909:									
Night	1,883	1.6	6.9	232.6	241.1	14.3	2.5	4.0	20.8
Day	3,644	1.4	3.8	255.8	261.0	12.3	1.7	4.0	18.0
1910:									
Night	1,857	.5	4.3	196.0	200.8	4.8	1.6	3.8	10.2
Day	3,604	1.1	5.5	229.5	236.1	10.0	2.0	3.8	15.8
1911:									
Night	1,703	....	1.8	182.0	183.8	....	.4	2.4	2.8
Day	3,618	.6	1.9	185.7	188.2	5.0	1.2	2.6	8.8
1912:									
Night	1,902	1.1	4.2	159.3	164.6	9.5	1.1	2.5	13.1
Day	3,863	1.3	1.3	133.8	136.4	11.6	1.0	1.9	14.5
1913:									
Night	2,012	.5	1.0	82.0	83.5	4.5	.3	1.2	6.0
Day	4,086	.7	2.2	63.6	66.5	6.6	1.1	1.1	8.8
1914:									
Night	1,416	....	2.1	41.0	43.1	....	1.6	1.1	2.7
Day	3,009	....	3.3	39.5	42.8	....	2.2	1.0	3.2
1907 to 1914:									
Night	14,287	.7	3.6	173.3	177.6	6.3	1.2	3.0	10.5
Day	28,646	.8	2.8	179.5	183.1	6.9	1.5	2.9	11.3

This plant presents, quite constantly from year to year, relations at variance with those disclosed by Plant A, and also by other plants. In 5 of the 8 years the day has higher frequency rates than the night, and 6 out of 8 years show higher severity rates in the day.

Only one of the important departments in this plant could be separately considered. The experience shown by it is in accord with the departmental experience of Plant A. During the 8 years there were in this department 5,752 300-day workers by night and 8,787 by day. The frequency rates were: Night, 167.7 cases per 1,000 300-day workers; day, 162.9 cases. The severity rates were: Night, 8.6 days lost per worker; day, 6.9 days lost per worker.

Evidently while the instances cited establish a strong tendency to high rates at night the rule is subject to notable exceptions which would well repay further and more intensive study.

EXPERIENCE IN THE DUSSELDORF DISTRICT, GERMANY.

In the Archiv für Soziale Hygiene (Leipsic, 1910. Band VI, Heft 1, p. 87) Dr. Walter Abelsdorff presents the following table in regard to accident rates for the Dusseldorf district of Germany:

TABLE 55.—DAY AND NIGHT ACCIDENT RATES FOR SPECIFIED INDUSTRY GROUPS IN THE DUSSELDORF DISTRICT, GERMANY.

Industry group.	Plants operating day and night shifts.	Number of work people.		Number of accidents.		Frequency rates (per 1,000 300-day workers).	
		Day.	Night.	Day.	Night.	Day.	Night.
Mining, blast furnaces, steel works	92	45,062	16,657	8,609	3,522	191	211
Quarrying and excavating	54	2,951	1,317	244	57	83	43
Metal working	15	3,692	1,658	661	181	180	109
Machine building, tools, etc	14	2,849	697	542	143	190	211
Chemical industries	31	8,865	1,410	465	119	52	84
By-products from timber	50	1,810	460	167	33	92	72
Paper making	9	776	338	72	11	93	32
Food products	18	536	209	27	7	50	33
Total	283	66,541	22,746	10,787	4,073	162	179

A comparison of rates in this table with those in the preceding table is not possible since the definition of accident used in the German experience is not the same as that used in this report.

The iron and steel industry and mining taken together show a higher rate at night. In the text of the article from which the table is taken it is stated that in large iron and steel works the night rates exceed the day rates in the proportion of 218 to 188. A comment is quoted from a Dusseldorff official to the following effect: "Large iron and steel works lead in respect to special risks to night workers." His explanation is insufficient illumination and less rigorous supervision.

A comparatively small group of machine builders shows the same tendency to higher night rates as do also the chemical workers.

For the main industrial groups presented this German experience is like that of the majority of the American plants examined.

CONJUGAL CONDITION AS INFLUENCING ACCIDENTS.

The question sometimes arises as to whether marriage and the having of dependents have any influence upon the worker in making him more careful in the avoidance of accidents.

No special study of this subject was made in the course of the present investigation. But, as still pertinent, the results of a study presented in the earlier report on accidents in the iron and steel industry is reproduced below in tabular form.[1] The table contrasts, over a series of years, the accident frequency rates of married and single men. The information was obtained from a large steel plant having records on this point, and was limited to persons in the age group 30 to 39 years in order that assurance might be had that the hazards were substantially the same for all of those included.

TABLE 56.—FREQUENCY OF ACCIDENT OCCURRENCE IN A LARGE STEEL PLANT, BY CONJUGAL CONDITION, 1906 TO 1910, BY YEARS.

Year.	Number of 300-day workers.		Number of accident cases.		Accident frequency rates (per 1,000 300-day workers).	
	Married.	Single.	Married.	Single.	Married.	Single.
1906	1,590	457	299	76	188.1	166.3
1907	1,827	429	288	80	157.6	186.5
1908	882	360	149	31	168.9	86.1
1909	1,350	347	224	60	165.9	172.9
1910	1,895	376	235	41	124.0	109.0
Total	7,544	1,969	1,195	288	158.4	146.3

The number of single men in each of the years is rather small, but the constancy of the accident rates indicates that such rates may be accepted as fairly typical. The rates for the married men, it will be noted, are higher in three of the five years and also slightly higher for the combined period—158.4 as against 146.3 cases per 1,000 300-day workers. But these differences are not sufficient to afford ground for concluding that either group is possessed of constant characteristics tending to give it a different rate from the other.

[1] Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, p. 168.

POSSIBLE INFLUENCE OF USE OF ALCOHOL UPON ACCIDENTS.

Safety men are thoroughly convinced of the importance of alcohol as a contributing cause of accidents. To this conviction the resolutions which they have adopted and the propaganda they have started bear emphatic witness.[1] In the present study an earnest effort was made to get at the ground of this conviction and to learn whether there was a substantial basis for its existence. But information of any value on this subject was obtainable in only one plant. In this plant the night accident rates were found to be higher than those of the day. The superintendents, without exception, were of the opinion that alcoholic excess was partly responsible. The points of their argument were these: (1) The smuggling of liquor into the plant is more possible by night than by day; (2) a workman quitting the day turn will, if he uses liquor, be apt to do so in the evening before going to bed; (3) on the other hand, a man who uses liquor, quitting in the morning, will be likely to get to sleep quite promptly, and then, waking some hours before his turn begins, will drink at that time, and so come to the mill under whatever immediate effect it may have. The superintendents regarded the frequent appearance of high rates in the early night hours as confirmatory of their views.

It will be recognized that the determination of the influence of alcohol upon accidents is exceedingly difficult. In a given injury the mechanical elements, such as tools or falling objects, can be determined, but the relation of personal condition to the occurrence is very complex and practically impossible of exact determination. The most that can be done is to establish coincidence of facts.

In the case of the plant now under consideration the supervisor of labor suggested that the records of disciplinary action, kept in detail in this plant, might shed some light upon the question whether alcoholic use was or was not more prevalent on the night turn. Thereupon these records were tabulated, with the following result:

TABLE 57.—DISCIPLINE IN A LARGE STEEL PLANT FOR USE OF ALCOHOLIC INTOXICANTS.

Year.	Number of 300-day workers.		Number of cases of discipline.		Discipline rates (per 1,000 300-day workers).	
	Night.	Day.	Night.	Day.	Night.	Day.
1907	1,897	5,688	41	26	21.4	4.6
1908	1,129	3,446	44	11	38.1	3.2
1909	1,647	4,568	40	6	24.3	1.3
1910	1,998	5,644	47	12	23.5	2.1
1911	1,559	4,215	43	18	27.6	4.3
1912	2,094	5,302	28	28	13.5	5.3
1913	2,003	5,559	33	19	16.5	3.4
Total	12,326	34,422	276	120	22.4	3.5

[1] See Proceedings of National Safety Council, 1914, pp. 158, 159, 221.

The above table shows very clearly that in cases of rules violations sufficiently pronounced to be detected and disciplined the night rate was very much in excess of that for the day. Since the same diligence of enforcement was observed by the management by day as by night, there can hardly be any other deduction than that rules violations were of greater prevalence at night. This is not, it may be noted, an inference regarding relative quantities of alcohol consumed by day and night, but simply one regarding the time of consumption and its possible effect on the accident rate.

There is another feature worth noting. For the day turn the discipline rates remain about the same throughout the period, but for the night rates there had occurred a marked reduction—from 21.4 cases in 1907 to 16.5 cases in 1913. If this decline in rates of discipline represents a reduction in the use of alcohol, it may in part account for the fact of the more rapid reduction of night accident rates which took place in this plant.

DISTRIBUTION OF ACCIDENTS AND PRODUCTION THROUGH THE WORKING HOURS.

The study of distribution was primarily undertaken with the idea of discovering its possible relation to the problem of fatigue and so contributing to the determination of the length of a reasonable working day.

It is not possible to show that fatigue is anywhere distinctly registered in the curves which have been plotted. The chief practical outcome of the study has been to call attention to the prevalence of high rates at night and to emphasize the necessity of adequate lighting and other measures tending to greater safety in night work.

The characteristic form of distribution shown by the great majority of the curves for accidents so far plotted may be summarily stated as follows: (1) A greater number of accidents in the morning than in the afternoon, (2) peaks of accident occurrence at about 10 o'clock in the morning and 3 o'clock in the afternoon, (3) a gradual rise to and decline from these high points. These characteristics appear so constantly that the curve showing them may fairly be termed a typical curve.

When an attempt is made to interpret these curves a difficulty at once arises from the fact that the possible influence of two factors can not yet be determined. These factors are (1) The distribution of employment through the hours, and (2) some possible constant errors in reporting the hour when the accident occurred.

Regarding distribution of employment, it may be said that it is entirely possible that it reaches a high point at the same hours when accidents appear to be most numerous, and that the greater number of accidents at those hours is simply a response to a greater amount of work being done. The determination of this point is possible only by a very extensive and laborious study of the records of some plant which registers hours of arrival and departure with exactness and from which the accident records are available.

Excellent reasons can be advanced for believing that in the iron and steel industry employment is substantially uniform. For example, records of consumption of electric power show a sharp rise in the majority of cases during the first hour, a constant level to the last hour, and then a sharp decline. Further, no reason can be assigned for employment reaching a high point in the afternoon in different relation to the time of beginning than in the morning. These arguments are not entirely conclusive.

Regarding constant errors in reporting the hour of occurrence, such errors in certain cases are known to exist. For example, in a compilation of some 1,600 cases by 5-minute intervals, it was found that 52 per cent were set down as occurring exactly at the hour and 26 per cent at 30 minutes past the hour. That is, for an indeterminate period before and after the hour the tendency of those reporting is strong to give the nearest hour. This tendency would not materially alter the distribution to 8 points in the ordinary working day, namely, those having a half hour of activity both before and after. Such points are 8, 9, 10, and 11 in the forenoon, and 2, 3, 4, and 5 in the afternoon. When such points are considered the curve is not changed in its essential form from that produced by tabulating all the accidents. When, therefore, the experience of concerns where the reporting is known to be reasonably prompt, and especially where the record is made at an emergency room immediately upon the arrival of the patient as well as by the foreman to the safety office, is considered, such constant errors would not disturb the distribution curve. This, however, does not apply to the extensive accumulations made by official bureaus. It may be that in such reporting a sufficient number of cases are turned in on the basis of memory, considerably after the fact, to materially modify the curve. It will be easily seen that in making return from memory the occurrence might be located with some degree of accuracy, as morning or afternoon. The hour would be often a matter of pure guess and the tendency would undoubtedly be to place it somewhere in the middle of the period.

Until these two points can be more rigorously examined than has hitherto been possible, final conclusions regarding the significance of distribution curves are not possible.

In view of these considerations, it is now proposed to show as briefly and summarily as possible the records which have been accumulated in connection with the study and to offer a suggestion regarding a possible explanation of the form of the distribution curves.

The following table brings together the experience of the iron and steel industry and of a large machine building plant for both day and night turns:

TABLE 58.—DISTRIBUTION OF ACCIDENTS IN THE IRON AND STEEL INDUSTRY AND IN MACHINE BUILDING THROUGH THE HOURS OF THE WORKING DAY.

Hour ending at—	161 small plants (2 years).	122 large plants (2 years).	Large company, 4 plants (2 years).	Large plants (6 years).	Machine building plant.	Total.
DAY TURN.						
7	75	369	79	189	39	751
8	190	816	145	406	449	2,036
9	252	1,111	201	430	601	2,595
10	*300*	*1,209*	*244*	*489*	*787*	*3,029*
11	223	1,109	193	456	693	2,674
12	154	650	170	294	491	1,762
Total, forenoon	1,194	5,294	1,032	2,264	3,063	12,847
1	123	524	117	239	304	1,307
2	221	959	187	508	517	2,422
3	223	*1,076*	*220*	*523*	*617*	*2,659*
4	*240*	1,000	188	472	522	2,422
5	153	780	144	385	362	1,824
6	82	432	105	219	109	947
Total, afternoon	1,042	4,771	961	2,346	2,461	11,581
Total, day turn	2,236	10,065	1,993	4,610	5,524	24,428
NIGHT TURN.						
7	66	355	97	228	62	808
8	*79*	*416*	103	245	*73*	*906*
9	70	408	*107*	232	63	890
10	63	361	102	*256*	68	850
11	48	375	99	217	52	791
12	48	240	64	188	33	571
Total, first half night	374	2,155	570	1,366	351	4,816
1	*48*	209	*104*	139	15	515
2	43	*294*	99	212	*50*	698
3	36	276	81	*269*	42	*704*
4	46	251	90	194	35	616
5	37	254	85	179	27	582
6	33	262	62	167	30	554
Total, second half night	243	1,546	521	1,160	199	3,669
Total, night turn	617	3,701	1,091	2,526	550	8,485
Grand total	2,853	13,766	3,084	7,136	6,074	32,913

In the effort to determine the effect of such changes as those brought about by the safety movement, the following table was prepared. It shows that the accident reduction which occurred in this plant did not in any material degree modify the form of the curves.

TABLE 59.—COMPARISON OF NIGHT AND DAY ACCIDENT RATES IN A STEEL PLANT FOR THE PERIODS 1905 TO 1907 AND 1908 TO 1910.

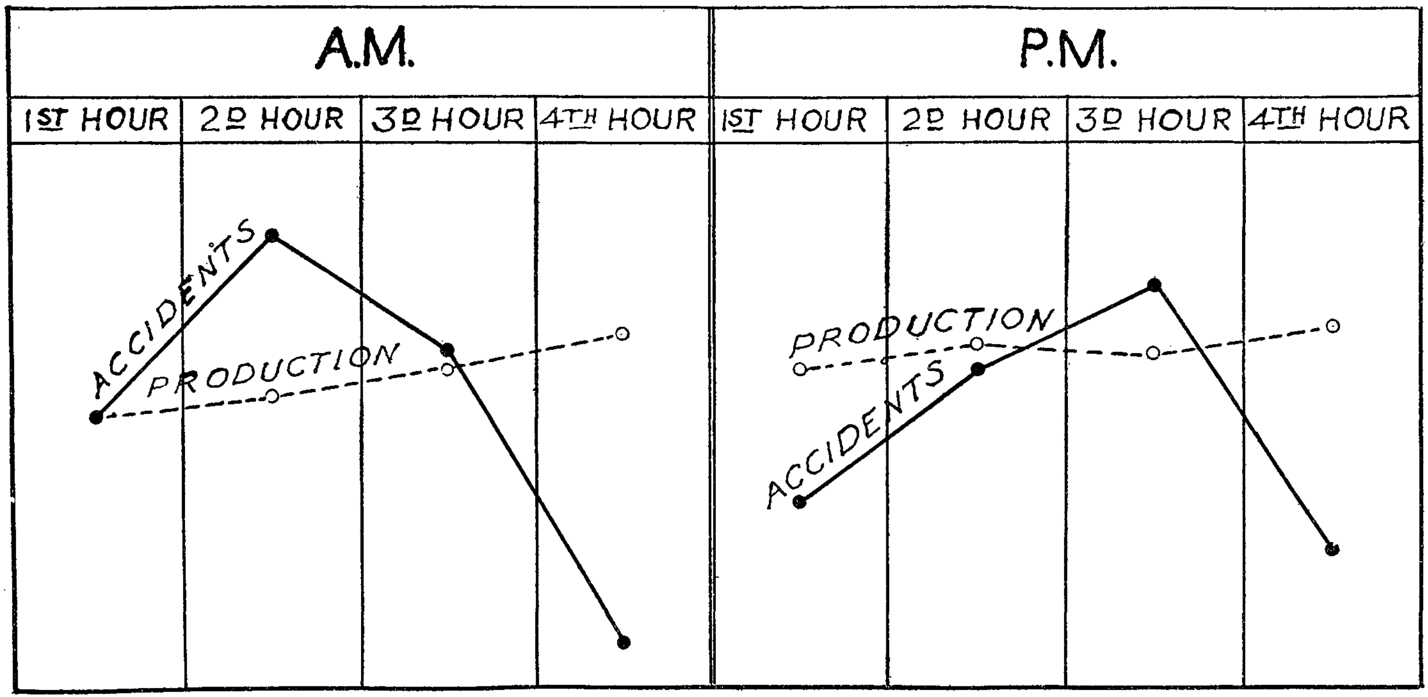
Hour beginning at—	Number of accidents.				Accident frequency rates (per 1,000 300-day workers).			
	1905 to 1907.		1908 to 1910.		1905 to 1907.		1908 to 1910.	
	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.
6	139	115	89	74	26.5	7.1	18.7	5.4
7	148	239	87	167	28.2	14.7	18.2	12.2
8	163	263	79	167	31.1	16.2	16.6	12.2
9	173	307	83	182	33.0	18.9	17.4	13.3
10	129	286	88	170	24.6	17.6	18.4	12.4
11	117	171	71	123	22.3	10.5	14.9	9.0
Total	869	1,381	497	883	165.7	85.0	104.2	64.5
12	99	155	40	84	18.9	9.5	8.4	6.2
1	130	305	82	203	24.8	18.8	17.2	14.9
2	173	301	96	222	33.0	18.5	20.1	16.3
3	144	292	50	180	27.5	18.0	10.5	13.2
4	120	228	59	157	22.9	14.0	12.4	11.5
5	117	145	50	74	22.3	8.9	10.5	5.4
Total	783	1,426	377	920	149.4	87.7	79.1	67.5
Grand total	1,652	2,807	874	1,803	315.1	172.8	183.2	132.0
Number of 300-day workers	*5,242*	*16,243*	*4,774*	*13,658*				

In attempting to discover the relation of production and accident the experience of press hands was assembled. The table and chart show that production rose pretty steadily throughout the working period, while accidents rise to a peak and then decline.

TABLE 60.—RELATION OF PRODUCTION AND ACCIDENTS AMONG PRESS HANDS.

Period.	Hour.				Total.
	First.	Second.	Third.	Fourth.	
Pieces formed:					
Forenoon	38,744	40,029	40,259	41,275	160,307
Afternoon	39,874	40,925	40,815	41,191	162,805
Accidents to press hands:					
Forenoon	195	233	211	145	784
Afternoon	175	205	222	165	767

CHART 16.—ACCIDENTS AND PRODUCTION AMONG PRESS HANDS.



In the further study of production from hour to hour the records of several rolling mills and of a Bessemer plant were assembled. The results are embodied in the following table and chart. They show a rising tendency in product throughout each turn, while accidents appear to rise and then decline.

TABLE 61.—PER CENT OF TOTAL PRODUCTION OF DAY TURNS ACCOMPLISHED DURING EACH SPECIFIED HOUR OF EMPLOYMENT IN NINE MILLS OF A STEEL PLANT, SEPTEMBER, 1912, TO APRIL, 1913.

Hour ending at—	Bessemer converter.	Blooming mill A.	Blooming mill B.	Slabbing mill.	Rail mill.	Structural iron mill A.	Structural iron mill B.	Plate mill A.	Plate mill B.
8 a. m.	8.14	6.37	6.43	6.97	8.21	6.74	5.78	8.18	8.23
9 a. m.	8.22	8.02	8.20	8.10	7.82	6.96	7.25	8.24	8.50
10 a. m.	8.18	8.31	8.62	8.07	8.36	8.24	7.99	8.11	8.39
11 a. m.	8.15	8.58	8.85	8.36	8.54	8.02	8.65	8.20	7.97
12 a. m.	8.34	8.65	8.69	8.23	8.11	8.39	9.05	8.23	8.08
1 p. m. (lunch hour)									
2 p. m.	8.44	8.92	8.53	8.61	8.85	8.70	8.50	8.64	8.41
3 p. m.	8.50	8.96	8.67	8.62	8.02	8.67	9.00	8.72	8.44
4 p. m.	8.41	9.36	9.14	8.68	8.77	9.41	9.37	8.69	8.76
5 p. m.	8.78	9.35	9.56	9.18	9.18	9.41	9.19	9.08	9.02

It must be clearly understood that these tabulations represent the records as they exist. Their interpretation is necessarily limited by the lack of knowledge specified earlier. Until that lack is supplied any explanation must be regarded as of an entirely provisional character.

If substantially uniform employment and essentially reliable record of the hour of occurrence be assumed, the following explanation seems to accord with the facts. It is offered in the hope that it will lead to further inquiries which, if they do not serve a directly practical purpose, may serve to prevent the expenditure of time upon statistical compilations essentially lacking in secure foundations.

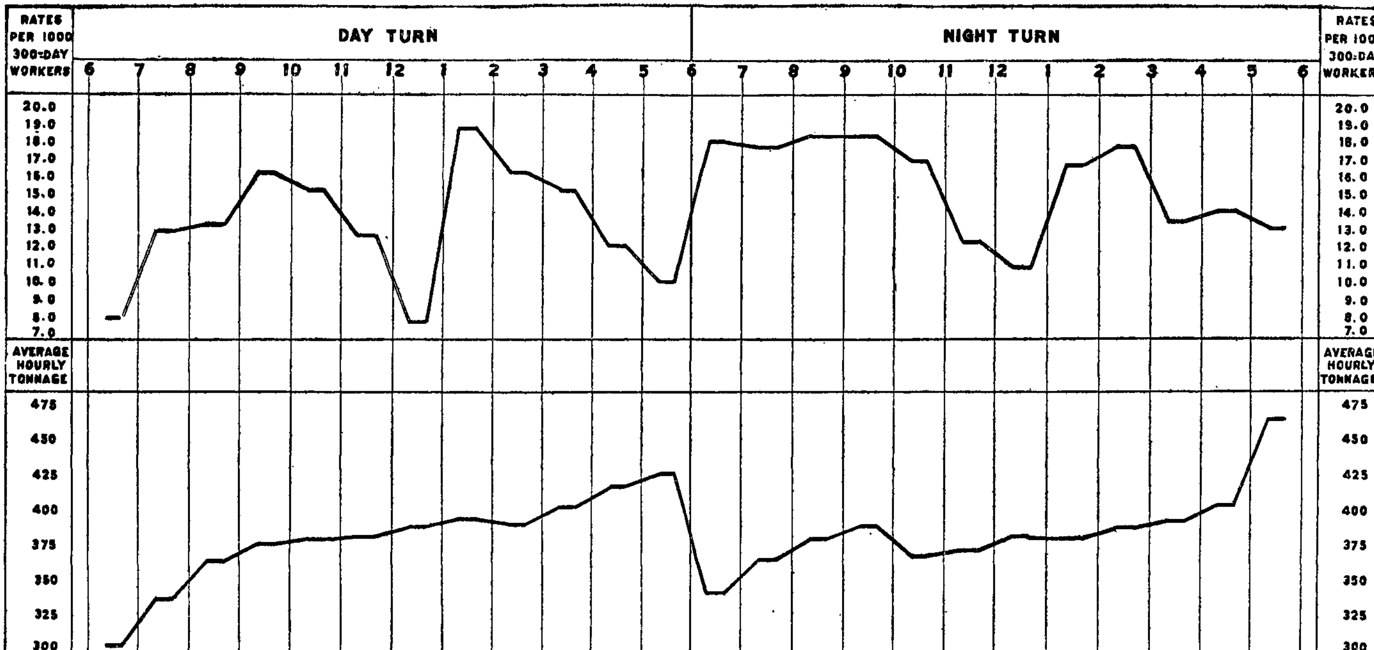
A PROVISIONAL EXPLANATION.

For purposes of further study the following explanation of the form and relation of the curves of accident and production throughout the day is proposed.

If the case were the simple one of rising accident rate with increased speed, the results already attained in the laboratory would afford a sufficient explanation. There is, however, the apparently contradictory situation of product rising and accident responding for a time, while later, with still rising product, accidents decline. If these indications are reliable, some change must occur in the worker in the course of his work.

The suggested explanation is as follows: At the outset of any effort there is a certain lack of harmony between the will and the nervous and muscular agents by which results are attained; the coordination

CHART 17.—HOURLY ACCIDENT RATES AND HOURLY PRODUCTION.



NUMBER OF 300-DAY WORKERS { DAY 12,407 / NIGHT 6,875 }

TOTAL PRODUCTION (TONS) 1,910,003
TOTAL ACCIDENTS 3,307

is not perfect. If along with this imperfect coordination there is some motive, of whatever character, leading to effort for increased speed the results shown by the curves will ensue, the product will rise, and the accident curve will rise more rapidly. As effort continues coordination improves until finally product may be rising while accident rate is falling. In practice the effects of imperfect coordination appear not to be overcome until about 10 o'clock in the morning. About that time comes the turning point, accident appears to go down, due, possibly, to the progressively better coordination, but the product continues to rise.

The afternoon repeats the morning experience with this important difference: (1) The period of adjustment is shorter; (2) the period of relatively good coordination is longer and naturally the afternoon product is larger.

In this connection the following quotation from a paper[1] by Prof. A. F. Stanley Kent on "The 'Monday Effect' in Industry" is in point:

> Thus the evidence points to the real cause of the inefficient work on Monday and in the first working period of any particular day, being traceable, not to any injurious influences acting on the worker, but rather to abstention from work resulting in operations which—as a result of practice—are ordinarily performed quickly and well, being to some extent forgotten, and to that extent having to be relearnt before the old efficiency can be regained. It is in fact a matter of loss of coordination rather than of actual fatigue.

EXTREME INEXPERIENCE.

Since the explanation offered above involves the idea that a rapidly rising accident rate at the beginning of employment may be due to the condition in which the worker begins his task it is of interest to inquire whether the extremely inexperienced worker gives indication of being unusually influenced by this condition.

It should first be emphasized that such a worker has an extraordinarily high accident rate. Since press hands are used for illustrative purposes the following table, drawn from "Women in the Metal Trades,"[2] is significant.

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[1] Journal of Physiology, vol. 50.

[2] Report on condition of women and child wage-earners. Vol. XI. Employment of Women in the Metal Trades. S. Doc. No. 645, 61st Cong., 2d sess.

TABLE 62.—AVERAGE NUMBER OF PRESS HANDS AND OF EMPLOYEES IN OTHER OCCUPATIONS INJURED PER DAY AFTER BEGINNING WORK ON MACHINE, BY SEX.

Occupation.	Average number injured per day.				
	1st day.	2d day to end 1 week.	2d week to end 1 month.	2d month to end 6 months.	7th month to end 1 year.
Press hands:					
Males	77	13	3	0.78	0.21
Females	252	33	4	.71	.26
Total	329	46	7	1.49	.47
Other occupations:					
Males	89	25	8	3	1
Females	42	12	2	.69	.32
Total	131	37	10	3.69	1.32
All occupations:					
Males	166	38	11	3	1
Females	294	45	6	1	.57
Total	460	83	17	4	1.57

This table shows a very great excess of accident occurrence on the first day on the machine. If this could be placed on a rate basis, it would be still more striking.

In connection with the study from which the table above is taken 435 cases of accident to press hands during the first day of employment on the press and 537 cases of metal workers injured after a year or more of experience were recorded for which the hour of injury was known. A tabulation of these cases follows:

TABLE 63.—ACCIDENTS TO INEXPERIENCED PRESS HANDS AND TO EXPERIENCED METAL WORKERS BY HOUR OF THE DAY.

Hours ending at—	Accidents in each hour.		Percentage in each hour.	
	Press hands—1st day of employment.	Metal workers—after 1 year or more of employment.	Press hands—1st day of employment.	Metal workers—after 1 year or more of employment.
8 a. m.	38	42	8.74	7.82
9 a. m.	50	65	11.49	12.10
10 a. m.	*66*	67	*15.17*	12.48
11 a. m.	58	*78*	13.33	*14.52*
12 m.	41	40	9.42	7.44
Total forenoon	253	292	58.15	54.36
2 p. m.	46	46	10.57	8.57
3 p. m.	*52*	65	*11.95*	12.10
4 p. m.	44	*66*	10.11	*12.29*
5 p. m.	30	50	6.90	9.31
6 p. m.	10	18	2.30	3.35
Total afternoon	182	245	41.85	45.64
Grand total	435	537	100.00	100.00

A comparison of the distribution through the day of the accidents to these two classes discloses that the morning rise is greater with the beginner. His reaction to the conditions is decidedly more pronounced than that of his more seasoned fellow worker. There is abundant reason why this should be so. The beginner is more likely to be influenced by motives leading to efforts at speed. The holding of the new and probably more profitable job is almost sure to be regarded by the beginner as depending on his speed record. On the other hand his coordination with his work is necessarily much more imperfect than that of the experienced worker who returns to a familiar sort of work after a brief interval.

It is evident that even if the experienced worker showed a uniform distribution through the day the effect of the presence of beginners with their high accident rate would determine the form of the curve for all workers. The table, however, indicates that the same form of curve, in its essential particulars, occurs for the experienced as for the inexperienced. The difference is one of degree, not of kind. The experienced worker has (1) a lower accident rate; (2) a more nearly uniform distribution.

The condition of incoordination and unpreparedness is perfectly well known to everyone who works. It consciously affects his initial efforts and is consciously overcome as time goes on. It is naturally more noticeable in the case of highly specialized efforts such as musical performance. A noted musician is quoted as saying "If I omit practice one day I notice the effect; if two days, my friends notice; if three days, the public."

An excellent illustration of the proposition offered above is afforded by the experience of a physician who is an expert operator of the typewriter. For a considerable period, occupied with other duties, he did not use the machine. He then had occasion to prepare a paper hurriedly. At intervals he made a count of the pages produced, not exact, but sufficient to show that the speed of production increased steadily. When the errors were corrected it appeared that for a time they increased from page to page, then a turning point was reached and errors began to decline. Toward the end when speed was highest there were no errors. Such an illustration is of peculiar force. The conditions are manifestly such that nothing disturbing the "natural affective behavior" of the subject is present. The conformity to the experience of press hands and steel mill workers is noteworthy.

The fatigue factor can not be identified in these curves. It does not follow that it has no influence. While not capable of demonstration it may be strongly suspected that its influence is more or less serious during the period of recoordination in the morning. The worker who is not given a sufficient period for recuperation may very likely approximate the much higher rate throughout the day and the form of curve of extreme inexperience.

CHAPTER VIII.

WHAT ARE THE LIMITS OF ACCIDENT PREVENTION?

Perhaps the most interesting inquiry regarding industrial accidents concerns the extent to which they may be prevented. Is it reasonable to look forward to a time when accidents will be so few as to be negligible, or must we contemplate always having a huge yearly toll of deaths and injuries in industry?

The prevailing belief is that it is hopeless to think of anything like the elimination of accidents, at least within a measurable time. But the results of the present study of accident causes in the iron and steel industry, as presented in the preceding chapters, pointedly suggest that the current belief may be erroneous—that, while it may not be possible to do away with accidents, it is quite practicable to make industry so safe that fatal accidents and other serious accidents will be of exceptional occurrence.

This conclusion is the result of a careful analysis of the accident experience of the iron and steel industry, but in a broad way it would seem applicable to all industries. The premises upon which the conclusion is based may be summarized as follows:

1. Up to very recently emphasis has been placed primarily upon the frequency of accidents rather than upon their severity. The vast majority of accidents occurring in the iron and steel industry are of a minor character. Thus, even when injuries of under a day's duration are excluded, more than 50 per cent of all the injuries reported caused disabilities terminating in less than one week. But from the standpoint of time lost these minor injuries were much less important than the small percentage of more serious injuries. The accidents resulting in death, although constituting only about 1.5 per cent of the total number of accidents, caused a total loss of time amounting to more than 65 per cent of the total time losses caused by accidental injuries. In order to arrive at the amount of time lost it is necessary to express fatal injuries and permanent disabilities, as well as temporary disabilities, in terms of workdays lost. This is done by valuing a fatal injury (assuming the employee killed of an average age of 30 years) as equivalent to the loss of 30 years' work time—9,000 days. Permanent total disability is placed at 35 years, or 10,500 workdays, such disability involving a greater burden to relatives and the community than death. Lesser permanent injuries—such as loss of hand or foot—are credited with lower time losses in proportion to their probable effect upon earning capacity—2,196 days for a hand, 1,845 days for a foot, etc. The severity rate is the number of days lost per annum per 300-day worker—that is, one who works 300 days a year, 10 hours per day, or 3,000 hours per annum.

2. The safety movement has dwelt unduly upon the carelessness of the worker and has stressed too little the importance of safe tools, safe machines, safe practices, and safe construction. Carelessness and ignorance on the part of the worker are undoubtedly responsible for many accidents but chiefly for the accidents of a minor character. It is this fact that places definite limitation upon the safety organization idea as usually practised. With its committees, its publicity methods, its quickening of foremen and workmen to an active interest, safety organization has been tremendously effective in the reduction of minor accidents.

Because the success of organization methods in reducing accident frequency was so great, it came to be regarded as the explanation not only of the decrease in frequency of accidents but also as accounting directly, by immediate effect on the workmen, for the decrease in fatal and serious accidents. This belief took root the more readily since the idea that accident is largely due to the reckless behavior of the workman is an ingrained notion inherited from the days when the slightest "contributory negligence" barred the victim from recovery. It may be said that if personal carelessness could be entirely eliminated the effect upon the number of fatal and serious accidents would not be great so long as the engineering defects are left unchanged.

3. Fatal accidents and serious accidents, as appears from the present study, are primarily due to fundamental engineering or structural defects in which the workman has no part. The reduction in the rates of death and severe injury has been due primarily to engineering revision of structure and practice, and it is in that direction that real progress lies.

In thus using the term "engineering revision of structure and practice" as expressive of the fundamental remedy for severe accident, the meaning of the term must be clearly understood. By "engineering revision" is meant much more than "mechanical safeguarding." The term is intended to suggest the widest application of engineering skill to industrial plants. The design and location of the buildings, the arrangement of the transportation facilities, the means of access to every point where a worker must go, the introduction of adequate lighting, the removal of hazardous conditions, the guarding or replacement of dangerous machines—all these must have adequate attention. Safety men are themselves hardly aware how great are the changes which have taken place in their own plants in these particulars. The changes have come about gradually, and to the man who has been in contact with the slow modification the contrast is much less striking than to one who returns after an interval and notes the transformation.

The first attack of the safety movement was upon unguarded machines. Exposed gears were covered, belts were fenced, and other things of similar character done. This came to be known as "mechanical safeguarding." Its results were rather disappointing. The machine when closely studied did not prove to be as important in causing accident as it had been supposed to be. At the same time that "mechanical safeguarding" was being tried and found somewhat wanting, the committee system was inaugurated, and the system now known as "safety organization" was coming into being. This appealed strongly to the human factor. The success in reducing accident frequency was immediate and extraordinary. The natural result was to concentrate attention upon organization as the chief factor in accident prevention. The contribution from what is here called "engineering revision" fell somewhat into the background. "Mechanical safeguarding" was given an extension of meaning to include in many minds these broader engineering problems. Since such "safeguarding" had not realized the returns which were expected from it, the results of the application of engineering skill were somewhat clouded by the idea that they rested upon nothing more than a form of "mechanical safeguarding." This presentation is designed to show that the appeal to the human factor is not sufficient for the control of serious accidents. For that, reliance must be upon adequate "engineering revision."

A considerable body of facts in support of the above line of reasoning has been presented in the preceding chapters. Evidence of particular importance is offered in the following analyses of (1) the accident causes in several departments of the iron and steel industry over a period of years, (2) the accidents causing death, and (3) the nature of the injuries causing death.

ACCIDENT CAUSES BY DEPARTMENTS OVER A PERIOD OF YEARS.

BLAST FURNACES.

A careful examination of the course of accident rates in certain blast furnaces from 1905 to 1914 indicates that the major part of the reduction in severity rates which took place was due to structural and mechanical improvements in the department. (See Table 33.) Thus, hot metal "breakouts" contributed far more than any other cause to the severity rates. From 1910 onward this cause disappears. Its disappearance was due to the completion of structural improvements which increased the resistance of the furnaces to such an extent as to eliminate the breakouts.

Second in importance as a cause of serious accident in the earlier years was asphyxiating gas, breakouts and gas together furnishing 56 per cent of the severity rate of 1906. The danger from gas has also been controlled mainly by structural improvements, such as carrying the gas mains high in the air and providing more effective control by means of improved valves. In addition, the introduction of protective devices such as oxygen helmets and of resuscitation apparatus must be credited with a considerable portion of the reduction in the severity rate.

When examination is made of the accident rates for those causes which are more affected by personal care on the part of the worker, it is evident that while accident reduction of great importance has occurred, it does not approach in significance that arising from the control of the causes above mentioned, which must be met by engineering revision. For example, falls of worker may be regarded as greatly influenced by personal care. In these blast furnaces the severity rate reduction was 1.9 days (i. e., from 7.5 to 5.6 days lost per 300-day worker) between 1906 and 1913. This may be compared with a reduction of 58.9 days lost in the case of injuries due to hot substances (i. e., from 60.8 to 1.9 days) and a reduction of 10 days lost (i. e., from 15.4 to 5.4 days) in the case of injuries due to asphyxiating gas.

Even these statements do not present the case fully. In the early days there were one or two deaths annually from falls of painters engaged upon the stacks or stoves. The provision of a suitable sling and seat for painters has entirely eliminated such deaths. Even in injuries due to falls of worker, depending, as suggested, a good deal upon personal care, a considerable portion of the reduction of 1.9 days lost was due to mechanical contrivances, such as safe ladders, and to the elimination of structural defects which made accident inevitable. Reducing injuries due to the handling of tools and objects is largely dependent upon personal care. The reduction in the severity rate from this cause was only 7.3 days between 1906 and 1913, an amount of relatively small importance when compared with the rate of reductions for injuries due to hot substances and gas. No inconsiderable part of this reduction must, however, be credited to better tools and greater care by the shop management in furnishing safer tools and keeping them in proper condition.

In the blast furnaces studied, therefore, striking success in reducing the severity of accidents is found in those causes to which engineering revision has been applied. Their experience strongly suggests the overwhelming importance of fundamental improvements in physical conditions.

OPEN HEARTH FURNACES.

In the open hearth department, injuries caused by cranes and hoists show high severity rates in the earlier years, particularly in 1907 (see Table 36). This was due almost entirely to the structural defects then prevalent, such as absence of footwalks, poor access to the crane cage, overhung gears, and others. By 1911 these defects had been largely corrected in the mills studied and from that time severity rates dropped markedly and continuously.

In injuries caused by hot substances, explosions other than ingot are the main cause of the early high severity rates. It is obvious that the carefulness of the individual workman can do little to prevent such explosions. When they occur some workmen are inevitably killed or injured more or less severely. There is rarely any warning to enable those exposed to escape. The lessened severity rate of recent years is mainly due to revisions in structure and in method which were primarily introduced to favor production. They both lessen the likelihood of explosion and protect the worker when explosion comes. These structural revisions have not been rated at their true value from a safety standpoint because, as stated above, they are almost all related to production.

The reduction of the severity rate for injuries due to power vehicles must be largely attributed to improved transportation facilities and improved methods of operation.

The cause groups noted above—cranes and hoists, hot substances, and power vehicles—are clearly influenced largely by engineering revision. The result of the application of engineering methods is seen in the figures which follow. These cause groups combined declined in severity from 47.5 days per 300-day worker in 1907 to 8.3 days in 1912, a reduction of 83 per cent. In cause groups in which personal care is a larger factor the decline was only 13 per cent. In fact in one such group, "handling tools and objects," the severity rate actually increased.

If frequency is considered the showing is very different. The cause groups dependent upon engineering improvement declined in frequency rates from 117.8 cases per one thousand 300-day workers in 1907 to 64.5 cases in 1912, 45 per cent, while "handling tools and objects" declined from 195.5 cases to 92.3 cases, 53 per cent. On the basis of frequency personal care has decidedly the better record. How completely this record is reversed when severity is considered is emphasized when it is remembered, as noted above, that while "handling tools and objects" was making the marked decline of 53 per cent in frequency, the severity increased 17 per cent.

ROLLING MILLS.

In heavy rolling mills the only cause of injury about which it is possible to make a positive statement is cranes and hoists. (See Table 40.) The reduction in severity rates recorded is very largely due to better cranes, better chains, and improved methods of operation.

Of tube mills it may be said that the lessened severity rates may very properly be attributed in large measure to the effects of increased personal care. The operations of such mills afford many opportunities to eliminate moderately severe accidents by that means. The occurrence of fatality is so rare that conclusions regarding its occurrence are not warranted.

MISCELLANEOUS DEPARTMENTS.

In plate and sheet mills (see Tables 43 and 44), in the mechanical department (see Table 46), and in the fabricating shops (see Table 47), it is difficult to decide which factor—personal care or engineering revision—has the greater importance. Since many of the operations are of a personal and manual nature it is fair to attribute much importance to individual care. Making due allowance for this it still appears that in cases of high severity rates due to fatality these fatalities are almost invariably the result of some structural defect admitting of remedy.

YARDS.

In the yard department injuries caused by hot substances show a remarkable decline in severity rates. (See Table 48.) Nearly all of this is attributable to improved methods of transporting hot metal. When the power vehicle as a cause of accident is studied it becomes evident that the introduction of automatic couplers, the provision of adequate clearances, improved loading methods such as the use of magnets, better signaling systems, and elimination of grade crossings have influenced the severity rates at least equally with and probably more than increased personal care.

IMPORTANCE OF ORGANIZATION.

This review of the several departments sustains very decidedly the contention that the effect of personal care appears mainly in reduced frequency rates and that engineering revision is reflected more largely in the decline of the severity rate. There must be no misunderstanding of this contention. It does not diminish the importance of organization. In an important respect it increases it materially. Organization and the interest it evokes lead to the discovery and remedy of structural defects. Without organization the revision so far accomplished would never have occurred. The facts here pointed out regarding experience in the various departments emphasize the importance of directing organization more vigorously to the discovery of faulty structure. Open and obvious faults have been noted, and it is becoming constantly more and more a matter of the most intensive engineering study to discover and remedy the less obvious faults. This goes beyond the province of many safety men. They should demand with increasing insistence the help of the best engineering skill.

ANALYSIS OF CAUSES OF FATAL INJURIES.

Because of the extreme seriousness of fatal accidents from the economic standpoint it is of particular importance to examine their causes with the view of placing the responsibility for their occurrence. Data for this purpose were available for 372 cases of death. These occurred in plants having a total exposure of 247,038 300-day workers, the fatality rate thus being 1.51 per 1,000 300-day workers. As the fatality rate for the whole industry for the years 1910 to 1914 was 1.20 cases per 1,000 300-day workers, it is evident that the plants here concerned were in no way exceptional. The following table lists these 372 death cases by causes:

Causes of 372 cases of fatal injury in the iron and steel industry, 1910 to 1914.

Engines, motors, etc	3
Transmission gear	3
Working machines:	
Adjusting	2
Operating	2
Oiling and cleaning	2
Repairing	5
Objects flying	4
Miscellaneous	2
Total	17
Cranes and hoists:	
Operating	1
Oiling and cleaning	3
Repairing	3
Breakage	7
Falling loads	23
Hoisting and lowering	8
Miscellaneous	32
Total	77
Hot substances:	
Electricity	16
Explosions	12
Hot metal	15
Hot metal flying	25
Flames	5
Miscellaneous	3
Total	76
Falling objects:	
Collapse of building, etc	9
Stored or piled materials	7
From trucks or vehicles	3
From buildings, scaffolds, etc	4
Miscellaneous	27
Total	50

Falls of worker:	
From ladders	5
From scaffolds	6
From vehicles	1
From structures	20
From other elevations	4
Into other openings	3
Miscellaneous	6
Total	45
Handling tools and objects:	
Tools in hands of worker	1
Loading and unloading	3
Objects from flying tools	1
Total	5
Power vehicles	57
Miscellaneous:	
Flying objects not otherwise specified	4
Asphyxiating gas	19
Heat	4
Moving objects not otherwise specified	6
Miscellaneous	6
Total	39
Grand total	372

It is necessary to state the principles upon which the following interpretation of these death cases rests:

First. It is assumed that it is the primary duty of the safety man to make conditions safe rather than to educate the men to avoid unsafe conditions over which they have no control. In considering any given case, if it appears that the immediate cause of the accident was some weakness in an appliance, or faulty construction, or poor arrangement, which, if remedied, would have prevented the injury, no amount of so-called "contributory negligence" on the part of the man is considered sufficient to transfer the responsibility to him.

Second. The fact that an apparatus can be used with entire safety by the exercise of special care is not regarded as excusing the failure to provide safer apparatus. For example, a ladder without safety feet may be used on a hard floor by taking certain precautions. If a man fell and was killed under such circumstances the unsafe apparatus is regarded as the point to be considered rather than the failure to take the possible precautions.

Third. The costliness of remedying structural defects, even to the extent of entirely reconstructing a mill, should not bar its consideration. An illustration of the principle may be drawn from the case of the wood planer. In the old type of this machine a revolving cutter was used which would sometimes take off an entire hand. This has now been replaced by a cutter which may inflict a painful, but can not inflict a serious wound. This is a notable advance, but it is possible to go further, since an automatic feed has been devised for such planers which makes injury impossible. The expression "prohibitive cost" is heard from time to time in the discussions of safety men. It is the contention in this discussion that if this element of cost is entirely disregarded serious and fatal injury can be very largely eliminated. The objection will be raised that this is an ideal impossible of attainment. The condition urged is ideal, but not unattainable. If an industry or plant can be made safe only by prohibitive expenditure, in reconstruction, it is a question whether that industry or plant should be permitted to continue maiming and killing workmen in order that profits may continue.

The cause groups of the table will now be followed and commented upon in the order in which they appear:

Engines and motors caused three deaths. Two of these could have been avoided by the guarding or removal of projections on the moving parts.

Transmission gear caused three deaths. Two of these were due to projecting set screws on shafts.

In working machines, 9 out of 17 deaths were due to mechanical or other conditions which should have been remedied and over which the operator had little or no control.

Cranes and hoists were the cause of the largest number of fatalities—77. One which occurred in operating a crane was due to some defect in the electrical control of the crane. Three which were of oilers were attributable to the necessity of approaching moving parts not properly guarded. Seven due to breakage were all preventable by proper design or greater strength. Of 23 due to falling loads, some weakness in the crane, imperfect chains, faulty signals, or some other condition which the management should have improved was a factor in all but one case. Some of these involved an element of contributory negligence, but if this had not been combined with mechanical defects no accident would have occurred. Miscellaneous causes incident to cranes and hoists contributed 32 cases, of which 10 were clearly due to defects such as absence of foot walks and of proper means for reaching the crane cage. To sum up, 43 out of 77 cases in the operation of cranes and hoists could have been prevented by better design in the crane and such operating methods as now prevail. It may be strongly suspected that into the other 34 causes there entered not infrequently elements of unsafe practice or imperfect structure for whose presence the workers were not responsible and which no education of them could remove.

Hot substances caused 76 fatalities. Sixteen of these were due to electric burns, and of these 13 were preventable by the kind of construction now in common use in electrical installation. Of 12 deaths due to explosions, 7 were of a kind which could scarcely occur at present with the improved modern practices. Hot metal caused 15 deaths, and in 14 of these bad method or imperfect structure had a part. For each condition under which these 14 cases occurred an effective remedy has been found. Of 25 deaths due to hot metal flying, 18 would probably not have occurred under the latest improved practice. It should be emphasized that this does not mean teaching the men caution. It means a correction of faults in the apparatus and in methods of using it. Not less, therefore, than 52 out of the 76 deaths due to hot substances presented problems of revision of structure and methods.

Of 50 deaths due to falling objects 29 were preventable by appropriate structural changes.

Falls of worker caused 45 deaths. Of these 22 might have been prevented by better scaffolds, stairs, platforms, railings, and other structural provisions which are now regarded as a matter of course.

Of 57 deaths due to power vehicles 34 were the result of causes such as the following: Failure to install automatic couplers, inadequate clearance between cars and buildings, grade crossings upon which men could come without being able to see the approaching locomotive, bad signal systems which permitted cars to be shunted down upon standing cars under which men were at work, and absence of proper grab irons for getting on and off cars. None of these present any insuperable difficulties to the engineer.

There were 19 deaths from asphyxia. All of these were related to imperfect gas mains, unventilated inclosed spaces, leaky valves, and other conditions involving changes in the apparatus.

To summarize this examination, 212 out of 372 deaths, i. e., 57 per cent, could have been prevented by some engineering revision. This can be said without qualification. It can not be said that all the other 43 per cent would have been amenable to educational methods in response to which caution would insure safety. In only about 10 per cent of these deaths would it be safe to say positively that the man's own carelessness clearly appears as the major factor. In the remainder either no conclusion is justified by the record or there is a mixture of contributory negligence with possible structural imperfection impossible to untangle.

The above compilation of fatal injury cases represents a combination of data for the years 1910 to 1914. It is of interest to compare with it a body of material, recently received by the bureau, for a group of plants for the year 1916, that year being one of extraordinary activity in the industry. In this group of mills, with 84,305 300-day workers, 72 deaths occurred. This is at a rate of 0.86 case per 1,000 workers as against the rate of 1.51 for the preceding group for the years 1910 to 1914. This lower fatality rate represents a distinct improvement, the probable result of very extensive structural revision made by these plants. In spite of this improvement, however, an analysis of the 72 death cases indicates that at least 58 per cent of them involve elements of structural defect or improper operative methods.

ANALYSIS OF THE NATURE OF INJURY IN FATAL CASES.

Further light upon the possibility of reducing the number of serious accidents may be derived from a study of the nature of the injury causing death. This is desirable also because the consideration of rates and distribution from year to year comes to have a rather formal interest and fails to give due emphasis to the vital importance of these cases.

The nature of the injury causing death was available in 956 cases. In the following table they are distributed according to the nature of the injury and the part of the body affected:

TABLE 64.—NATURE AND ANATOMICAL LOCATION OF INJURIES CAUSING DEATH IN 956 CASES IN THE IRON AND STEEL INDUSTRY, 1905 TO 1914.

Nature of injury.	Anatomical location of injury.						
	Head, general.	Skull.	Scalp.	Face.	Neck.	Back.	Chest.
Bruises, cuts, lacerations, and punctures	3				1	2	5
Bruises, etc., with infection	1		6	1	1	1	1
Burns and scalds				1		8	74
Concussions	5						
Dislocations					1		
Fractures		218		3	20	13	220
Traumatic dismemberment	[1] 4						
Total	[1] 13	218	6	5	23	24	300

Nature of injury.	Anatomical location of injury.							
	Abdomen.	Pelvis.	Arm.	Hand.	Leg.	Foot.	Not located.	Total.
Bruises, cuts, lacerations, and punctures	26							37
Bruises, etc., with infection			1	4	2			18
Burns and scalds	26		2		19		[2] 6	136
Burns, etc., with infection				1	1			2
Concussions								5
Dislocations								1
Fractures		33	6		65	7		585
Fractures, with infection			1	1	1			3
Traumatic dismemberment			6		[3] 9	4	1	24
Asphyxia							71	71
Electrocution							23	23
Heat exhaustion							7	7
Miscellaneous	3				1	1	39	44
Total	55	33	16	6	[3] 98	12	[2] 147	956

[1] Includes 2 cases of decapitation caused by hot rod.
[2] Includes 4 cases of cremation by falling into a furnace or being covered by molten metal.
[3] Includes 1 case of dismemberment caused by hot rod.

The largest group in the table is that of fractures. When severe enough to cause death these involve nearly always an element of crushing injury. When the cases are closely studied there is found to be in a majority of them—it is impossible to determine the exact number—some indication of faulty structure which might have been remedied. For example, a man's life is crushed out between a moving car and a post beside the track. What was needed to make him safe? Six inches more of space—easy, almost costless, to give at the time of building, but looking so difficult and costly after construction is finished that it is not provided until after the man is killed.

Next in importance to fractures are burns and scalds, with 136 cases. Of these the most striking are 4 cases of cremation, 1 due to falling into a furnace, 3 to being overwhelmed by molten metal. In the cremation cases due to molten metal, rearrangements were worked out after the catastrophe which tend to lessen very much the chance of a recurrence of such an accident. In a large proportion of the less striking cases some structural improvement, lessening the danger, has been made subsequent to the accident.

The fact that infection was formerly a very serious menace is attested by the fact that 23 deaths occurred in which without this complication there would very likely have been recovery. None of the injuries in which it figured were in themselves of sufficient seriousness to cause death. This emphasizes very strongly the great value as a life saver of adequate emergency treatment with sufficient insistence upon it to secure prompt report of even slight injury.

The 23 cases of electrocution were largely needless. They represent faulty installation or a method of doing work which should not be tolerated. The same statement is, in a measure, to be made regarding 71 cases of asphyxia. Sufficient care in construction and in methods of work would do away almost entirely with this death hazard.

Finally, 24 cases are presented which afford a startling climax to this presentation. These are cases of traumatic dismemberment, in which arms, legs, or heads were burned, sheared, or forcibly torn from the body. Of the nine cases of legs so lost one leg was burned off by a hot rod in a rod mill. The feet lost were ground off in the exposed gearing of the transfer tables of rolling mills. Four decapitations are recorded. Of these, two were due to being caught by the hot rod loop in the rod mills; the other two were the result of power vehicle accidents.

The question of the reasonableness of the costliest efforts to render such events impossible can scarcely be debated. It is but just to say that in many cases efforts have been made with small regard to cost and that usually such efforts have been successful. The larger proportion of the striking cases in the table above belong to the earlier portion of the period included in the survey.

EXAMPLES OF SO-CALLED "CARELESSNESS."

The wide prevalence of the view which attributes the accident largely to the worker, when he is at best but a contributing cause, is illustrated in numerous safety manuals and safety directions. The following are taken from recent publications. The cases listed were all cited as illustrations of carelessness on the part of the worker.

Case 1.—A workman in a foundry was wheeling a barrow, and while passing under a heavy flask being carried by a crane the chain broke, the load dropped on him and he was killed. This case is listed under the heading "disobeying safety orders."

The man clearly contributed to his death by disobeying a rule which forbade him to walk under moving loads, and, in one view, the remedy would clearly be a renewed insistence on the rule. There is, however, another view. What was the matter with the chain? This question is the really fundamental one. The man's disobedience endangered himself only. The faulty chain endangered many men, men who were blamelessly doing their appointed tasks. It may be urged that it is not possible to produce a perfectly safe chain. In reply it may be said that recent investigation shows conclusively that there are defects in structure and in use of chains which can be removed by engineering attention. Until that is done the chain problem is the fundamental problem in all such cases as the one here listed.

Case 2.—At a point where the clearance between railway track and wall was too small for a man to stand safely, there was located an outlet for water. It was intended for no other purpose than the flushing of an adjacent gutter and the men were forbidden to get supplies from it. In spite of the order it was used from time to time because of its more convenient location instead of the more distant faucet provided. Finally a man was caught and killed. A clearer case of personal negligence could hardly be imagined. Is there anything more to say? At a slight additional expense the outlet could have been located in a safe place. No amount of negligence on the part of the men excuses a trap in which even a violator of rules may be caught.

Case 3.—An oiler was caught on a smooth shaft by some loose portion of his clothing. He had been expressly and personally forbidden to wear such clothing. It is possible to equip all shafts with bearings which render approach while the machinery is in motion wholly unnecessary.

Case 4.—A machinist who operated a planer was in the habit of using the open bed of his planer to store some of his tools. In spite of an order to the contrary he continued the practice. Finally, while reaching into the space, he slipped and fell in front of the moving platform and was fatally crushed. The expenditure of a few dollars would have closed the openings in the planer bed in such a manner that an accident of this kind would have been entirely impossible.

Such illustrations can be extended almost indefinitely. These particular cases have been chosen because the element of human imperfection is so perfectly clear. The tendency has been to dismiss such cases as soon as this was established or even reasonably suggested. The remedy was thought to be entirely obvious. Make more stringent rules and spur up the foremen regarding their enforcement. This is useful but superficial. In each case cited above there is an obvious engineering remedy. The constant presence of human fault must not be permitted to obscure the fundamental causes which can only be reached by the reformation of wrong conditions. In such obscurity, rules may multiply and men still die.

EXTENT OF ACCIDENT REDUCTION.

Summing up this survey, the following points deserve special emphasis:

The statement that "accidents can not be entirely prevented" rests to a considerable degree upon the conviction that accident occurrence is due in the main to the human factor. Since a perfect humanity is not yet in sight it is urged that results which demand perfection can not be expected. Accordingly the expression "an irreducible minimum" of accident occurrence has appeared from time to time.

If, as appears to be indicated by this study, the severity of accidents is influenced much more by engineering perfection than by human perfection the problem of cutting down the severity is quite different and much more solvable. Structures so strong, so well designed, their material so well selected that they can not fail, except so rarely that failure is negligible, are possible, at a price. It is not a question of possible attainment, but one of thought and time and money. Spend enough upon the engineering problems and serious and fatal accidents will be very largely eliminated.

What is the limit of reduction in severe and fatal cases? The possibilities of improvement in physical conditions are almost unlimited. It is possible to conceive industry conducted under conditions so safe that the occurrence of severe injury will excite the same surprise that its absence now does.

CHAPTER IX.

NATURE OF INJURY.

From the accident-prevention standpoint the subject of nature of injury is of much less importance than is that of cause of accident. Nevertheless, an analysis of the injuries according to their nature is not without value in accident-prevention work and especially so because protective devices must sometimes be placed upon the worker himself rather than upon the machine.

The proper classification of nature of injury has been a matter of considerable discussion. In the present study it has seemed that the most useful classification is one which makes the pathological condition (burns, crushing injuries, fractures, etc.) the basis and then subdivides according to the anatomical region affected—head, hands, etc.[1] If this is supplemented by information showing the resulting permanent injury, if any (such as loss of hand, loss of sight), a very complete picture of the nature of the injury is offered. Thus, a particular injury would be listed as follows: A crushing injury (pathological) to the hand (anatomical region) causes the ultimate loss of the hand (result).

The following table gives a general analysis of the nature of the injuries which occurred in a large number of iron and steel plants over a period of several years, and represents a total of 37,261 injuries occurring among a total of 207,803 300-day workers. A further analysis of these injuries, by anatomical region affected, is shown, on the basis of frequency rates, in Table 108, the amount of the material not being sufficient to justify a similar analysis on a basis of severity. For convenience of comparison there is added to the table the corresponding accident rates for the machine-building industry, taken from the recent report of the bureau on accidents and accident prevention in that industry.[2]

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[1] For classification adopted by the International Association of Accident Boards and Commissions, in May, 1916, see Bulletin of U. S. Bureau of Labor Statistics, No. 201. The tabulation of the present report had progressed too far to permit the application to it of this classification. The two systems, however, are not very different.

[2] Bulletin No. 216, U. S. Bureau of Labor Statistics.

TABLE 65.—NATURE OF INJURY IN THE IRON AND STEEL INDUSTRY AND IN MACHINE BUILDING FOR THE PERIOD 1905 TO 1914.

[Number of 300-day workers included: Iron and steel, 207,803; machine building, 179,956.]

Nature of injury.	Iron and steel industry.				Machine builders.	
	Total cases.	Total days lost.	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).
Asphyxia	138	146,070	0.7	0.7	....	....
Bruises, cuts, and lacerations	22,168	359,023	106.7	1.7	51.4	1.3
Burns	3,810	564,088	18.3	2.7	4.2	.7
Crushing injuries	1,083	1,364,405	5.2	6.6	3.0	2.1
Dislocations and sprains	2,454	33,220	11.8	.2	4.8	.1
Electric shock	9	80,936	(1)	.4	....	....
Eye injuries	3,698	136,261	17.8	.7	8.3	.4
Fractures	2,537	823,150	12.2	4.0	6.2	1.4
Heat prostration	136	38,476	.6	.2	....	....
Infections	990	43,592	4.8	.2	....	....
Unclassified	238	194,528	1.1	.9	1.3	.9
Total	37,261	3,783,749	179.3	18.2	78.9	6.7

1 Less than 0.05.

It will be noted from this table that the frequency of particular kinds of injuries affords no measure of the severity of such injuries. Thus, in the iron and steel industry, "bruises, cuts, and lacerations" show by far the highest frequency rate (106.7 cases per 1,000 300-day workers) but have a relatively low severity rate (1.7 days lost per worker), whereas "crushing injuries," with a low frequency rate (5.2 cases) have the highest severity rate (6.6 days).

NATURE OF INJURY, BY DEPARTMENTS.

Further analysis of nature of injury, and one of greater practical usefulness, is made in the next table, which shows frequency and severity rates by departments. The rates given are based, in every case, upon the amount of employment in the particular department.

Table 108 in Appendix H shows in greater detail the frequency rates for these departments, by nature of injury.

TABLE 66.—FREQUENCY AND SEVERITY OF ACCIDENTS, BY NATURE OF INJURY AND BY DEPARTMENTS.

Nature of injury.	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
	ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS).										
Asphyxia	4.8	0.3	0.7			0.2	0.2			0.8	0.3
Bruises, cuts, and lacerations	88.9	104.4	136.2	85.0	102.9	91.6	153.4	78.0	168.9	116.7	97.3
Burns	44.6	38.1	50.3	17.7	15.3	9.4	14.6	8.1	4.0	9.8	6.1
Crushing injuries	4.8	6.5	7.1	6.5	4.3	4.3	6.0	7.2	5.8	2.3	4.5
Dislocations and sprains	11.1	11.0	21.3	6.2	13.6	10.5	17.8	6.7	12.6	14.2	12.9
Electric shock	.1					.1	.1				.1
Eye injuries	16.5	12.6	27.6	32.5	22.1	11.6	13.0	3.4	38.8	27.9	10.7
Fractures	10.2	12.8	13.5	9.1	6.2	11.7	13.3	6.0	35.2	9.8	10.1
Heat prostration	.1	1.5	.1	.2	.4	.3	1.6	1.6	.6	.1	.2
Infections	8.0	4.7	7.1	2.3	15.0	3.5	5.2	.6	.7	4.4	3.7
Unclassified injuries	1.6	.8	1.8	.8	2.0	.9	1.0	.7	1.5	1.4	1.0
Total	190.5	192.8	265.7	160.3	181.8	144.1	226.3	112.4	268.2	187.5	147.3
	ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).										
Asphyxia	6.98	0.38	0.01			(1)	(1)			(1)	(1)
Bruises, cuts, and lacerations	2.41	1.12	1.96	1.71	1.75	2.04	2.47	0.83	1.22	1.71	2.15
Burns	9.61	6.36	10.44	1.78	.32	1.36	1.14	.10	.64	1.08	.61
Crushing injuries	10.72	7.64	7.95	6.15	3.94	2.59	7.75	8.54	12.62	2.91	6.90
Dislocations and sprains	.18	.11	.26	.06	.22	.12	.18	.12	.10	.22	.31
Electric shock	.46					1.20	.63				.97
Eye injuries	1.15	.89	1.13	.70	.33	.63	.36	.09	.92	.97	.23
Fractures	8.70	3.13	9.43	.81	2.48	3.68	.60	.76	3.85	6.31	6.07
Heat prostrations	(1)	.42	(1)	(1)	.01	(1)	.63	.93	(1)	(1)	(1)
Infections	.60	.40	.12	.05	.28	.28	.05	.04	.01	.11	.07
Unclassified	2.35	.39	1.26	.03	.66	.74	.02	.02	.60	3.27	1.00
Total	43.17	20.84	32.56	11.29	9.98	12.65	14.13	11.43	19.38	16.59	18.33
Number of 300-day workers	*19,425*	*26,011*	*7,329*	*15,710*	*16,443*	*37,464*	*14,346*	*19,498*	*16,164*	*19,384*	*18,481*

[1] Less than 0.005.

The most noteworthy facts brought out in this table may best be shown by a brief discussion of each of the more important classes of injury as listed. Attention will be limited, for the most part, to the severity rates, as given in the second part of the table, inasmuch as severity rates are a much truer measure of hazard than are frequency rates.

Asphyxia, as will be noted, is a serious matter only in blast furnaces. The remedy, as has been pointed out in the discussion of accident causes in blast furnaces, lies in engineering reconstruction and in the adoption of respiration apparatus where applicable.

Bruises, cuts, and lacerations show greatest severity in blast furnaces (2.41 days lost per worker), blooming mills (2.04 days), plate mills (2.47 days), and yards (2.15 days). The great majority of these injuries occur to the feet and hands of the workers [1] and are evidently reducible by better training and equipment of the men and by the development of improved methods of handling, especially the substitution of mechanical for manual means. A striking example is found

[1] See Table 108.

in some plate mills where magnets were introduced for moving plates which had before been manipulated by hand. The highest frequency of bruises to the hands is naturally in fabricating shops where the tools used and the material handled conduce to this result. The introduction of improved apparatus, such as the electric reamer, affects this hazard favorably.

Burns have greatest severity (10.44 days per worker) in the Bessemer department. This arises, no doubt, from the frequency of injuries due to hot metal (49.5 cases per 1,000 workers). In the operation of the Bessemer converter the "blow" throws out particles of metal which are at times capable of causing disabling burns. The emptying of slag into cars or on the pit floor adds to the danger. Proper clothing and eye protection are large factors in reducing these hazards. Blast furnaces (9.61 days) and open hearths (6.36 days) have the next highest severity in injuries from burns. Here the hazards are of similar character and the same remedies are applicable as in the Bessemer department.

Crushing injuries show the greatest severity in the fabricating shops (12.62 days), followed by blast furnaces (10.72 days), sheet mills (8.54 days), Bessemer converters (7.95 days), plate mills (7.75 days), open hearths (7.64 days), and yards (6.90 days). The large number of such injuries is due mainly to injuries to the feet and hands. But their high severity rates are attributable to those injuries, comparatively few in number, which occur to the abdomen, chest, head, and legs, and which arise very largely in connection with the transportation problems of these departments. The very high severity shown for fabricating shops is not due so much to transportation proper as to shifting by cranes. The large girders and other articles which must constantly be moved afford many chances for injury. Crane construction, methods of operation, and particularly the care of chains, in the matter of safe loads and the substitution of cables, need close attention. The rate for yard operations, as above given, is probably too low, as not infrequently an injury due to yard operations is credited to some other department, because the man injured belongs to the force of that department.

Dislocation and sprains, while quite numerous, have such low severity rates as to call for little comment. The yards show the highest rate (0.31 day), followed closely by Bessemer converters (0.26 day), tube mills (0.22 day), and the mechanical department (0.22 day). It is very probable that plant cleanliness is here an important remedial measure, but the main stress must be laid upon the exercise of proper care on the part of the men.

Eye injuries do not show severity proportional to their number, but are of much importance in spite of that fact. This hazard is most serious in blast furnaces (1.15 days). Bessemer converters (1.13 days), mechanical departments (0.97 day), fabricating departments (0.92 day), and open hearths (0.89 day) follow in order.

Fractures, closely related to crushing injury and often difficult to distinguish separately, show very high severity rates. The highest occurs in the Bessemer department (9.43 days), followed by blast furnaces (8.70 days), mechanical departments (6.31 days), and yards (6.07 days). These departments doubtless owe their preeminence in this respect to the combination of transportation hazards with those due to their own departmental dangers. Mechanics suffer such accidents largely through their work on difficult repair jobs. Much can be done to modify this condition for the better by provision of better apparatus, such as ladders and trestles for temporary purposes. It is often necessary to employ makeshift devices, but they can be constructed of adequate strength and approved design, and can often be replaced by permanent adjustable apparatus of much greater safety.

Heat prostration shows severity rates of significance in only three departments—sheet mills (0.93 day), plate mills (0.63 day), and open hearths (0.42 day). This will appear as normal to those familiar with the conditions formerly prevalent in these departments. In sheet mills the heat hazard can be greatly reduced by the changes already introduced in the better plants. By the use of water-cooled floor plates or entire water-cooled floors in the vicinity of rolls and furnaces, a contributory cause of prostration can be removed. The installation of ventilating fans, so that a stream of air can be delivered both to relieve the men and to carry off surplus heat, is important. Most important is the provision of a supply of good drinking water properly cooled. The common symptom of heat exhaustion is violent cramps. These have often been attributed to drinking water of a too low temperature. It is doubtful if this is the real cause. The cramps are apparently due to a depletion of the watery element of the blood such as occurs in profuse perspiration, and having the drinking water too cold may lead to the use of an insufficient quantity, since the cold gives a mistaken sense of satisfaction. The water should be of such a temperature as to be agreeable and to encourage the drinking of a sufficient quantity to keep the blood of proper consistency. Where water must be cooled artificially, it is best accomplished by a refrigerating system by which the temperature can be properly regulated and from which the water can be forced around the circuit and delivered at all points at a uniform temperature. The lessening of heat prostration and improved health in other respects upon the introduction of such arrangements have been very marked.

Infections show fairly uniform frequency rates as between departments, but with much the higher severity rates in those departments where burns are frequent—blast furnaces having a severity rate of 0.60 day per worker from infections, and open hearths a rate of 0.40 day. This is because a burn often presents an extended surface liable to infection and proper protection is a matter of greater difficulty than it is in the case of a laceration or cut.

Since infections are almost entirely preventable if proper care is taken, special effort was made to study the frequency of such cases from year to year in order to determine whether they are decreasing at a more rapid rate than would result from the general decline in accident rates. The results are presented in the following table, which shows for five departments, over a period of years, the course of frequency rates for infected cases of injury in contrast with the rates for other cases of injury, all of which are, of course, potentially subject to infection. The data for blast furnaces were available as early as 1905; for the other departments, only from 1907.

TABLE 67.—ACCIDENT FREQUENCY RATES FOR INFECTED AND OTHER CASES OF INJURY IN FIVE DEPARTMENTS, BY YEARS.

Department.	Accident frequency rates (per 1,000 300-day workers).										Per cent of decrease from earliest year to 1914.
	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	
Blast furnaces:											
Infected cases	32.3	15.4	8.9	3.9	8.7	10.3	5.8	3.4	3.6	2.6	92
Other	392.3	315.8	295.1	218.2	178.3	176.7	121.2	121.2	87.5	72.4	82
Open hearths:											
Infected cases	(1)	(1)	7.7	3.3	7.7	4.8	6.2	4.0	5.0	2.4	69
Other	(1)	(1)	305.7	199.6	223.1	186.4	142.8	146.1	146.3	112.8	63
Rolling mills:											
Infected cases	(1)	(1)	3.3	2.2	5.7	4.3	1.7	2.3	2.6	1.4	58
Other	(1)	(1)	192.5	168.8	179.4	136.9	137.5	130.9	96.7	55.7	71
Tube mills:											
Infected cases	(1)	(1)	22.4	18.6	19.3	12.3	24.5	22.1	3.3	2.0	91
Other	(1)	(1)	266.6	129.5	235.1	216.0	199.7	146.3	75.3	43.2	84
Mechanical:											
Infected cases	(1)	(1)	4.7	7.4	5.6	7.6	1.9	3.0	1.2	1.8	62
Other	(1)	(1)	247.4	266.7	225.1	177.2	143.6	119.8	109.9	104.7	58

[1] Data not available.

The table indicates that improved care in the treatment of wounds has had a considerable effect upon the frequency of infection. In each department, except rolling mills, the decline in infected cases exceeds the decline in other cases. In blast furnaces, where it was possible to go back as far as 1905, the prevalence of infection in the early years is most striking. If the other departments could be followed to the same point somewhat similar conditions would probably be disclosed. It is extremely probable that the data for 1907 do not show the full frequency of infection in those other departments since the recording of infected cases was somewhat imperfect at that time.

The control of infection rests upon prompt reporting of infectable cases to the emergency room and upon adequate skill and equipment at that point. Emergency rooms and emergency methods of a character tending to spread infection rather than check it are still in use. In one large plant where special effort was being made to secure reports of all infectable cases, disabling accidents showed a constant decline in frequency, while at the same time nondisabling accidents showed a steadily increasing rate.[1] This was not due to an increasing number of nondisabling injuries occurring, but to the gradual response on the part of the work people to the urgent request that they have slight injuries properly treated. This fuller reporting of minor cases was accompanied by an equally steady reduction in infections.

The importance of this matter may be illustrated by the following experience. Some years ago a large steel plant was visited in which cases of serious injury were cared for by a local hospital. Two wards were assigned to the patients from the steel works. One ward had noninfected cases, the other had infected cases. At the time of the visit the ward for infected cases had the larger number of patients. This situation provoked inquiry. It was found that the company had provided emergency outfits throughout the works, had given training in their use to foremen of the different mills and shops, and that unless a man's condition became serious enough to call for hospital care, this emergency treatment was last aid as well as first aid. Later the company equipped an emergency hospital with physician and nurse. Infection dropped almost out of sight immediately.[2]

NATURE OF INJURY AND OCCUPATION.

Some very important conclusions are to be derived from a study of the relations between occupational groups and the nature of the injuries occurring therein. Accordingly, special effort was made to determine rates by occupations wherever the employment of an occupational group could be ascertained and was sufficiently large to permit the computation of reliable rates. In the present case, this was possible for the more important characteristic occupations of the blast furnaces, the open hearths, and the tube mills.

BLAST FURNACES.

Four occupational groups have been isolated in this department, namely, cast-house men, common labor, mechanics, and stocking labor. These cover the characteristic operations of the blast fur-

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1 See chart 13.

2 The introduction of the Carrel-Darkin methods of treating infectible and infected wounds should still further improve the situation.

nace. Their frequency rates, by nature of injury, are shown in the following table:

TABLE 68.—ACCIDENT FREQUENCY RATES IN BLAST FURNACES, BY NATURE OF INJURY AND OCCUPATION, 1905 TO 1914.

Nature of injury.	Frequency rates (cases per 1,000 300-day workers).					
	Cast-house men.	Common labor.	Mechanics.	Stocking labor.	Other occupations.	Total.
Asphyxia	4.4	6.5	5.2	3.4	7.3	6.6
Bruises, cuts, and lacerations:						
Of abdomen		.6	.8		.7	.6
Of arm or arms	7.4	5.5	3.8	1.1	2.3	4.3
Of trunk	4.4	9.9	6.8	5.6	5.0	7.2
Of foot or toes	30.2	31.6	13.1	38.4	11.3	22.6
Of hand or fingers	37.6	31.2	16.3	13.5	15.6	23.4
Of head or neck	18.4	26.6	9.5	10.2	9.3	16.4
Of leg or legs	15.5	15.2	7.6	13.5	5.3	11.0
Unclassified	4.4	4.9	4.4		2.0	3.8
Total	117.9	125.6	62.3	82.4	51.6	89.2
Burns:						
By electricity		.2	.5	2.3	2.7	.9
By gas	2.2	4.9	2.5	1.1	5.0	3.8
By hot metal	97.3	21.5	2.2	2.3	8.6	19.9
By hot water and steam	10.3	4.1	4.9	3.4	4.7	5.0
Unclassified	60.4	21.7	8.4	11.3	17.6	20.4
Total	170.2	52.3	18.5	20.3	38.9	50.0
Crushing injuries:						
Of abdomen			.3			.1
Of arm or arms						
Of trunk				1.1	.3	.1
Of foot or toes	1.5	.6	.5	1.1	.3	.6
Of hand or fingers	2.9	1.8	1.6		3.0	2.0
Of head			.3			.1
Of leg or legs		.2	.3			.1
Unclassified			.5	1.1		.2
Total	4.4	2.6	3.5	3.3	3.6	3.3
Dislocations and sprains:						
Of ankle	3.7	5.9	4.1	5.6	2.7	4.5
Of back	6.6	3.4	1.9		1.0	2.6
Of elbow		.2	.3		.3	.2
Of foot or toes		.2	.3	1.1		.2
Of hand or fingers		.8			.7	.4
Of knee	1.5	1.2	.5	2.8	1.3	1.2
Of shoulder	.7	.4	.3	1.1	.3	.4
Of wrist	3.7	2.8	1.4		1.0	1.9
Unclassified			.3			.1
Total	16.2	15.0	9.0	10.2	7.3	11.5
Electric shock		.2				.1
Eye injuries	34.6	24.3	15.0	7.9	11.3	18.8
Fractures:						
Of arm	.7	.8	1.1	3.4	1.3	1.2
Of both arms						
Of collar bone					1.0	.2
Of face	1.5	.2				.2
Of foot or toes	2.9	1.6	.8	2.3	2.0	1.7
Of hand or fingers	1.5	3.7	2.5	6.8	5.0	3.6
Of leg	.7	1.4	2.5	3.4	1.3	1.7
Of both legs		.2				.1
Of pelvis						
Of ribs		.6	.5	2.3	.3	.6
Of skull	1.5	1.0	1.4	2.3	2.3	1.5
Unclassified	1.5		.3		.3	.1
Total	10.0	9.3	9.0	20.3	13.6	10.9
Heat exhaustion	.7					.1
Infections	20.6	13.2	3.8	6.8	4.3	9.1
Unclassified	1.5	1.4	1.6	2.2	2.0	1.7
Grand total	380.3	250.5	128.1	156.9	139.1	200.6
Number of 300-day workers	*1,357*	*4,930*	*3,670*	*886*	*3,006*	*13,849*

Contrary to experience elsewhere the common labor here does not have the highest frequency. The cast house men (with a frequency rate of 380.3 cases per 1,000 workers) considerably exceed common laborers (with a rate of 250.5 cases). Upon consideration of details it becomes evident that this excess is due largely to burns and to infections which, as has been pointed out, are very apt to arise in cases of burning. Cast house men show a frequency rate of 170.2 cases per 1,000 workers in burns against 52.3 cases for common labor. Hot metal (cast house 97.3, laborers 21.5) naturally furnishes the major share of the burns.

Considering the items of the classification in order, the following points are especially to be noted:

Asphyxia most frequently affects men in the unclassified group. This arises from the exposure of stove tenders, gas washers, and others who, while characteristic blast furnace workers, are not numerous enough to justify separate treatment. Common labor (6.5 cases per 1,000 workers) has the next highest rate, followed in order by mechanics (5.2 cases), cast house men (4.4 cases), and stockers (3.4 cases). The most impressive thing in this connection is that all classes of workers are evidently subject to the hazard of asphyxiation. Since it is known that death often results, the importance of using all the preventive measures earlier suggested receives a new emphasis.

Under "bruises, cuts, and lacerations," it may be noted that common labor has the highest rate (125.6 cases per 1,000 workers), with cast house men a close second (117.9 cases). With the exception of burns (170.2) among cast house men, the rates for bruises, cuts, and lacerations are markedly higher in each occupational group than for any other kind of injury. Naturally the hands and feet suffer most in all occupational groups. This suggests the importance of well-designed shoes and hand protectors. In one large plant shoes with a stout and rigid box over the toes and hand leathers of a standard pattern with handy and durable fastenings exercised a remarkable influence upon the seriousness of foot and hand injuries.

Cast house men suffer crushing injuries more frequently (4.4 cases) than other occupations. In injuries involving crushing of the hand or fingers cast house men (2.9 cases) are exceeded slightly by the unclassified workers (3.0 cases). This is due to the fact that the latter group include switchmen who have the coupling and uncoupling of cars.

In dislocations and sprains cast house men (16.2 cases) and common labor (15.0 cases) differ but little in the frequency of their injuries. Back and wrist suffer most. This is due to heavy lifting, which is required often in both occupations. The substitution of magnets in the handling of pig iron has reduced such injuries among laborers and in addition has done away with a very laborious process.

Eye injuries are frequent in all of the occupations listed, cast house men leading with a rate of 34.6 cases per 1,000 workers, and laborers coming second with a rate of 24.3 cases. As repeatedly indicated, this type of injury can and should be nearly eliminated.

Fractures bring another occupational group into prominence—the stockers with a frequency rate of 20.3 cases per 1,000 workers. These are followed by cast house men with a rate of 10.0 cases, laborers with a rate of 9.3 cases, and mechanics with a rate of 9.0 cases. The prevalence of this form of injury among stockers is due to their work on the ore piles, bins, and trestles which serve to hold and handle the raw material. The great improvements of recent years in these structures have had a very important effect upon the reduction of accidents.

OPEN HEARTHS.

For the open hearth department, four occupational groups were separated from the total—common labor, pit side furnace workers, pouring platform workers, and stocking floor workers. The following table shows the frequency rates for these occupations by nature of injury:

TABLE 69.—ACCIDENT FREQUENCY RATES IN OPEN HEARTHS, BY NATURE OF INJURY AND OCCUPATION, 1907 TO 1914.

Nature of injury.	Frequency rates (cases per 1,000 300-day workers).					
	Common labor.	Pit side furnaces.	Pouring platform.	Stocking floor.	Not classified.	Total.
Asphyxia	0.6			0.3	0.7	0.4
Bruises, cuts, and lacerations:						
Of abdomen	1.6			.5	1.1	.7
Of arm or arms	11.5	1.8	1.0	2.8	4.1	4.5
Of trunk	14.2	1.8	3.1	2.8	4.3	5.2
Of foot or toes	70.1	7.8	5.2	13.4	17.2	23.9
Of hand or fingers	117.9	12.9	5.2	19.1	32.1	39.6
Of head or neck	51.1	8.2	3.1	5.8	10.9	16.4
Of leg or legs	22.5	3.5	3.1	6.7	8.5	9.4
Unclassified	10.3	1.5	1.0	2.4	3.9	4.0
Total	299.3	37.5	22.0	53.6	82.1	103.8
Burns:						
By electricity	1.0			.4	2.2	.8
By gas	6.4	.3	1.0	3.6	6.3	4.0
By hot metal	23.1	23.7	26.2	18.9	20.2	21.4
By hot water and steam	5.2	1.3		.1	2.6	1.9
Unclassified	16.5	11.5	2.1	7.7	8.0	10.1
Total	52.2	36.9	29.3	30.7	39.3	38.2
Crushing injuries:						
Of abdomen	.4				.6	.2
Of arm or arms	.2					(1)
Of trunk	.8	.2		.3	.4	.4
Of foot or toes	2.5	.4	1.0	.8	2.4	1.4
Of hand or fingers	7.6	1.5		2.1	5.0	3.6
Of head						
Of leg or legs	.2			.5	.9	.4
Unclassified						
Total	11.8	2.0	1.0	3.6	9.3	6.0

1 Less than 0.05.

TABLE 69.—ACCIDENT FREQUENCY RATES IN OPEN HEARTHS, BY NATURE OF INJURY AND OCCUPATION, 1907 TO 1914—Concluded.

Nature of injury.	Frequency rates (cases per 1,000 300-day workers).					
	Common labor.	Pit side furnaces.	Pouring platform.	Stocking floor.	Not classified.	Total.
Dislocations and sprains:						
Of ankle	6.8	2.0	1.0	1.7	5.0	3.5
Of back	6.8	2.2	....	4.5	3.2	4.0
Of elbow	.4	....	....	.5	.2	.3
Of foot or toes	.8	.4	....	.4	.9	.6
Of hand or fingers	.8	.2	....	.3	.2	.3
Of knee	1.4	.2	....	.5	.6	.6
Of shoulder	.2	.5	....	.5	.2	.4
Of wrist	2.3	1.5	....	.4	1.5	1.2
Unclassified	.2	.2	....	.3	....	.2
Total	19.7	7.1	1.0	9.0	11.7	11.0
Electric shock	....	....	....	....	....	....
Eye injuries	34.4	3.5	11.5	7.7	10.9	12.9
Fractures:						
Of arm	1.9	.5	2.1	.4	1.9	1.1
Of both arms	....	....	....	....	....	....
Of collar bone	.6	....	1.0	.1	.6	.3
Of face	.4	.5	....	.1	.2	.3
Of foot or toes	8.2	.9	1.0	2.2	3.9	3.4
Of hand or fingers	9.9	1.5	1.0	1.5	6.1	4.2
Of leg	5.4	.7	....	.3	2.6	1.9
Of both legs	....	.2	....	....	.2	.1
Of pelvis	.2	....	1.0	.1	....	.1
Of ribs	2.5	.2	1.0	.3	.6	.8
Of skull	.8	.7	....	....	.9	.5
Unclassified	.4	....	....	....	....	.1
Total	30.3	5.3	7.3	5.0	16.9	12.8
Heat exhaustion	3.3	.5	....	1.3	1.9	1.6
Infections	14.4	1.6	2.1	3.0	3.0	4.9
Unclassified	1.6	.2	1.0	.6	.7	.7
Grand total	467.7	94.7	75.4	114.9	176.5	192.4
Number of 300-day workers	*4,851*	*5,492*	*954*	*7,761*	*5,395*	*24,453*

In this table common labor resumes its usual position as the occupation having the highest frequency rate—467.7 cases per 1,000 workers.

Asphyxia is, as regards frequency, of slight importance, but the fact that fatal cases do occur from time to time about open hearths makes it a factor to be considered. It usually occurs in some more or less confined space where workmen at times have occasion to go. It would probably be difficult if not impossible to apply any ventilating devices which would insure that the harmful gas would not stagnate in such places, though sometimes this would be a simple and effective practice. Thorough instruction of the men regarding the danger, and very careful study of the plant to determine places where accumulation might occur, must be the foundation of prevention. When the men know the danger and the safety department knows where it is likely to arise, suitable warnings can be posted.

Bruises, cuts, and lacerations, especially to feet and hands, predominate very greatly among laborers.

Burns are more evenly distributed among the occupations, those from hot metal being of almost uniform frequency among the groups. The pouring platform has the highest rate (26.2 cases per 1,000 workmen), but it is doubtful if it involves as great severity as some of the other occupations.

Crushing injuries are relatively most frequent among laborers (11.8 cases per 1,000 workers). As has been pointed out, this is undoubtedly connected with transportation problems which actually invade the mill in the open hearths more than in any other department. Only close and studious attention to transportation methods can possibly modify this hazard in a really material way.

Dislocations and sprains are not a monopoly of the common laborer, but his frequency rates for these injuries (19.7 cases) exceed the corresponding rates for the other occupations. In blast furnaces it was noted that the back and wrist suffered most from dislocations and sprains; in the open hearths the back shows the highest rate (4 cases), with the ankle second (3.5 cases), and the wrist third (1.2 cases); and in each of these instances the common laborer is the chief sufferer. The workers on the stocking floor are also particularly liable to injuries of this kind.

In eye injuries the common laborer has much the highest frequency rate—34.4 cases per 1,000 workers as against 11.5 cases on the pouring platform.

The frequency of leg fractures (5.4 cases per 1,000 workers) among laborers is important, inasmuch as such injuries are always very serious.

The entire table bears witness to the fact that the unskilled and inexperienced man bears the brunt of industrial hazard. Since this is true, too great emphasis can not be placed on the obligation to save him wherever possible and to give him adequate relief when misfortune overtakes him. Carelessness is a very undescriptive term for the untrained and ignorant. The word implies that he might take care if he really wished to. This is very far from the truth. He does the best that he can. His will is good, but with the equipment given him by industrial methods he has hitherto been entirely unable to escape the swarm of dangers around him. If safety effort does not bring better conditions to common labor, it must be regarded as a dismal failure. The situation is improving, but not so fast nor so thoroughly as it should.

TUBE MILLS.

For the tube mills it has been possible to distinguish three occupational groups—the finishing crew, furnace crew, and common labor. The following table shows the frequency rates for these occupations by nature of injury.

TABLE 70.—ACCIDENT FREQUENCY RATES IN TUBE MILLS, BY NATURE OF INJURY AND OCCUPATION, 1907 TO 1914.

Nature of injury.	Frequency rates (cases per 1,000 300-day workers).				
	Finishing crew.	Furnace crew.	Common labor.	Other occupations.	Total.
Asphyxia					
Bruises, cuts, and lacerations:					
Of abdomen		0.3	2.8	0.6	0.7
Of arm or arms	1.2	.7	17.8	5.1	5.0
Of trunk	.5	.3	11.7	2.9	3.0
Of foot or toes	4.9	4.2	86.5	18.9	21.7
By hand or fingers	20.4	9.8	197.8	50.0	54.8
Of head or neck	1.5	1.6	46.5	7.8	10.4
Of leg or legs	1.7	4.6	34.8	5.7	8.6
Unclassified	.5	1.0	8.5	2.9	2.6
Total	30.7	22.5	406.4	93.8	106.8
Burns:					
By electricity	.2	.3	4.2	1.7	1.4
By gas			2.3	1.7	1.0
By hot metal		10.4	44.6	6.3	11.0
By hot water and steam		.3	5.2	1.0	1.2
Unclassified		.7	3.8	1.1	1.1
Total	.2	11.7	60.2	11.8	15.6
Crushing injuries:					
Of abdomen					
Of arm or arms				.2	.1
Of trunk	1.0				
Of foot or toes	.2	.7	1.4	1.0	.8
Of hand or fingers		1.3	8.9	3.1	3.0
Of head				.2	.1
Of leg or legs			.9		.1
Unclassified			.9	.4	.3
Total	1.2	2.0	12.2	4.8	4.3
Dislocations and sprains:					
Of ankle	.7	1.6	10.3	5.0	3.9
Of back	1.2		11.7	4.2	3.6
Of elbow	.5	.3	.9	.6	.6
Of foot or toes			1.4	.2	.3
Of hand or fingers	.5	.3	2.3	1.7	1.2
Of knee	.2		3.3	.6	.8
Of shoulder			1.4	1.1	.6
Of wrist	1.0	1.3	7.5	3.6	3.0
Unclassified		.7	2.3	.8	.8
Total	4.1	4.2	41.4	17.7	14.5
Electric shock					
Eye injuries	17.5	11.1	63.0	19.3	23.5
Fractures:					
Of arm	.2		1.4		.3
Of both arms					
Of collar bone					
Of face		.3			.1
Of foot or toes	1.2		5.2	1.7	1.7
Of hand or fingers	.2	1.0	5.6	3.1	2.2
Of leg			2.3	.4	.5
Of both legs					
Of pelvis			.5	.2	.1
Of ribs			.9	1.0	.5
Of skull			1.9	.8	.6
Unclassified					
Total	1.7	1.3	18.0	7.1	5.9
Heat exhaustion		1.0	1.4	.2	.5
Infections	4.9	6.5	55.0	15.0	15.5
Unclassified	.7		1.9	3.2	2.3
Grand total	61.0	60.3	659.3	172.9	188.8
Number of 300-day workers	*4,110*	*3,066*	*2,128*	*5,235*	*14,539*

The above table adds further emphasis to what has just been said regarding the hazards of the common laborer. His frequency rate in the tube mills is no less than 659.3 cases per 1,000 workers as against 61.0 cases for the finishing crew and 60.3 cases for the furnace crew.

It is not yet possible to follow adequately the laborer's experience from year to year. When this can be done it will appear that he has shared in the general downward movement of accident rates, but not to the extent of his skilled associates. Needing it more, he has received it less. No blame attaches to safety men or employers that this is so. Common labor is a difficult problem from other standpoints than this. When what has been accomplished in accident prevention is considered, the further radical improvement of his condition should not be regarded as impossible.

In the frequency of bruises, cuts, and lacerations, as shown by the table, laborers are very far in the lead—406.4 cases per 1,000 workers. Of this total rate, no less than 197.8 is found in injuries to the hands and 86.5 to the feet. Better methods in handling, better hand protectors, and better shoes are the points worth much study.

In burns, while laborers also have the highest frequency rate (60.2 cases), a rather high rate occurs among the furnace crews (11.7). These skilled men are associated directly with the operation of the furnaces where the hot material is coming and going constantly, yet they suffer less than laborers who have the moving of hot pipe after the formative operations are completed.

High frequency among laborers of dislocations and sprains (particularly of the back and ankle), fractures, and infections are other interesting facts brought out in this table.

USE OF HOSPITAL RECORDS.

The study of the nature of injury necessarily involves consideration of the hospital records of the accident cases treated. These records, as contained in the original memoranda of the surgeon in charge, are usually quite full, and it becomes a question as to the extent to which it is profitable to subject them to tabulation and analysis. A few of the important conclusions which may be derived from such analysis may be considered briefly in this place.

THE MORE RAPID DECLINE OF SHORT-TERM DISABILITIES.

In the first report on accidents in the iron and steel industry the fact was brought out that minor disabilities were decreasing more rapidly than the more serious disabilities. The accuracy of the figures is confirmed by the much greater amount of material accumulated for the present report. It was found that, for a large group of plants, frequency rates for temporary disabilities declined 33 per cent from 1910 to 1914 while severity rates declined only 28 per cent.[1]

[1] These data are given in detail in Table 71.

This can be explained only on the ground that the short-term disabilities were decreasing more rapidly than those of longer duration. As illustrating the same point, it may also be noted that the severity rates for cases terminating from the first to the fifth week declined 32 per cent during the same period, 1910 to 1914, while the severity rates for cases terminating in the sixth and later weeks showed only a 20 per cent decline. This difference in rate of decline indicates directly the more rapid elimination of minor injuries.

AVERAGE TIME LOST IS NOT A MEASURE OF PROGRESS.

Some safety men have endeavored to draw conclusions regarding their progress from the changes in lost time per accident. If the time loss per accident was decreasing it was thought to indicate improvement.

A very striking illustration of the essential unsoundness of this conclusion is furnished by the fact that as safety activity has increased loss per accident has steadily increased, and by the fact that loss per accident in plants having at the present time the lowest rates may be as much as 22 days per accident while in plants having a high rate it may be about 14 days.[1]

DISTRIBUTION OF ACCIDENT CASES DURING THE FIRST WEEK.

It has sometimes been assumed that recoveries in the first week should have a distribution similar to that found in successive weeks. For example, of 232,909 cases tabulated, 52 per cent returned to work in 7 days or less, 22 per cent in from 8 to 14 days. Observing this distribution, it has been argued that those returning after 1 day of disability should outnumber those returning after 2 days. This, however, is not what actually occurs. Study of 22,829 cases having 1 to 7 days disability disclosed the fact that 13 per cent had 1 day disability, 18 per cent 2 days, 18 per cent 3 days, 15 per cent 4 days, 14 per cent 5 days, 12 per cent 6 days, and 10 per cent 7 days. That is to say, disabilities for each of the periods 2 to 5 days were in excess of those for 1 day.

There is a perfectly sound surgical reason for this distribution. A great number of the injuries are cuts and lacerations which must have from two days upward to heal sufficiently to permit the return of the men to work. These cases which from the nature of the injury can not return under two days properly increase the percentages as far as the fifth day.

CARE OF THE INJURY.

The development of medical and surgical care is not always given its full due as a safety factor. Ultimately it must come to exercise a more important influence than it does now. Medical advice before

[1] No new studies have been made on loss per accident in connection with the preparation of this report. For earlier study of this subject by the Bureau, see Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, pp. 52, et seq.

encountering the danger will become the rule and much liability to serious disability will be removed by proper treatment of the injury immediately upon its occurrence. No attempt is made in this report to discuss with fullness the subject of hospital conditions and medical care. It is intended merely to touch upon a few points which relate to recent progress in this field.

The most important step of recent years undoubtedly has been the relegation of first-aid appliances to their proper place. The misfortune of first-aid instruction and installation has been in giving the idea that it was ever safely final. Kept strictly to its legitimate sphere, great good can be accomplished and much suffering avoided. But it should never be assumed that it can take the place of nurse and physician.

A second striking improvement has been in the means and methods of getting the injured man from the point at which he was injured to the dispensary or hospital. A number of instances are on record when life has been saved by the possibility of prompt and careful movement supplied by the improved ambulance service.

The place to which a patient is removed has no small importance. Special emergency rooms with proper equipment are gradually becoming universal in the industry. The possibilities of surgical cleanliness thereby afforded are of the highest importance in saving from infection and bringing about rapid recovery.

There is a growing tendency not to rely upon those having only the training of a nurse but to insist upon the wider knowledge and greater skill of a fully equipped physician. There can be no doubt that the lessened death rate of recent years is in considerable measure due to this fact.

The problem of adequate care must be worked out for each company according to local circumstances. But, especially with the advent of accident compensation laws, it would appear advantageous that the large companies should provide their own hospital accommodations.

A most serious need of most plants at the present time is a closer and more cordial cooperation of three agencies—the employment department, the safety department, and the medical staff. If accident prevention is to progress still further, a program of cooperative effort between these departments is seriously needed. Nowhere has complete cooperation to the full extent of the possibilities been observed, and in some instances a condition of "armed neutrality" has been very evident.

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CHAPTER X.

PROGRESS OF SAFETY MOVEMENT IN IRON AND STEEL INDUSTRY.

The present report carries the accident history of the iron and steel industry back to the year 1907—back, that is to say, to the infancy of the safety movement. Before that time some plants had begun to devote serious thought to preventive work, but the number was small and their efforts were not very effective. There was no such thing as safety engineering and no such thing as what is now called the organized safety movement.

In the years since 1907 a great change has taken place. A widespread organized safety movement has come into existence. Almost every steel plant is engaged in serious preventive work. The safety engineer and the safety man have established themselves as members of a recognized profession.

These activities have met with different degrees of success in different plants. But in practically every one there has been some measure of success, and the accident rates for the combined industry show a vacillating but definite progress downwards. This downward movement is still under way, and there is no reason why it should not continue. Indeed, as has been pointed out earlier (Chapter VIII), safety men must compromise on no lesser goal than the elimination of all serious accidents.

The course of the safety movement from 1907 to 1914 will be traced in this chapter. The whole body of material accumulated for this report is available for such a review. This material falls into the two general groups listed below:

First. Detailed data regarding employment and accidents from over 400 plants, employing about 90 per cent of all the workers in the industry and including every important steel plant in the country, with three exceptions. The data cover a period of five years, from 1910 to 1914. The number of 300-day workers concerned ranges from 202,157 to 319,919 per year, and the total number of accident cases for all five years was 232,909.

Second. Similar data for 6 important plants for the 8 years from 1907 to 1914. This special compilation was made in order to carry the yearly comparisons of accident experience back to the beginning of the safety movement. It was impracticable to do this for all of the 400-odd plants referred to above, but the 6 for which such a course was possible represented an annual employment of from 19,481 to 29,766 300-day workers and were, as regards operative activities, entirely typical of the industry.

ACCIDENT RATES OVER A SERIES OF YEARS.

The following table shows the number of 300-day workers, the number of accident cases, and the resulting accident rates for the iron and steel industry in each of the years for which data were obtained. The first part of the table covers the experience of the industry as a whole from 1910 to 1914; the second part covers the experience of the special group of 6 plants from which information was obtainable as early as 1907. The accompanying chart (chart 18) reproduces the data of the table in graphic form.

CHART 18.—ACCIDENT RATES IN THE IRON AND STEEL INDUSTRY OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

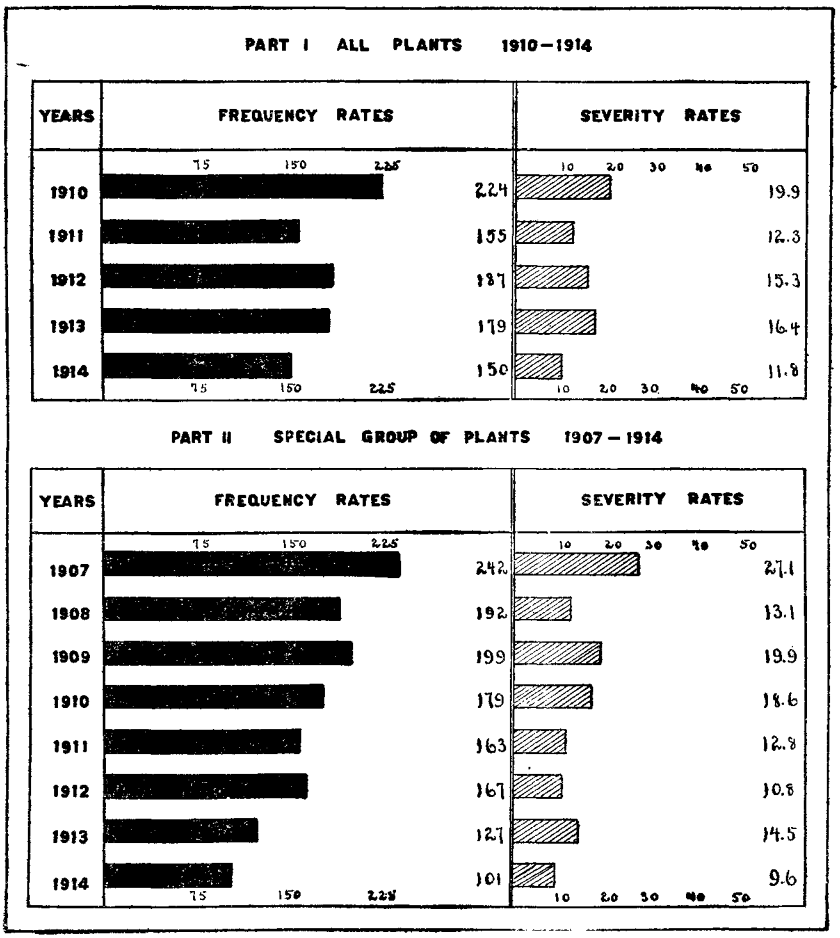


TABLE 71.—ACCIDENT RATES OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Number of cases.				Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	202,157	327	848	44,108	45,283	1.6	4.2	218.2	224.0	14.6	2.9	2.5	19.9
1911	231,544	204	931	34,676	35,811	.9	4.0	149.8	154.7	7.9	2.5	1.9	12.3
1912	300,992	348	1,241	54,575	56,164	1.2	4.1	181.3	186.6	10.4	2.6	2.3	15.3
1913	319,919	426	1,200	55,556	57,182	1.3	3.8	173.7	178.7	12.0	2.2	2.2	16.4
1914	256,299	219	860	37,390	38,869	.9	3.4	145.9	150.1	7.7	2.2	1.8	11.8
Total.	1,310,911	1,524	5,080	226,305	232,909	1.2	3.9	172.6	177.7	10.5	2.5	2.1	15.1

PART II.—SPECIAL GROUP OF 6 PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	27,632	61	106	6,530	6,697	2.2	3.8	236.3	242.4	19.9	4.0	3.2	27.1
1908	19,481	18	67	3,656	3,741	.9	3.4	187.7	192.0	8.3	2.2	2.6	13.1
1909	24,543	43	79	4,757	4,879	1.8	3.2	193.8	198.8	15.8	1.4	2.7	19.9
1910	27,144	42	124	4,691	4,857	1.5	4.6	172.8	178.9	13.9	2.1	2.6	18.6
1911	24,519	24	68	3,901	3,993	1.0	2.8	159.1	162.8	8.8	1.6	2.4	12.8
1912	28,922	19	126	4,685	4,830	.7	4.4	162.0	167.0	5.9	2.5	2.4	10.8
1913	29,766	37	93	3,646	3,776	1.2	3.1	122.5	126.9	11.1	1.4	2.0	14.5
1914	20,241	13	81	1,957	2,051	.6	4.0	97.7	101.3	5.8	2.1	1.7	9.6
Total.	202,248	257	744	33,823	34,824	1.3	3.7	167.2	172.1	11.4	2.2	2.5	16.1

The accident rates, as here presented, despite certain irregularities, show a marked tendency to decline over the period 1910 to 1914, and even more so over the longer period 1907 to 1914. This is clearly brought out in the chart, although the small scale on which the chart is necessarily drawn makes the tendency appear less emphatic than it really is.

The frequency rates decline for the industry as a whole from 224.0 cases per 1,000 full-time workers in 1910 to 150.1 in 1914. In the special group of plants the decline during the same period is from 178.9 to 101.3 cases per 1,000 workers, and for the longer period, 1907 to 1914, it is from 242.4 to 101.3. Similarly, the severity rates for the whole industry decreased from 19.9 days per worker in 1910 to 11.8 days in 1914, and for the special group of plants during the same period from 18.6 days to 9.6 days. A reduction in severity rates of almost one-half during a period of 5 years is a matter of much significance. That the reduction in rates is more marked in the special group of 6 plants than in all plants combined is traceable to the fact that the 6 plants, with records running back to 1907, are all of larger size, and the accident prevention movement began with the larger organizations.

The fact that the rates show considerable fluctuations, with such a marked upward movement as occurs in 1913, does not nullify in any way the gain made during the whole course of the period covered. The increases were apparently only temporary, due to the intensified industrial activity of particular years. The speeding up of production almost invariably results in increased accident rates.[1]

Special attention should be called to the fact, indicated in the above tables, that the lessened severity rate of recent years is very largely due to a decrease in the fatality rate. This is very significant. The importance of cutting down the minor disabilities must be constantly insisted upon, but the real success of safety efforts must be judged ultimately by their influence in reducing the more serious injuries.

ACCIDENT RATES ACCORDING TO RESULTS OF INJURY OVER A SERIES OF YEARS.

In the preceding section it was noted that the general downward tendency in the accident rates of the iron and steel industry was particularly well marked in the case of fatal injuries. But it is also of interest to note that the improvement was fairly regular for all kinds of injuries as measured by their results. This is brought out in Tables 72 and 73, which classify injuries according to results and show the accident rates for each class. Table 72 applies to the whole industry for the 5-year period, 1910 to 1914, and gives both frequency and severity rates.

Accident frequency rates by results of injury are shown for individual departments in Table 109.

TABLE 72.—ACCIDENT RATES, BY RESULTS OF INJURY, ALL PLANTS, 1910 TO 1914.

Result of injury.	Accident frequency rates (per 1,000 300-day workers).						Accident severity rates (days lost per 300-day worker).					
	1910	1911	1912	1913	1914	Total.	1910	1911	1912	1913	1914	Total.
Death	1.62	0.88	1.16	1.33	0.85	1.16	14.56	7.93	10.41	11.98	7.96	10.46
Permanent disability:												
Loss of—												
Great toe	.10	.10	.08	.09	.07	.09	.034	.032	.027	.031	.023	.029
1 joint great toe	.03	.06	.04	.05	.04	.05	.005	.011	.007	.009	.007	.008
Other toe or toes	.08	.16	.12	.16	.09	.12	.012	.022	.017	.023	.012	.018
1 joint other toe or toes	.02	.05	.07	.09	.07	.06	.001	.004	.005	.007	.005	.005
Foot	.10	.06	.14	.08	.10	.10	.183	.127	.257	.144	.187	.182
Both feet	(2)	......	(2)	......	(2)	(2)	.052	......	.035	......	.041	.024
Leg	.17	.07	.08	.05	.05	.08	.449	.190	.215	.138	.121	.210
Both legs	(2)	......	......	......	(2)	(2)	.052	......	......	......	.041	.016
Thumb	.07	.12	.12	.15	.07	.11	.040	.065	.065	.081	.038	.060
1 joint thumb	.22	.22	.20	.19	.21	.21	.059	.058	.055	.052	.056	.056
1 joint finger or fingers	1.18	1.16	1.02	1.06	.92	1.06	.186	.184	.161	.167	.145	.167
1st finger	.73	.41	.40	.29	.26	.40	.303	.170	.164	.120	.108	.165
2d finger	.17	.16	.22	.18	.13	.18	.045	.044	.060	.049	.035	.047
3d finger	.07	.12	.19	.14	.12	.13	.017	.026	.042	.031	.027	.030
4th finger	.10	.12	.19	.17	.13	.15	.014	.016	.026	.023	.017	.020
Hand	.08	.10	.05	.08	.07	.08	.174	.228	.117	.185	.146	.168
Both hands	......	(2)	......	......	......	(2)	......	.045	......	......	......	.008
Arm	.06	.04	.07	.05	.03	.05	.167	.109	.205	.140	.077	.134
Both arms	......	......	......	......	.01	(2)	......	......	......	......	.123	.024
Eye	.45	.39	.37	.31	.34	.37	.513	.448	.425	.360	.369	.421
Both eyes	.01	.01	(2)	.01	(2)	.01	.104	.091	.035	.131	.041	.080
Other	.54	.66	.76	.59	.65	.64	.485	.591	.682	.531	.583	.579
Total	4.19	4.02	4.12	3.75	3.36	3.87	2.89	2.46	2.60	2.22	2.23	2.46

[1] See Chapter VII.

[2] Less than 0.005.

TABLE 72.—ACCIDENT RATES, BY RESULTS OF INJURY, ALL PLANTS, 1910 TO 1914—Concluded.

Result of injury.	Accident frequency rates (per 1,000 300-day workers).						Accident severity rates (days lost per 300-day worker).					
	1910	1911	1912	1913	1914	Total.	1910	1911	1912	1913	1914	Total.
Temporary disability:												
Terminating in—												
1st week	114.93	**78.66**	**96.68**	**89.38**	**74.42**	90.18	0.402	0.275	0.338	0.344	0.260	0.316
2d week	49.86	32.90	38.29	37.10	32.90	37.78	.474	.313	.364	.352	.313	.359
3d week	20.47	14.21	17.14	17.48	14.33	16.67	.317	.220	.266	.270	.222	.258
4th week	10.90	7.33	9.17	9.92	7.99	9.06	.234	.158	.197	.213	.171	.195
5th week	7.33	4.75	5.60	5.60	4.76	5.55	.201	.131	.154	.154	.131	.153
6th-13th weeks	12.16	8.57	10.00	9.50	8.50	9.67	.669	.471	.550	.523	.467	.532
14th week and later	1.32	2.10	2.45	2.44	1.74	2.07	.189	.302	.352	.352	.251	.298
Unknown	1.22	1.23	1.98	2.23	1.25	1.65	.021	.021	.034	.038	.021	.028
Total	218.19	149.76	181.32	173.66	145.88	172.63	2.51	1.89	2.26	2.22	1.84	2.14
Grand total	224.00	154.65	186.60	178.73	150.09	177.67	19.96	12.28	15.27	16.42	11.76	15.06

The most important single item in this table is, of course, the decline in the death rates of almost one-half between 1910 and 1914. But the changes in the severity rate for the other two main classes—i. e., permanent disabilities and temporary disabilities—are also of much interest. They have been irregular, but the tendency has been distinctly downward.

The smaller classes of the table present some interesting comparisons, although they are for the most part too small to permit the tracing of definite tendencies.

Similar data to those given above for the results of injury in the entire industry for the period 1910 to 1914 are given in the following table for the special group of 6 plants over the 8-year period, 1907 to 1914. Only severity rates are given, these being the more important as an index of conditions.

TABLE 73.—ACCIDENT SEVERITY RATES, BY RESULTS OF INJURY, SPECIAL GROUP OF 6 PLANTS, 1907 TO 1914.

Result of injury.	Accident severity rates (days lost per 300-day worker).								
	1907	1908	1909	1910	1911	1912	1913	1914	Total.
Death	19.9	8.3	15.8	13.9	8.8	5.9	11.1	5.8	11.4
Permanent disability: Loss of—									
Great toe	.09	.04	.06	.08	.06	.04	.02	....	.05
1 joint great toe	.01	....	.01	.01	....	.01	.01	.01	.01
Other toe or toes	.02	....	.02	.01	.02	(1)	.02	.01	.01
1 joint other toe or toes	....	.01	(1)	(1)	.01	(1)	(1)	.01	(1)
Foot	.40	.19	.15	.14	.15	.19	.06	....	.16
Both feet	....	....	....	....	....	....	....	....	....
Leg	.53	.53	....	.19	.11	.18	.12	.13	24
Both legs	....	....	....	....	....	....	....	....	....
Thumb	.04	.03	.09	.04	.02	.19	.11	....	07
1 joint thumb	.05	.04	.07	.10	.03	.10	.05	.03	.06
1 joint finger or fingers	.16	.16	.21	.29	.19	.13	.17	.20	.19
1st finger	.18	.36	.17	.24	.05	.30	.10	.20	20
2d finger	.02	....	.03	.06	.01	.10	.05	.04	.04

1 Less than 0.005.

TABLE 73.—ACCIDENT SEVERITY RATES, BY RESULTS OF INJURY, SPECIAL GROUP OF 6 PLANTS, 1907 TO 1914—Concluded.

Result of injury.	Accident severity rates (days lost per 300-day worker).								
	1907	1908	1909	1910	1911	1912	1913	1914	Total.
Permanent disability: Loss of—Concluded.									
3d finger	0.02	....	....	0.02	0.01	0.02	0.02	0.01	0.01
4th finger	....	0.01	0.01	.02	....	.03	.04	.02	.02
Hand	.40	.11	.09	.16	.18	.08	.15	....	.15
Both hands	.37	....	....	....	....	....	....	....	.05
Arm	.20	....	.11	....	.11	.29	.09	....	.11
Both arms	....	....	....	....	....	....	....	....	....
Eye	.54	.41	.23	.55	.56	.36	.43	.63	.46
Both eyes	.38	....	....	....	....	....	....	....	.05
Other	.20	.28	.11	.20	.11	.50	.03	.85	.27
Total	4.0	2.2	1.4	2.1	1.6	2.5	1.4	2.1	2.2
Temporary disability terminating in—									
1st week	.43	.33	.33	.28	.26	.27	.20	.15	.28
2d week	.43	.37	.40	.37	.33	.35	.22	.19	.34
3d week	.35	.31	.30	.32	.26	.25	.22	.17	.27
4th week	.26	.24	.26	.27	.20	.23	.16	.14	.22
5th week	.24	.18	.20	.17	.18	.15	.15	.15	.18
6th-13th weeks	.86	.68	.84	.63	.69	.65	.60	.45	.68
14th week and later	.58	.44	.34	.52	.45	.48	.43	.45	.46
Unknown	.03	.01	.04	.02	.01	.01	.01	.01	.02
Total	3.2	2.6	2.7	2.6	2.4	2.4	2.0	1.7	2.5
Grand total	27.1	13.1	19.9	18.6	12.8	10.8	14.5	9.6	16.1
Number of 300-day workers	*27,632*	*19,481*	*24,543*	*27,144*	*24,519*	*28,922*	*29,766*	*20,241*	*202,248*

Following the items of this table onward from 1907, a very definite downward trend is discernible, even in most of the minor items. To illustrate, take so important a permanent injury as loss of the foot. The severity rates are: 1907, 0.40 day; 1908, 0.19 day; 1909, 0.15 day; 1910, 0.14 day; 1911, 0.15 day; 1912, 0.19 day; 1913, 0.06 day. In 1914 no injury of this kind occurred. There are exceptions but the illustration is in accord with the general tendency.

When the total column for the eight years is examined it appears that loss of the eye entails the greatest severity of any of the permanent injuries—0.46 day. This high severity is found in each of the years. Loss of the eye stands at the head in each year but one, and no material improvement is to be noted. In fact, 1914 is markedly higher than any other year.

ILLUSTRATIONS OF PROGRESS IN ACCIDENT PREVENTION.

It may be said in general that the comparison of accident rates by individual plants is not desirable. Plants may combine departmental activities in unequal proportion so that when rates are presented for whole plants comparisons are invited which can not be exact and may be misleading. For this reason most of the material herein contained is assembled on a departmental basis and individual plants do not appear.

But, while plant rates may not afford a sound basis for comparison between plants, they do afford excellent opportunity for tracing experience from year to year. Progress in an industry may be slow; in a plant where intensive effort is applied it may be very rapid. Such cases give illustrations of possibilities which can not be secured when attention is confined to the average condition prevalent in an industry or department.

The following charts afford the readiest means of grasping at a glance what has been accomplished in such special cases.

Chart 19 gives the experience of a large plant for a period of 14 years. The first period, 1900 to 1904, shows the gradual effect of such effort at accident reduction as this and many other companies made before the beginning of intensive safety work, and a part of even that slow decrease was due, not to direct accident prevention efforts but to reconstruction and improved methods intended primarily to increase production. An immediate and very considerable fall in accident frequency attended the beginnings of serious preventive activity in 1906, and the decline continued during the succeeding years.

The experience of this same plant for both severity and frequency rates is shown in chart 1 (see chapter 1), from 1905 onward, it being impossible to determine severity rates prior to 1905. The steady decline of the severity rates as shown in that chart, from 54.3 days in 1906 to 14.3 days in 1912, is very noteworthy. The rise in 1913 has a special explanation not necessary to enter into here. This steady reduction in severity constitutes one of the most striking achievements of a consistently pursued accident prevention policy.

Chart 20 contrasts conditions in 1910 for the departments of a poorly organized plant with those of a plant having a well-organized accident prevention system. Comparing this with the previous chart it will appear that conditions in the unorganized plant were similar to those of the earlier years of the plant there presented, the frequency ranging on the whole considerably higher.

COMPARISON OF THE IRON AND STEEL INDUSTRY WITH OTHER INDUSTRIES.

Because of the absence of the necessary data, the accident hazards incident to iron and steel making can be compared with other industries in only three cases—coal mining, metal mining, and machine building. In coal and metal mining the comparison must be limited to fatality rates.

CHART 19.—RESULTS OF SAFETY ACTIVITY IN A LARGE STEEL PLANT: ACCIDENT FREQUENCY RATES, 1900 TO 1913.

[Frequency rate means number of accidents per 1,000 300-day workers.]

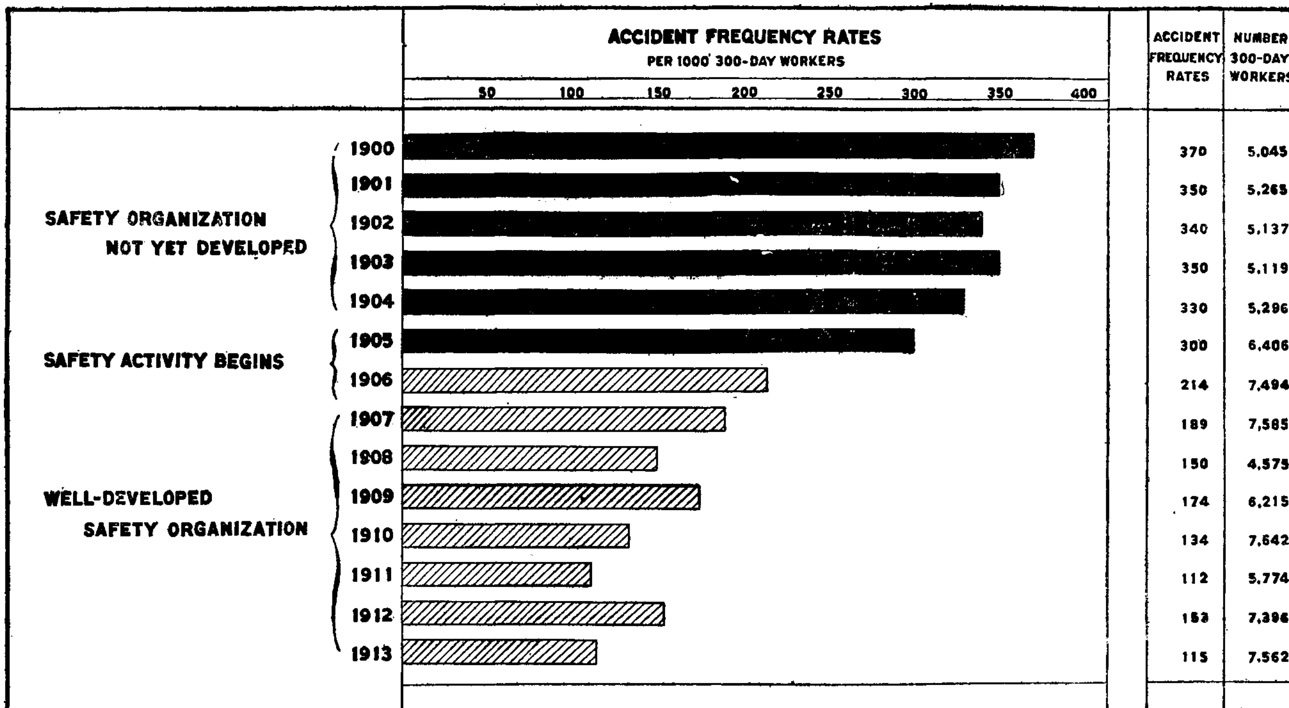
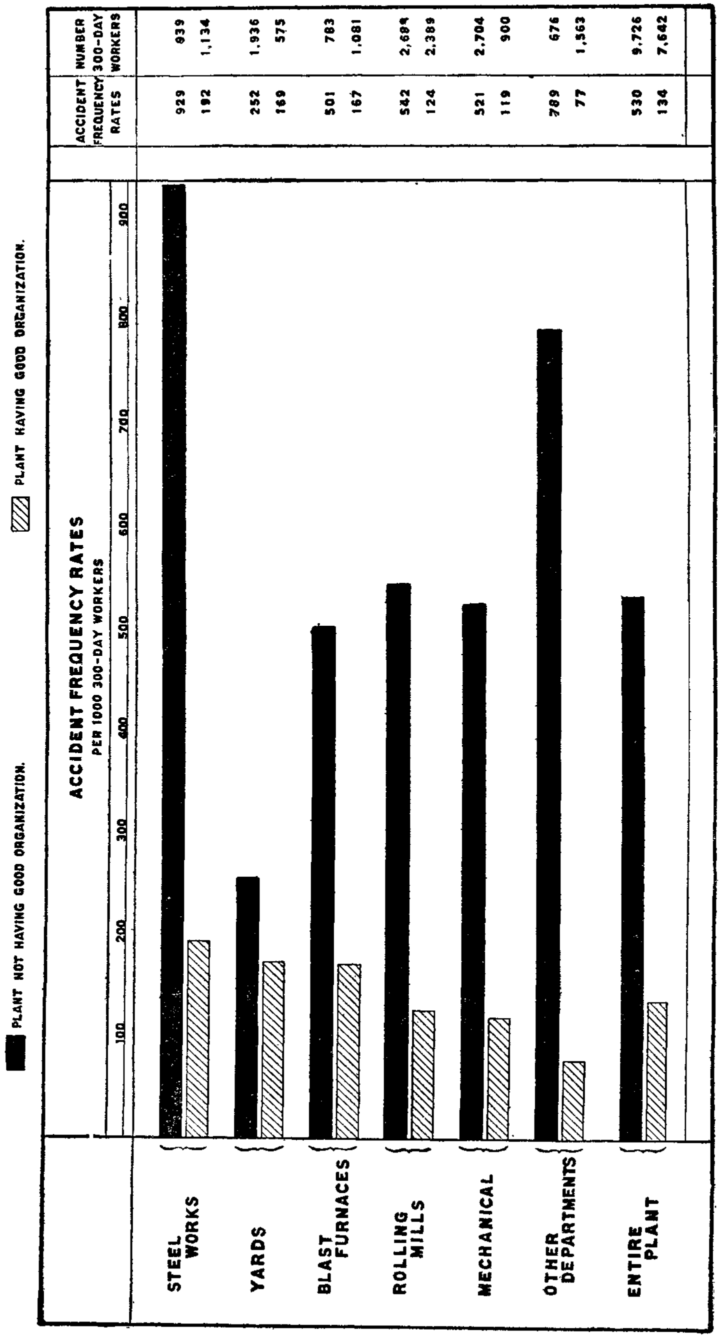


CHART 20.—RESULTS OF SAFETY ACTIVITY IN A LARGE STEEL PLANT, BY DEPARTMENTS.

[Frequency rate means number of accidents per 1,000 300-day workers.]



The following table shows the fatality frequency rate for the entire iron and steel industry, for the especially hazardous departments of that industry, and for the industries of coal mining and metal mining:

TABLE 74.—FATALITY FREQUENCY RATES (PER 1,000 300-DAY WORKERS) IN IRON AND STEEL, COAL MINES, AND METAL MINES.

Year.	Entire iron and steel industry.	Blast furnaces.	Open hearths.	Bessemer converters.	Coal mines.[1]	Metal mines.[2]
1910	1.62	3.46	3.02	3.94	6.05	....
1911	.88	2.42	1.68	1.16	5.67	4.45
1912	1.16	2.72	2.65	1.38	4.98	4.09
1913	1.33	2.66	1.70	2.32	5.37	3.72
1914	.85	1.73	1.09	1.12	4.67	3.92
Total	1.16	2.60	1.98	1.99	5.83	4.03

[1] Computed from rates in report of United States Bureau of Mines: Coal-mine Fatalities in the United States, 1915.

[2] From report of United States Bureau of Mines: Metal Mine Accidents in the United States: 1912, p. 16; 1913, p. 18; 1914, p. 59. These rates are upon a 300-day basis, not taking account of unequal hours. If placed upon a strict 3,000-hour year they would be slightly higher.

The coal and metal mines exhibit the same downward tendency in fatality rates as does the iron and steel industry, but the level of these rates is constantly lower in the latter industry.

It is impossible to carry the above data as a whole farther back than 1910. But for a typical group of blast furnaces and for the coal-mining industry, information is available as early as 1907. At that date, the fatality frequency rate for coal mines was 7.31 per 1,000 workers, while for the group of blast furnaces it was 5.75. The reductions which occurred between 1907 and 1914 were as follows: In coal mines, from 7.31 to 4.67; in blast furnaces, from 5.75 to 1.73. Thus the fatality hazard is seen to have declined much more rapidly in blast furnaces than in coal mines. It is extremely probable, however, that the dangers incident to blast furnaces are more easily controlled than those of coal mining.

EFFECT OF ORGANIZED SAFETY WORK IN REDUCING ACCIDENTS.

In the first report of this bureau upon accidents in the iron and steel industry,[1] the success of organized safety work was strikingly shown by a comparison of the rates in plants which had safety organizations with the rates in plants which had done little in that direction. The comparison was for the year 1910, a time when safety organization, already well developed in some few plants, was beginning to spread throughout the industry. For the purpose of this comparison only such plants were included as were fairly comparable as regards size, character of product, and operating conditions. These were divided into three classes, according to the degree in which

[1] Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV.

safety systems had been developed. In class A were placed those plants in which safety systems were well developed; in class B, those in which such systems were in process of development; and in class C, the plants in which safety activities were not at all well developed. Accident frequency rates were then computed for each of these plants and groups, and it was found that without exception the plants having the better safety systems had the lower accident rates. The detailed results were shown in a table, a summary of which is reproduced below:

TABLE 75.—COMPARISON OF ACCIDENT RATES IN PLANTS CLASSIFIED ACCORDING TO DEGREE OF DEVELOPMENT OF SAFETY SYSTEMS, YEAR ENDING JUNE 30, 1910.

Plants having safety systems of specified class.	Number of 300-day workers.	Number of accidents.	Accident frequency rates (per 1,000 300-day workers).
A. System well developed:			
Plant No. 1	975	113	115.9
Plant No. 2	6,137	881	143.5
Plant No. 3	6,225	1,000	160.6
Plant No. 4	7,642	1,287	168.4
Plant No. 5	1,084	241	222.3
Plant No. 6	2,348	557	237.2
Total	24,411	4,079	167.1
B. System in process of development:			
Plant No. 7	5,572	1,335	239.6
Plant No. 8	8,109	2,115	260.8
Plant No. 9	4,185	1,173	280.3
Plant No. 10	6,833	1,980	289.8
Plant No. 11	4,131	1,249	302.3
Total	28,830	7,852	272.4
C. System not developed:			
Plant No. 12	1,491	601	403.1
Plant No. 13	1,131	481	425.3
Plant No. 14	1,272	552	434.0
Plant No. 15	9,726	5,144	528.9
Plant No. 16	1,296	798	615.7
Total	14,916	7,576	507.9

It will be seen from this table that, while class A had a frequency rate of only 167.1, the rate for class B was 272.4, and for class C no less than 507.9 cases per 1,000 300-day workers. Similarly striking differences in the accident rates of the groups were shown to exist when the classification was made by departments instead of by whole plants.

The above comparisons apply, as noted, to the year 1910. Since that time class C has practically disappeared, due to the rapid growth of the safety movement, aided by the development of workmen's compensation laws. It is very probable that without the steady pressure of compensation legislation the movement would neither have assumed its present proportions nor have sustained itself so satisfactorily.

CHAPTER XI.

ACCIDENT EXPERIENCE, BY DEPARTMENTS AND OCCUPATIONS.

The preceding chapter has traced, in somewhat broad lines, the progress of accident prevention in the iron and steel industry as a whole over a period of years. The steel industry, however, is composed of a number of departments—blast furnace, Bessemer, rolling mills, etc.—each with its distinctive activities and its distinctive hazards. That these hazards are by no means uniform is brought out in the following table, which shows the accident rates for the more important departments, the data for each department being a combination of several years' experience. The first part of the table includes all plants covered for the 5-year period 1910 to 1914; and the second part, the special group of 6 plants for the 8-year period 1907 to 1914.

TABLE 76.—ACCIDENT RATES, BY DEPARTMENTS.

PART I.—ALL PLANTS, 1910 TO 1914.

Department.[1]	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Bessemer	28,101	2.0	5.2	262.1	269.3	18.0	3.1	3.8	24.8
Fabricating	108,538	.9	3.9	235.0	239.7	7.8	2.2	2.4	12.4
Open hearths	71,293	2.0	4.6	218.4	224.9	17.8	3.0	2.9	23.7
Foundries	95,917	.9	4.7	185.2	190.8	7.9	2.6	2.2	12.7
Mechanical	97,162	1.1	4.0	183.1	188.2	9.5	2.5	2.3	14.2
Blast furnaces	124,636	2.6	2.9	181.1	187.6	23.4	2.8	2.5	28.7
Sheet mills	128,423	.7	2.6	150.0	153.3	6.1	1.4	1.7	9.2
Yards	55,932	2.0	4.4	145.8	152.1	18.0	3.1	1.9	23.0
Plate mills	21,711	.9	4.8	144.1	149.8	7.9	3.0	2.0	12.9
Heavy rolling mills	67,663	1.1	3.9	133.1	138.0	9.4	2.2	1.9	13.5
Tube mills	73,338	.5	3.4	117.6	121.5	4.5	1.7	1.5	7.7
Total	872,714	1.3	3.8	177.3	182.4	11.6	2.6	2.0	16.2
PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.									
Bessemer	5,920	1.9	3.4	204.1	209.4	16.7	1.9	4.0	22.6
Fabricating	15,764	1.5	4.8	261.9	268.2	13.7	3.1	2.6	19.4
Open hearths	23,453	1.6	3.9	183.3	188.8	14.6	2.6	2.7	19.9
Foundries	7,338	.8	3.1	192.7	196.6	7.4	1.5	2.9	11.8
Mechanical	17,098	1.1	2.7	172.5	176.3	9.5	1.5	2.4	13.4
Blast furnaces	11,626	2.8	4.0	161.0	167.8	25.5	3.2	2.9	31.6
Sheet mills	19,119	.9	4.6	106.9	112.4	8.0	2.2	1.4	11.6
Yards	16,160	1.2	3.5	132.9	137.6	11.1	2.7	2.2	16.0
Plate mills	13,625	.9	4.3	214.5	219.7	7.9	2.6	2.8	13.3
Heavy rolling mills	34,999	.9	3.1	136.1	140.1	8.2	1.5	2.3	12.0
Tube mills	14,539	.5	3.0	185.4	188.9	4.3	1.5	2.9	8.7
Total	179,642	1.2	3.7	171.4	176.3	10.9	2.1	2.5	15.5

[1] For miscellaneous departments not shown here see Table 99.

Table 76 does no more than offer a general comparison between the accident rates of the more important departments. The experience of each of these departments over a series of years is presented below.

In addition, an analysis of the department into its constituent occupations is made wherever the necessary material is available. This could not be done for individual years because of the limited amount of data.

The value of occupational rates such as those offered can not be too much emphasized.[1] They isolate the hazards of particular kinds of work, and thus permit preventive work to be concentrated most effectively. From the standpoint of the safety man, indeed, occupational rates may be said to constitute the ultimate goal of accident statistics.

Unfortunately, however, such rates are, as a rule, extremely difficult to determine, partly because the groups are often too small to permit of conclusive deductions, partly because records of employment are seldom kept by occupations. The former difficulty—the small size of certain occupations—can be overcome to some extent by combining occupations of closely associated hazards. This method has been followed in this study.

The second difficulty—determination of occupational employment—was more serious. In no case was it possible to obtain exact employment for an occupation. The desired information, therefore, had to be approximated. This was done as follows: At intervals during the period under review the number of men in each of the occupational groups was determined for each department. From these determinations an average percentage distribution was computed and the resulting percentages applied to the employment for the entire period. This method does not produce precise results, as it takes no account of the differing lengths of the working days in different occupations. Thus the rates for common labor tend to be somewhat lower than they should be, as their working day is usually longer than that of the more skilled employees. But, on the whole, the method described does produce rates of sufficient accuracy to make them of very material value in the study of accident problems.

BLAST FURNACE DEPARTMENT.

The following table, with accompanying chart, shows the course of accident rates in blast furnaces, the first part covering all plants for the 5 years 1910 to 1914, the second part covering the special group

[1] In Chapters III, IV, and V occupational frequency rates for certain important occupations were presented by causes.

of plants for the 10 years 1905 to 1914. For the blast furnaces, data for the special group of plants were available for the years 1905 and 1906, and such data are here presented, although in most of the other departments the earliest year available was 1907.

CHART 21.—ACCIDENT RATES IN BLAST FURNACES OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

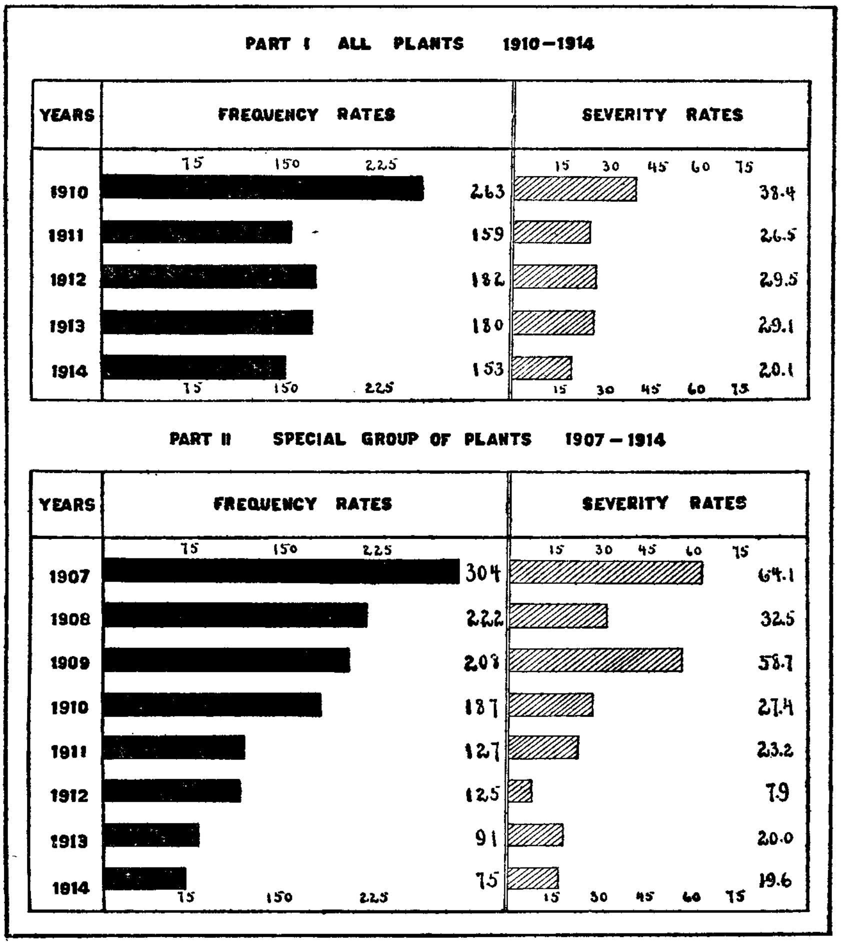


TABLE 77.—ACCIDENT RATES IN BLAST FURNACES OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	19,389	3.5	3.5	256.4	263.3	31.1	4.4	2.9	38.4
1911	21,479	2.4	2.5	153.8	158.8	21.8	2.4	2.3	26.5
1912	27,154	2.7	3.2	176.4	182.3	24.5	2.5	2.5	29.5
1913	31,988	2.7	2.5	174.4	179.5	23.9	2.6	2.6	29.1
1914	26,572	1.7	2.9	148.1	152.6	15.6	2.5	2.0	20.1
Total	124,636	2.6	2.9	181.1	186.7	23.4	2.8	2.5	28.7
	PART II.—SPECIAL GROUP OF PLANTS, 1905 TO 1914.								
1905	961	5.2	6.2	413.1	424.6	46.8	4.8	5.2	56.8
1906	1,262	15.1	6.3	309.8	331.3	135.5	2.8	5.0	143.3
1907	1,566	5.8	7.0	291.2	304.0	51.7	6.9	5.5	64.1
1908	1,274	2.4	6.3	213.5	222.1	21.2	6.5	4.8	32.5
1909	1,486	6.1	2.7	199.2	207.9	54.5	.9	3.3	58.7
1910	1,353	2.2	4.4	180.3	187.0	20.0	4.2	3.2	27.4
1911	1,380	2.2	5.1	119.6	126.8	19.6	1.4	2.2	23.2
1912	1,749	.6	2.3	121.8	124.6	5.1	1.1	1.7	7.9
1913	1,658	1.8	2.4	86.9	91.1	16.3	2.2	1.5	20.0
1914	1,160	1.7	2.6	70.7	75.0	15.5	2.5	1.6	19.6
Total	13,849	4.1	4.4	192.1	200.6	37.0	3.2	3.3	43.5

The severity rates of the blast furnaces very considerably exceed those of any other department of the industry, with a rate of 28.7 days per worker for the five-year period 1910 to 1914 and a rate of 43.5 days in the special group of plants over a 10-year period. Particularly noteworthy are the high rates in the years 1905 and 1906 and the manner in which frequency and severity rates between these years moved in opposite directions, frequency declining from 424.6 to 331.3 cases per 1,000 workers, while severity rose from 56.8 to 143.3 days per worker. This latter severity rate is by far the highest found in the course of this study and was the result of a very large number of fatal accidents in the year concerned. In the earlier discussion of causes of injury (Ch. III) it appeared that the high severity hazard of blast furnaces was largely due to the effects of asphyxiating gas.

For the whole period covered by the table, the blast furnaces show a definite and satisfactory improvement. The accident rates fluctuate irregularly but the tendency has been very definitely downward, both the frequency and severity of accidents being from 40 to 50 per cent lower in 1914 than in 1910.

Occupational rates.—Some of the hazards of the blast furnace department are peculiar to that department; others it shares with other departments. The importance of the peculiarly blast furnace hazards is brought out in the following table, which gives accident rates by certain important occupational groups. The method of grouping used and the method of computing occupational rates were described above. The group listed as "unclassified" contains those occupations which the blast furnace has in common with other departments, or which are not especially important. In considering this and similar tables it seems desirable to repeat that the general practice has been to compute rates for groups of less than 1,000 300-day workers only when unavoidable and then always with a caution that the small groups may not give typical rates.

TABLE 78.—OCCUPATIONAL ACCIDENT RATES IN BLAST FURNACES, FOR THE PERIOD 1905 TO 1914.

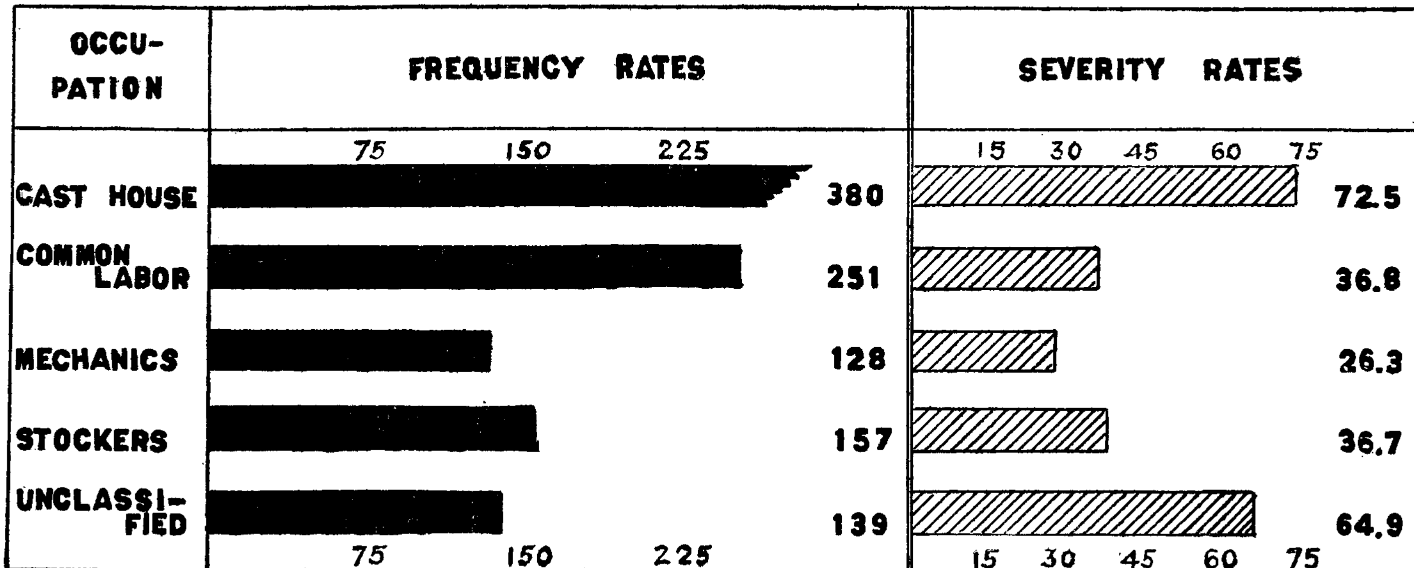
Occupational group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Cast-house men [1]	1,357	6.6	6.6	367.1	380.3	59.7	6.5	6.3	72.5
Common labor	4,930	3.4	3.2	243.8	250.5	31.0	1.8	4.0	36.8
Mechanics [2]	3,670	2.5	4.1	121.5	128.1	22.1	2.4	1.8	26.3
Stockers [3]	886	3.4	2.3	151.2	156.9	30.5	3.5	2.7	36.7
Unclassified [4]	3,006	6.3	6.3	126.4	139.1	56.9	5.0	2.4	64.9
Total	13,849	4.2	4.4	192.1	200.6	37.0	3.2	3.3	43.5

[1] Includes bar and clay men, cinder snappers, keepers and helpers, ladle men, etc.
[2] Includes blacksmiths, boilermakers, carpenters, machinists, millwrights, pipe fitters, riggers, etc.
[3] Includes cagers, bottom fillers, larry men, stockers, top fillers, etc.
[4] Includes crane hookers, cranemen, switchmen, etc.

Among the groups listed the cast-house men are nearest to uniform hazard. This group includes bar and clay men, cinder snappers, keepers and their helpers, and ladle men. All these occupations are engaged upon the operations necessary to preparing the cast-house floor, getting ladles ready when they are used, and tapping off the cinder and iron. In the study of accident causes (Ch. III), it appeared that the molten iron and slag were the great sources of danger to these men. Other occupations have a higher frequency (380.3 cases per 1,000 300-day workers), but no group has greater severity (72.5 days per worker) except switchmen in yard operations.

In the blast furnace, as everywhere, common labor has both high frequency (250.5 cases per 1,000 workers) and high severity (36.8 days per worker). As noted in Chapter VII, this condition is very largely a result of ignorance and inexperience among the new men whom it is necessary constantly to introduce. The significance of this as pointing out a most important field of accident prevention effort must be repeatedly emphasized.

CHART 22.—OCCUPATIONAL ACCIDENT RATES IN BLAST FURNACES.



The occupations assembled under stocking include stockers proper and all others whose duties are related to the stocking of the furnace. Since the composition and methods of this group have undergone material change during the period covered, the rates can not be regarded as typical of present conditions. If it were possible to follow these occupations from year to year it would be found that in the general decline the stocking crew would have the most rapid downward curve.

It is worthy of note that the mechanics employed about the blast furnaces have a severity of 26.3 days, while the general mechanical department, including the same occupations and for the same period, has one of 16.5 days. This higher severity in blast furnaces is associated with a lower frequency—128.1 cases per 1,000 full-time workers as against 187.5 among the workers in the mechanical department. The reasons for this discrepancy are not far to seek. The general mechanical department performs much shop work giving rise to a considerable number of short-term disabilities. For example, the frequency rates for the disabilities terminating in the first week are: General mechanical department, 99; blast furnace mechanics, 56 cases per 1,000 workers; but the fatality frequency rates are: General mechanical department, 1.3; blast furnace mechanics, 2.5. In the blast furnaces the shop work is at a minimum. In fact, when the furnaces are associated with other departments the blast-furnace shop work is likely to be done in the general shop. The blast-furnace mechanic is almost exclusively engaged in what is called field work—repairing and replacing parts involving the hoisting of heavy masses or working about the furnace where he is liable to the effects of gas.

The high severity rate of the unclassified group—64.9 days per worker—arises largely from its containing the operators of cranes and railways. As has been explained, the effort has been to include among the unclassified of a department those occupations which the department has more or less in common with all others or which were not specially important. The size of this group emphasizes constantly that the iron and steel industry has throughout common dangers, having everywhere the same possible remedies. What these are and how they should be met was indicated in the chapter on accident causes.

BESSEMER DEPARTMENT.

The following table, with accompanying chart, shows the accident rates in the Bessemer departments for all plants from 1910 to 1914 and for the special group of plants from 1907 to 1914:

CHART 23.—ACCIDENT RATES IN THE BESSEMER DEPARTMENT OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

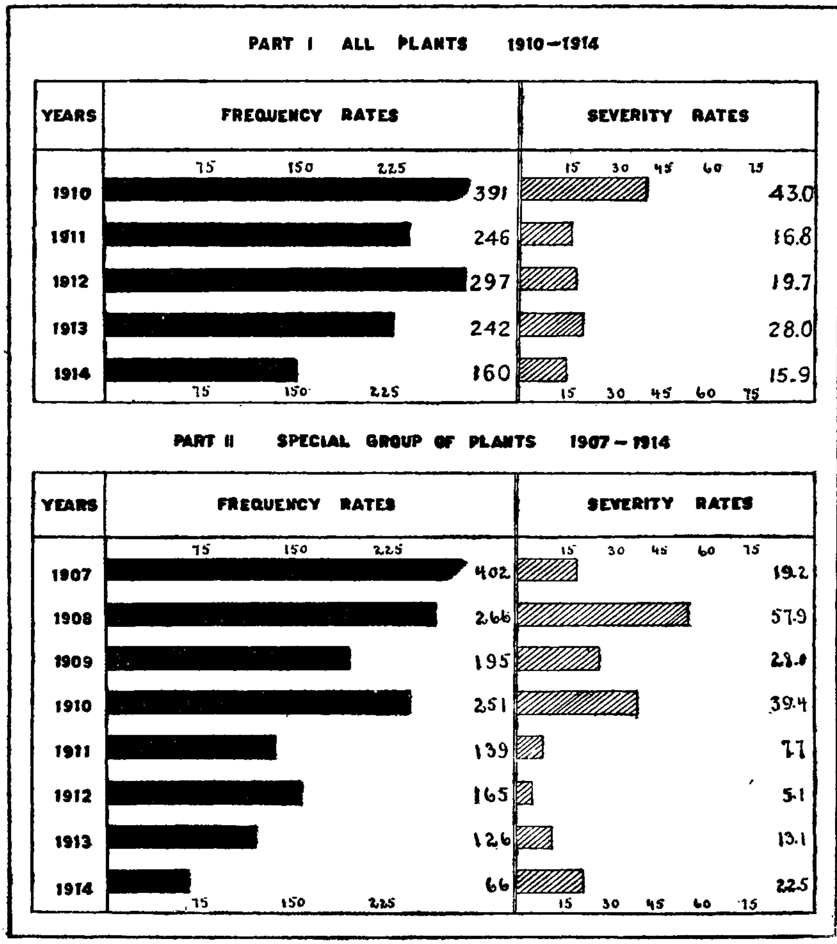


TABLE 79.—ACCIDENT RATES IN BESSEMER DEPARTMENTS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	5,070	3.9	3.6	383.2	390.7	35.5	2.6	4.9	43.0
1911	5,155	1.2	4.7	239.8	245.6	10.5	3.0	3.3	16.8
1912	6,521	1.4	5.7	290.1	297.2	12.4	2.9	4.4	19.7
1913	6,885	2.3	6.1	233.8	242.3	20.9	3.3	3.7	28.0
1914	4,470	1.1	5.4	153.2	159.7	10.1	3.3	2.6	15.9
Total	28,101	2.0	5.2	262.1	269.3	17.9	3.1	3.8	24.8

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Frequency: Death.	Frequency: Permanent disability.	Frequency: Temporary disability.	Frequency: Total.	Severity: Death.	Severity: Permanent disability.	Severity: Temporary disability.	Severity: Total.
1907	967	1.0	5.0	396.1	402.1	9.3	2.6	7.3	19.2
1908	511	5.9	2.0	258.3	266.2	52.8	.3	4.8	57.9
1909	750	2.7	....	192.0	194.7	24.0	....	4.0	28.0
1910	784	3.8	2.6	244.9	251.3	34.4	.4	4.6	39.4
1911	669	....	4.5	134.5	139.0	....	5.2	2.5	7.7
1912	788	....	5.1	159.9	165.0	.2	2.4	2.7	5.1
1913	875	1.1	2.3	122.3	125.7	10.3	.4	2.4	13.1
1914	576	1.7	5.2	59.0	65.9	15.6	4.3	2.6	22.5
Total	5,920	1.9	3.4	204.1	209.4	16.7	1.9	4.0	22.6

The Bessemer rates show a very great irregularity from year to year. In the case of the special group of plants from 1907 to 1914, this is due in part to the rather small amount of employment in each year. But, in addition, extremely fluctuating accident rates seem to be rather normal to the Bessemer department.

On the whole, it would appear from the above figures that the accident hazards have been much better controlled since 1910 than had previously been the case, although in the intervening years since 1911 there has certainly been no marked tendency to further decline.

Examination of the severity rates in detail will show that the irregularity of these rates is almost entirely due to the uneven distribution of fatality. This, in groups no larger than those for the years 1910 to 1914, would be sufficient to produce considerable irregularity of movement. Its effect would be still more pronounced in the small group of plants for 1907 to 1914. In temporary disability, which is the only class to present a somewhat uniform experience, there is a definite improvement when earlier years are compared with later. From 1910 to 1914, for example, the severity rate for temporary disability declined from 4.9 days to 2.6 days per worker. For the special group of plants the decline is from 7.3 in 1907 to 2.6 days in 1914. This would seem to indicate that in the plants covered it was possible to bring about a material improvement in temporary disabilities while the problem of fatality and permanent injury seems to have been controlled less satisfactorily.

It was not possible to make any arrangement of Bessemer employment from an occupational standpoint.

OPEN HEARTH DEPARTMENT.

The accident rates for the open hearth department are presented in the following table and chart:

CHART 24.—ACCIDENT RATES IN OPEN HEARTHS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

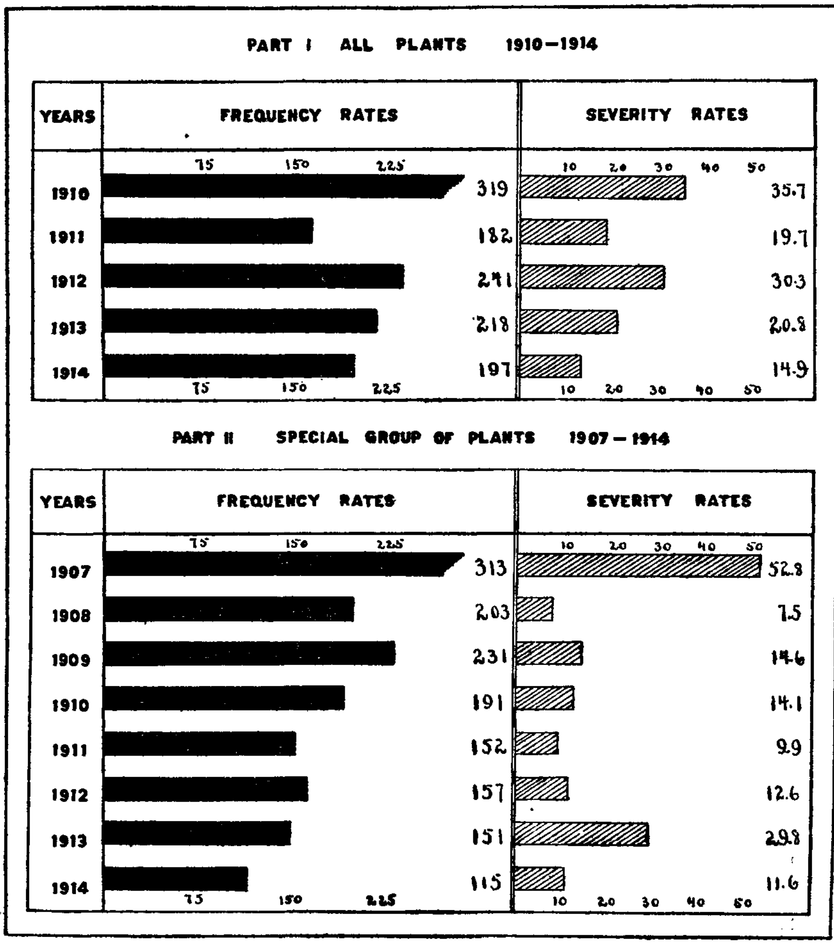


TABLE 80.—ACCIDENT RATES IN OPEN HEARTHS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	9,739	3.0	5.4	310.9	319.3	27.1	4.4	4.1	35.7
1911	10,718	1.7	4.2	176.3	182.1	15.1	2.1	2.6	19.7
1912	17,355	2.7	5.7	232.7	241.0	23.9	3.6	2.9	30.3
1913	20,604	1.7	4.6	212.0	218.3	15.3	2.5	2.9	20.8
1914	12,877	1.1	3.2	192.9	197.2	9.8	2.7	2.3	14.9
Total	71,293	2.0	4.6	218.4	224.9	17.8	3.0	2.9	23.7

PART II.—SPECIAL GROUP OF 6 PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,987	4.7	4.7	304.0	313.4	42.2	7.4	3.2	52.8
1908	2,120	.5	1.9	200.5	202.9	4.2	1.1	2.2	7.5
1909	2,872	1.0	3.1	226.7	230.8	9.4	2.0	3.2	14.6
1910	3,138	1.0	5.7	184.5	191.2	8.6	2.6	2.9	14.1
1911	2,725	.7	2.6	149.0	152.3	6.6	.6	2.7	9.9
1912	3,525	.9	5.7	150.1	156.7	7.7	2.7	2.2	12.6
1913	3,603	2.8	2.8	145.7	151.3	25.0	1.7	3.1	29.8
1914	2,483	.8	4.0	110.4	115.2	7.2	2.6	1.8	11.6
Total	23,453	1.6	3.9	183.3	188.8	14.6	2.6	2.7	19.9

The open hearths show a quite steady downward movement in accident frequency. Severity is, as is to be expected, much more variable, although all the later years are lower than the initial year. When the extremes are compared the contrast is quite marked, the whole industry from 1910 to 1914 showing a decline from 35.7 days to 14.9 days per worker, while the special group of plants declined from 52.8 days in 1907 to 11.6 days in 1914.

One phase of rate variation is so forcibly illustrated by these tables that it deserves a repetition of some comment which was earlier made. The year 1907 represents in its very high rates (frequency 313.4 cases, severity 52.8 days) the condition nearly universal throughout the iron and steel industry in that year and earlier. As has been elsewhere pointed out it is very possible that this and the preceding year, 1906, constitute, as it were, a climax to the earlier serious conditions. Even granting this, these years remain fairly typical of the period from the introduction of the Bessemer steel making process down to that time. It was the tremendous expansion of the industry due to the introduction of this and the open hearth processes, without adequate provision for safe operation, that gave the industry in the United States its sanguinary reputation.

In 1908 there was a remarkable drop in accident rates, frequency coming down to 202.9 cases per 1,000 workers, while severity touched its lowest point. This drop was undoubtedly in part due to safety efforts inaugurated in that year, but was much more largely due to the almost complete cessation of the introduction of new and inexperienced men which marked that year. In proportion to the severity of an industrial depression, labor recruiting will fall off and may cease entirely. With this may go, when the depression is serious, the laying off and discharge of old employees. This is a selective process. Recent and therefore relatively inexperienced employees are the first to go. The average experience of the force is thus improved and accident rates drop. The direct effect of slackened industrial activity is of some influence in this reduction of rates but must be regarded as secondary.

To determine, therefore, whether accident prevention effort is really effective, appeal can rarely be made to the years immediately following such a depression. They are apt to be years of gradual recovery, with a fluctuating and somewhat rising accident rate. This rise by no means proves the failure of the effort.

To get a clear view of what has been accomplished it is necessary to observe a year of similar activity when labor recruiting again becomes active and large numbers of the inexperienced are being introduced. In the case under consideration, 1913 was such a year. Its accident frequency was slightly below that of 1912, and only about half that of 1907. In severity there is a marked increase over 1912, but the rate is much below 1907. This is a true test of efficiency. If under similar conditions the rates can be kept down well below the earlier level the effort may be regarded as successful. But this is not the full measure of success. Until the tendency to rise with renewed industrial activity can be controlled better than it now is, safety officials can not rest content.

In all comparisons such as these it must not be forgotten that while the figures may represent the facts with perfect mathematical accuracy they can not in the nature of the case make known the underlying industrial conditions controlling the facts. The figures may therefore appear arbitrary and lawless because it is impossible many times to make evident the presence and influence of some most important factors.

CHART 25.—OCCUPATIONAL ACCIDENT RATES IN OPEN HEARTHS.

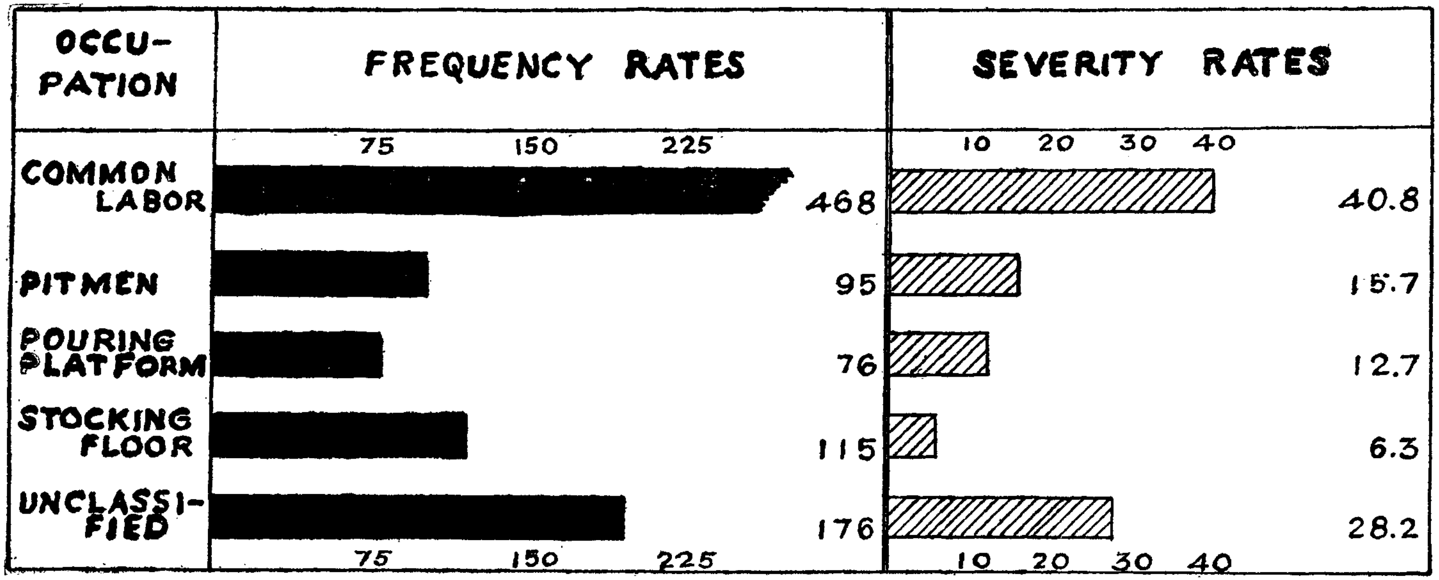


TABLE 81.—OCCUPATIONAL ACCIDENT RATES IN OPEN HEARTHS FOR THE PERIOD 1905 TO 1914.

Occupational group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Common labor	4,851	3.3	10.1	454.3	467.7	29.7	5.4	5.7	40.8
Pitmen [1]	5,492	1.5	.9	92.3	94.7	13.2	.6	1.9	15.7
Pouring platform men [2]	954	1.0	2.1	72.3	75.5	9.4	.5	2.8	12.7
Stocking floor man [3]	7,761	.4	1.9	112.6	114.9	3.5	1.1	1.7	6.3
Unclassified [4]	5,395	2.2	5.9	168.3	176.4	20.0	5.7	2.5	28.2
Total	24,453	1.6	4.2	188.6	192.4	14.7	2.8	2.8	20.3

[1] Includes cinder men, ladle liners, ladle men, pitmen, stopper setters, etc.
[2] Includes mold cappers, steel pourers and helpers, etc.
[3] Includes charging car operators, door operators, melters and helpers, etc.
[4] Includes crane hookers, cranemen, engineers, firemen, foremen, ingot strippers, mixer men, oilers, stopper makers, switchmen, weighers, etc.

Occupational rates.—For the open hearths it was possible to compute accident rates for certain important occupational groups. These rates are presented in Table 81. The method used in computing them was explained earlier in this chapter. Also, it is to be repeated, that the "unclassified" group includes such occupations as were in no way peculiar to the open hearth department or which were of no special importance.

Of the occupational groups listed common labor shows much the highest accident rate, both as regards frequency (467.7 cases per 1,000 workers) and severity (40.8 days per worker). The unclassified group is next, including, as in blast furnaces, those occupied with the hazardous work of cranes and transportation. Their rates are: Frequency, 176.4 cases, and severity, 28.2 days. The workers on what is called the pit side of the furnace, although in modern open hearths there is no longer what can properly be called a pit, have a frequency rate of 94.7 cases, and a severity rate of 15.7 days. The men on the pouring platform are skilled men or directly under the charge of a skilled man. The rates are: Frequency, 75.5 cases, and severity, 12.7 days.

The men of greatest responsibility, the melters and their helpers, are found on the stocking floor. It will be noticed that while the frequency rate is here very high (114.9 cases per 1,000 workers) the severity rate (6.3 days) is one of the lowest found anywhere.

CRUCIBLE MELTING DEPARTMENT.

In this department the details could not be secured conveniently for a careful discussion. All the information available was in the form of tabulations of results not giving specific facts about each case. Relatively low rates prevail in this department during the period covered (frequency, 103.5; severity, 7.3 days).

FOUNDRIES.

The foundries covered by this study are largely such as are associated with other departments and produce castings exclusively for those departments, as, for example, the production of ingot molds for the steel works. In the former report on accidents in the iron and steel industry,[1] however, a number of independent foundries were included on the ground that they were steel makers, and these have been retained in the present tabulation.

The following table gives the accident rates of steel foundries:

TABLE 82.—ACCIDENT RATES IN FOUNDRIES OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	16,885	0.4	4.6	154.9	160.0	3.7	2.2	1.7	7.6
1911	13,499	1.3	4.2	145.9	151.4	12.0	2.2	1.9	16.0
1912	23,294	1.0	5.8	193.7	200.6	9.3	3.4	2.5	15.1
1913	24,605	.9	4.8	212.8	218.5	7.7	2.7	2.4	12.8
1914	17,634	.8	3.5	194.6	198.9	7.1	2.3	2.1	11.5
Total	95,917	.9	4.7	185.2	190.8	7.9	2.6	2.2	12.7

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	939	1.1	3.2	190.6	194.9	9.6	0.8	3.1	13.5
1908	719	....	....	168.3	168.3	....	....	2.5	2.5
1909	985	....	4.1	233.5	237.6	....	1.7	3.8	5.5
1910	1,189	....	2.5	221.1	223.6	....	1.4	3.0	4.4
1911	875	2.3	3.4	185.1	190.8	20.6	1.7	2.6	24.9
1912	1,056	1.9	6.6	223.5	232.0	17.0	2.8	3.3	23.1
1913	990	1.0	2.0	149.5	152.5	9.1	1.3	2.4	12.8
1914	585	....	1.7	128.2	129.9	....	2.0	1.7	3.7
Total	7,338	.8	3.1	192.7	196.6	7.4	1.5	2.9	11.8

Foundry accident rates are thus seen to fluctuate greatly and without evidence of any very marked improvement. The larger group of plants, with data from 1910 to 1914, does show a steadily declining severity rate from 1911 onward, dropping from 16.0 days in 1911 to 11.5 days in 1914. This may represent a growing control over foundry accidents, the very low rate of 1910 (7.6 days) being due perhaps to exceptional conditions in that year. In the special group of plants,

[1] Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV.

with data from 1907 to 1914, the number of workers concerned is almost too small to produce satisfactory rates.

It was not possible to apportion foundry employment according to occupations for either of the two groups of plants as a whole. But for part of the plants of the 1910–1914 group the data were reported in such a manner as to afford almost exact occupational rates. In the case of these plants the precise time of employment—that is to say, the number of "man hours"—was available for each occupation covered. The resulting occupational rates are presented in the next table:

TABLE 83.—OCCUPATIONAL ACCIDENT RATES IN FOUNDRIES, FOR THE PERIOD 1910 TO 1914.

Occupation.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Cleaners	4,196	1.0	14.3	513.1	528.4	8.6	9.0	4.7	22.3
Core makers	1,273	....	.8	189.3	190.1	....	.1	1.5	1.6
Melters and helpers	1,261	....	6.3	174.5	180.8	....	4.2	1.8	6.0
Molders and helpers	5,266	1.0	10.3	309.7	320.9	8.5	6.8	3.3	18.7
Total	11,996	.8	10.2	353.9	364.9	6.8	6.6	3.4	16.8

The rates for the cleaners are noteworthy, being no less than 528.4 cases per 1,000 workers in frequency and 22.3 days per worker in severity. An unusual proportion of this high severity rate is due to permanent partial disabilities, the most common being the loss of the eye.

The core makers show the lowest rates, melters coming next. Molders have a severity rate of 18.7 days, almost as high as that for cleaners, their chief hazards being incident to their work with molten metal, though the fall of heavy flasks and castings is also an important cause of accident in this occupation.

HEAVY ROLLING MILLS.

The term "heavy rolling mills" is here used to include blooming and slab mills and such rail and structural mills as roll heavy work direct from the ingot. These mills are all mechanically operated. The division, undertaken in the earlier report,[1] into mechanically operated mills and hand operated mills did not prove very satisfactory and is not followed in this study. A comparison of somewhat similar character is offered in the contrast of the rates given below for heavy

[1] Report on Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong. 1st Sess.), Vol. IV.

rolling mills, which are largely mechanically operated, with those given later (Table 90) for miscellaneous rolling mills which are to a considerable degree hand operated. Such a comparison shows the mechanically operated heavy rolling mills to have the higher severity rate (13.5 against 12.8 days) but the lower frequency (138 against 220 cases per 1,000 full-time workers).

CHART 26.—ACCIDENT RATES IN HEAVY ROLLING MILLS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

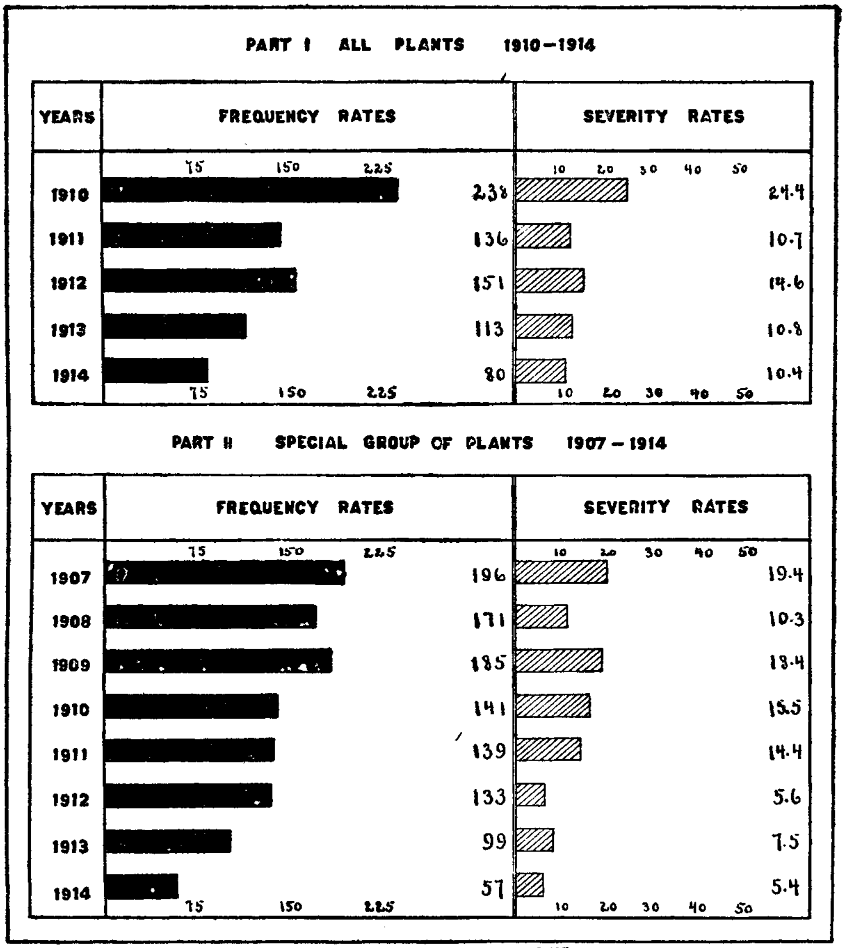


TABLE 84.—ACCIDENT RATES IN HEAVY ROLLING MILLS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	9,442	2.0	6.0	229.5	237.6	18.1	3.5	2.8	24.4
1911	12,409	.7	3.9	131.8	136.4	6.5	2.1	2.0	10.7
1912	16,258	1.2	2.5	147.3	150.9	10.5	2.1	2.0	14.6
1913	17,569	.9	3.4	108.7	112.9	7.7	1.4	1.7	10.8
1914	11,985	.8	4.6	75.0	80.4	6.8	2.4	1.3	10.4
Total	67,663	1.1	3.9	133.1	138.0	9.4	2.2	1.9	13.5

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	4,556	1.8	2.2	191.8	195.8	15.8	0.7	2.9	19.4
1908	3,135	.6	4.8	165.6	171.0	5.7	2.3	2.3	10.3
1909	4,210	1.7	1.7	181.7	185.1	15.0	.6	2.8	18.4
1910	4,886	1.2	4.3	135.7	141.2	11.1	2.1	2.3	15.5
1911	4,195	1.0	3.8	134.4	139.2	8.6	3.2	2.6	14.4
1912	5,226	.2	2.3	130.7	133.2	1.7	1.6	2.3	5.6
1913	5,287	.6	3.2	95.5	99.3	5.1	.6	1.8	7.5
1914	3,504	.3	2.9	53.9	57.1	2.6	1.4	1.4	5.4
Total	34,999	.9	3.1	136.1	140.1	8.2	1.5	2.3	12.0

The accident rates for these heavy rolling mills show a constant decline in both frequency and severity, the degree of decline being more pronounced in the case of accident frequency. The irregularities observable are due to variations in industrial activity, the influence of which is constantly to be expected unless some effective check can be devised to meet it. From 1910 to 1914 the frequency rate for the whole industry dropped from 237.6 to 80.4 cases per 1,000 full-time workers, the severity rate from 24.4 days to 10.4 days per worker. For the special group of plants the frequency rate dropped from 195.8 in 1907 to 57.1 in 1914, the severity rate during the same period declining from 19.4 days to 5.4 days. On the whole, these mills may be regarded as making a very satisfactory showing in steadiness and regularity of improvement.

PLATE MILLS.

The accident rates of the plate mills are exhibited in the following chart and table:

CHART 27.—ACCIDENT RATES IN PLATE MILLS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

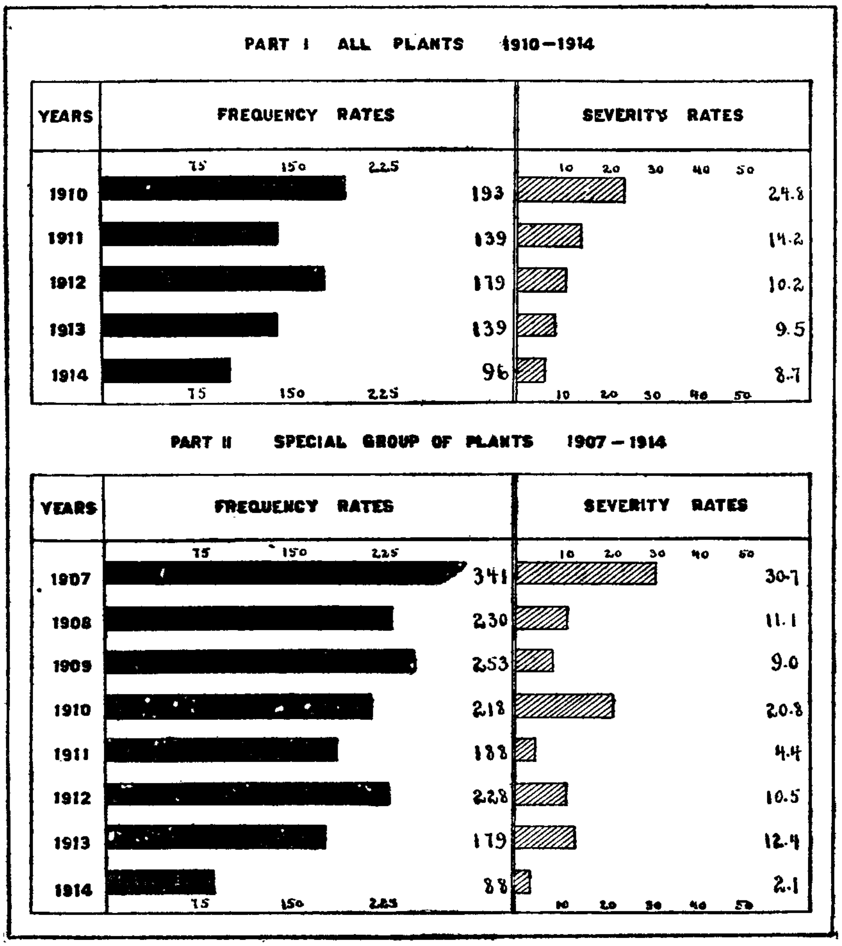


TABLE 85.—ACCIDENT RATES IN PLATE MILLS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	3,287	2.1	8.2	183.2	193.5	19.2	3.6	2.0	24.8
1911	4,390	1.1	3.4	134.4	139.0	10.3	2.1	1.9	14.2
1912	5,128	.4	4.9	174.1	179.4	3.5	4.3	2.3	10.2
1913	5,430	.6	4.6	133.5	138.7	5.0	2.7	1.8	9.5
1914	3,476	.6	3.7	91.8	96.1	5.2	2.1	1.4	8.7
Total	21,711	.9	4.8	144.1	149.9	7.9	3.0	2.0	12.9

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	1,915	2.1	6.3	332.6	341.1	18.8	8.2	3.7	30.7
1908	1,173	.9	2.6	226.8	230.3	7.7	.8	2.6	11.1
1909	1,634	.6	3.1	249.1	252.8	5.5	.4	3.1	9.0
1910	1,872	1.6	8.5	207.8	217.9	14.4	3.7	2.7	20.8
1911	1,645	....	2.4	186.0	188.4	....	1.6	2.8	4.4
1912	1,992	.5	4.0	223.9	228.4	4.5	3.0	3.0	10.5
1913	2,015	1.0	3.5	174.7	179.2	8.9	.9	2.6	12.4
1914	1,379	....	2.1	86.3	88.4	....	.6	1.5	2.1
Total	13,625	.9	4.3	214.5	219.7	7.9	2.6	2.8	13.3

No department of the iron and steel industry shows, over the period 1910 to 1914, a more consistent decline in severity rates than do the plate mills. The steps in the progress are worth emphasizing. A severity rate of 24.8 days was reduced to 14.2 days in 1911, to 10.2 days in 1912, to 9.5 days in 1913, and to 8.7 days in 1914.

The special group of plants for 1907 to 1914 shows much greater irregularity, but the reduction in severity rates is clearly defined. In 1914 the severity rate for this group touches the very low mark of 2.1 days, a mark not reached by any other department.

PUDDLE MILLS.

Under puddle mills are included the puddling process by which the iron is refined and also the rolling of the resulting blooms into muck bars.

It is probable that the puddling process itself is less hazardous than any of the other refining methods, although the heat and physical labor involved in the work demand unusual bodily vigor. In any case the combination of the relatively nonhazardous puddling process with the rolling of the resulting blooms gives to puddle mills as a unit a frequency rate of only 136.7 cases per 1,000 workers, which is lower than that for any other of the rolling mills except tube mills, where the inclusion of other than strictly rolling occupations modifies the rate. The severity rate of the puddle mills is 10 days per worker, a rate closely similar to the severity rates for other mills for which the range is from 8 days in tube mills to 14 days in heavy rolling mills.

The rates quoted in the preceding paragraph are shown in Table 109. It has not been possible to compute satisfactorily accident rates for puddle mills by individual years.

ROD MILLS.

Accident rates by individual years could not be satisfactorily shown for rod mills. Probably there are included under the term mills of quite different hazard. In continuous rod rolling the amount of hand manipulation is much reduced, whereas in the Garret looping mill the shift from stand to stand is largely accomplished by the workers with tongs. It has not proved feasible to separate these processes. It is probable that hand manipulation is here, as often elsewhere, associated with a relatively high accident frequency while the more mechanical processes may have a higher accident severity.

In frequency rod mills, with a rate of 159.9 cases per 1,000 workers, are next to unclassified rolling mills, with a rate of 219.9 and in which the proportion of hand manipulation is still greater. In severity the rod mills, with a rate of 11.5 days per worker, are only exceeded, among the rolling mills, by heavy rolling mills (13.5 days) and by plate mills (12.9 days).

SHEET MILLS.

The accident rates for sheet mills over a series of years are shown in the following table with accompanying chart:

TABLE 86.—ACCIDENT RATES IN SHEET MILLS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	18,501	1.5	2.8	178.9	183.1	13.1	1.7	1.7	16.5
1911	29,710	.3	2.4	122.0	124.7	3.0	1.5	1.3	5.9
1912	32,087	.6	2.1	171.3	174.0	5.3	1.6	2.1	9.0
1913	25,938	.8	2.6	143.3	146.7	7.3	1.2	1.7	10.1
1914	22,187	.5	2.3	140.3	143.0	4.1	1.2	1.7	6.9
Total	128,423	.7	2.6	150.0	153.3	6.1	1.4	1.7	9.2

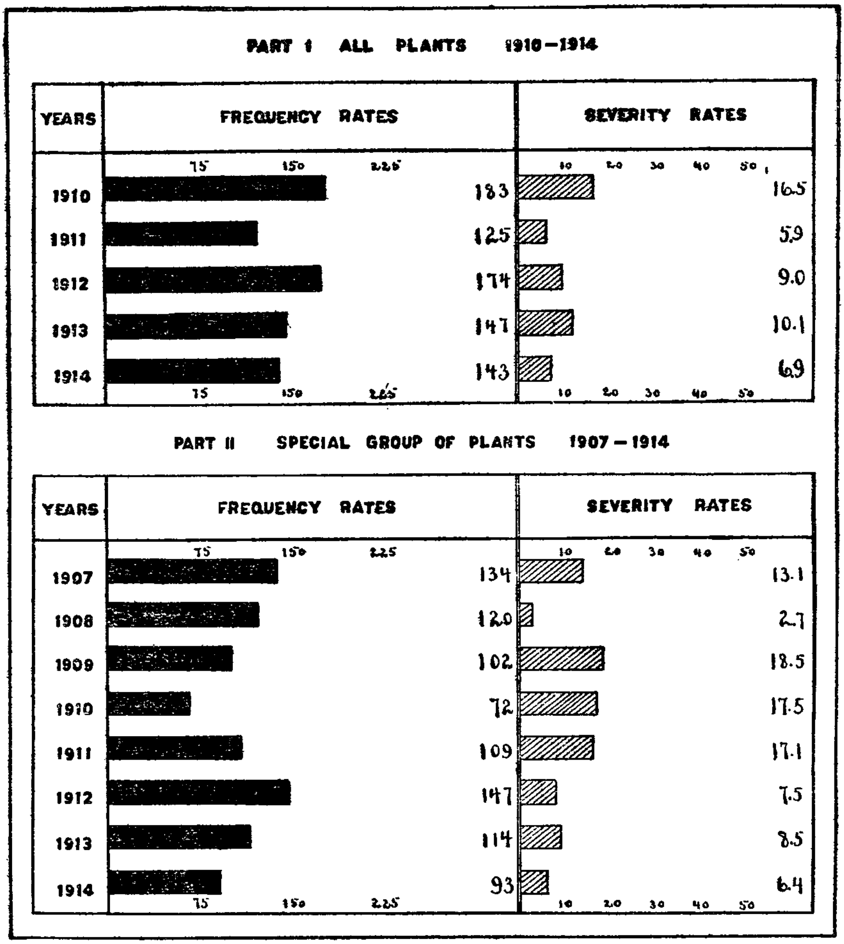
PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,211	0.9	3.6	129.8	134.3	8.1	3.8	1.2	13.1
1908	1,951	....	1.5	118.9	120.4	....	1.5	1.2	2.7
1909	2,366	1.7	5.9	94.7	102.3	15.2	2.0	1.3	18.5
1910	2,637	1.5	4.9	66.0	72.4	13.7	2.4	1.1	17.5
1911	2,433	1.6	3.7	103.6	108.9	14.8	.8	1.5	17.1
1912	2,925	.3	5.8	141.2	147.3	3.1	2.4	2.0	7.5
1913	2,691	.4	7.1	107.0	114.5	3.3	3.5	1.7	8.5
1914	1,905	.5	2.1	90.8	93.4	4.7	.3	1.4	6.4
Total	19,119	.9	4.6	106.9	112.4	8.0	2.2	1.4	11.6

These mills have distinctly lower accident rates than have other rolling mills, but hardly so much lower as might be expected from the known conditions of work.

CHART 28.—ACCIDENT RATES IN SHEET MILLS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



The frequency rate in plate mills, for example, is 149.8 cases per 1,000 workers in the period 1910 to 1914 and 219.7 in the period 1907 to 1914, while in sheet mills it is 153.3 in 1910 to 1914 and 112.4 in 1907 to 1914. When severity is considered, the sheet mills, with severity rates of 9.2 days in 1910 to 1914 and 11.6 in 1907 to 1914 have little advantage over plate mills, with rates of 12.8 days in 1910 to 1914 and 13.3 days in 1907 to 1914.

From this showing it may reasonably be concluded that the sheet mills, having less hazardous conditions to contend with, have not been led to study the safety problem as closely as some other departments. At all events the improvement shown by the tables is neither constant nor considerable.

Accident rates by occupational groups could be made in the case of sheet mills only for the special group of plants over the period 1910 to 1914. And the only occupational group that could be set off with reasonable exactness was the hot mill crew, which includes catchers, doublers, heaters, matchers, openers, rollers, roll hands, roughers, etc. Since this is the characteristic group of sheet mill workers its rates will give a definite idea of sheet mill hazards.

TABLE 87.—OCCUPATIONAL ACCIDENT RATES IN SHEET MILLS FOR THE PERIOD 1910 TO 1914.

Occupational group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Hot mill crews [1]	5,200	0.4	1.3	104.0	105.8	3.5	0.8	1.7	6.0
Other occupations	7,391	1.2	7.4	100.9	109.5	13.4	2.9	1.5	17.8
Total	12,591	.9	4.9	102.1	107.9	7.9	2.0	1.5	11.4

[1] Includes catchers, doublers, heaters, openers, rollers, screw boys, and shearmen.

The average frequency rate of the hot mill crews for the five years is 105.8 cases per 1,000 workers, while severity is 6.0 days per worker. The rates for all other workers for the same period are: Frequency, 109.5 cases; severity, 17.8 days. Thus, the hot mill crews have injuries nearly as often as those employed in other operations of the plant but of a severity only one-third as great. This contrast reinforces what was said above. The large group of sheet mill workers is relatively little exposed to hazards producing serious injury, and the frequency of accidents does not seem excessive when compared with other departments. There is reason to believe that a treatment as vigorous as has been applied in more hazardous departments would further decrease these rates to a very material degree.

TUBE MILLS.

The next table presents the accident rates for the tube mills:

TABLE 88.—ACCIDENT RATES IN TUBE MILLS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	9,767	0.3	2.6	164.6	167.5	2.8	1.0	2.1	5.8
1911	13,676	.1	3.9	152.1	156.0	.7	1.9	1.6	4.2
1912	17,080	.6	3.5	126.1	130.1	5.8	1.9	1.5	9.2
1913	18,909	.8	3.8	83.9	88.5	7.1	1.7	1.2	10.0
1914	13,906	.5	2.8	85.9	89.2	4.5	1.4	1.2	7.2
Total	73,338	.5	3.4	117.6	121.5	4.5	1.7	1.5	7.7

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,007	0.5	2.1	286.4	289.0	4.5	1.5	4.6	10.6
1908	1,451	....	4.8	212.3	217.1	....	.8	3.7	4.5
1909	1,813	.6	6.1	247.7	254.4	5.0	4.0	3.6	12.6
1910	1,792	.6	3.9	223.8	228.3	5.0	1.1	3.7	9.8
1911	1,717	....	1.2	224.2	225.4	....	.8	3.1	3.9
1912	2,131	.9	2.3	165.2	168.4	8.4	1.1	2.3	11.8
1913	2,101	1.0	1.4	76.2	78.6	8.6	.9	1.2	10.7
1914	1,527	....	2.6	42.6	45.2	....	1.9	1.1	3.0
Total	14,539	.5	3.0	185.4	188.9	4.3	1.5	2.9	8.7

The severity rate of the tube mills is seen to be 7.7 days per worker for the entire industry for the period 1910 to 1914, and 8.7 days for the special group of plants for the period 1907 to 1914. These are the lowest severity rates of any productive department, with the exception of crucible melting, which had a rate of only 7.3 days for the period 1910 to 1914.

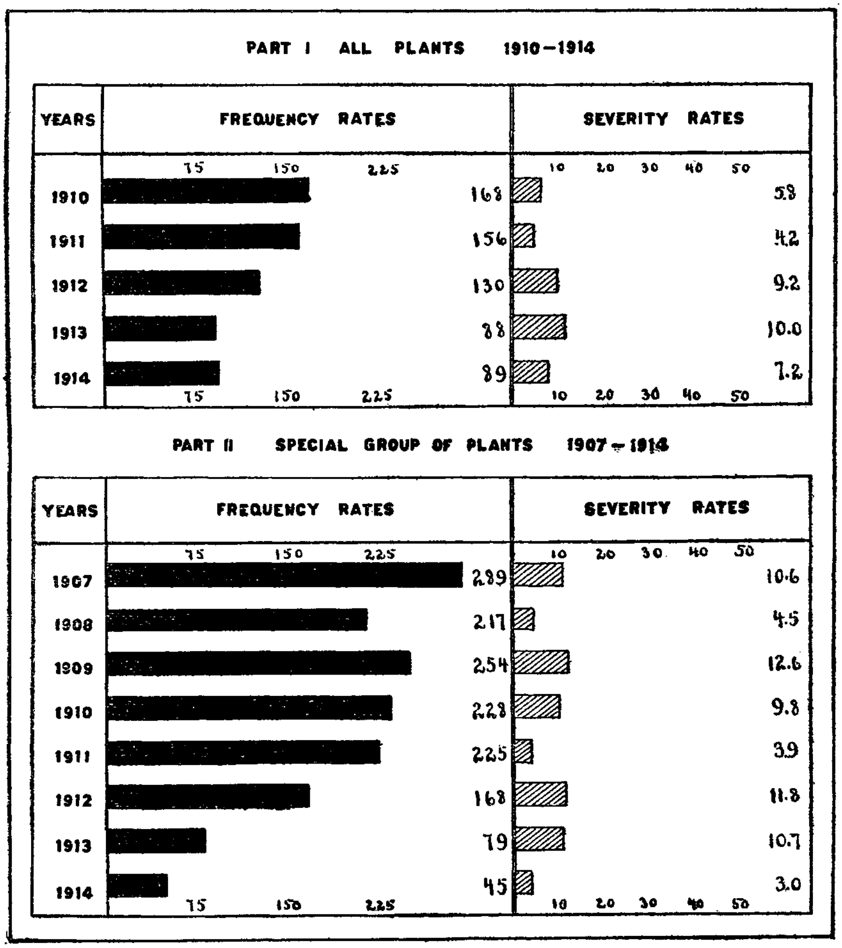
On the other hand, the operations of these mills afford opportunity for a great number of minor injuries. These have been reduced in a most notable manner as is attested by the general frequency rates from year to year, and still more emphatically by the frequency of temporary disability.

There might be some tendency to feel that such a reduction of minor injuries, which in themselves are not serious enough materially to affect the severity rates, is of little significance. This would be a serious mistake. The reduction in frequency is an index of an important effort applied to the accident problem. The frequency rate may in time doubtless reach a somewhat static condition, but this is some time in the future.

One caution is necessary. A company achieving a marked success in reducing frequency and having rather low severity might be led to give less vigorous attention to serious cases than should be given. It might well happen that under such circumstances a severity rate which could be further reduced by proper attention would remain

CHART 29.—ACCIDENT RATES IN TUBE MILLS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



stationary or even rise. Success in one field should not be permitted to divert attention from another even more important.

Occupational accident rates were computable for certain important occupational groups in the tube mills for the special group of plants for the period 1907 to 1914. These are as follows:

TABLE 89.—OCCUPATIONAL ACCIDENT RATES IN TUBE MILLS FOR THE PERIOD 1907 TO 1914.

Occupational group.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Common labor	2,123	0.9	7.1	653.3	661.3	8.5	3.8	10.7	23.0
Pipe furnace crews [1]	3,066		.9	59.4	60.3		.2	.9	1.1
Pipe finishing crews [2]	4,110	.3	1.2	59.0	60.5	2.2	.4	1.0	3.6
Unclassified [3]	5,240	.8	3.8	168.3	172.9	6.9	2.2	2.4	11.5
Total	14,539	.5	3.0	185.4	188.9	4.3	1.5	2.9	8.7

[1] Includes ballers, bar pullers, benders, heaters, hook runners, pushers, take-offs, tongmen, turndowns, welders, etc.
[2] Includes bundlers, pipe threaders, pipe testers, weighers, etc.
[3] Includes crane hookers, cranemen, mechanics, galvanizers, switchmen, etc.

The very high frequency among common labor is a notable feature of the above table, and illustrates very forcibly the class of accidents prevalent in such mills. It is instructive to compare the rates given with those in blast furnaces (Table 78), which show for common labor a frequency of 250.5 cases per 1,000 workers, and a severity of 36.8 days per worker. In the tube mills the corresponding figures are: Frequency, 661.3; severity, 23 days.

The rates for skilled workers at the furnaces and on the finishing floor are strikingly low and explain the low severity rates of the mills as a whole.

MISCELLANEOUS LIGHT ROLLING MILLS.

The rolling mills included under this heading comprise a group of mills engaged in light rolling and for the most part hand operated. The following table gives their accident rates by years from 1910 to 1914. Bar mills are included in the yearly grouping and are also shown separately for the period as a whole.

TABLE 90.—ACCIDENT RATES IN MISCELLANEOUS ROLLING MILLS OVER A SERIES OF YEARS.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	14,434	1.0	3.4	336.8	341.2	9.4	3.5	4.0	16.8
1911	21,231	.8	3.6	159.6	164.0	6.8	2.3	2.1	11.1
1912	22,909	.7	3.3	203.4	207.4	6.7	2.1	2.7	11.5
1913	23,382	1.0	3.6	216.0	220.7	9.2	2.3	2.9	14.5
1914	22,873	.5	3.3	154.8	158.7	4.7	1.8	2.2	8.7
Total	99,809	.8	3.6	215.4	219.8	7.6	2.4	2.8	12.8
Bar mills, 1910 to 1914	21,555	.6	2.3	255.5	258.4	5.4	1.7	3.6	10.7

These mills, as noted, are very largely of the hand-operated type. In accordance with usual experience, this hand manipulation tends toward a high frequency rate in these mills, the rate for the whole period being 219.8 cases per 1,000 workers. The strictly hand-operated bar mills, having 21,555 300-day workers, show a frequency rate even higher—258.4 cases per 1,000 workers. When severity is considered, the average rate for the 5 years is seen to be 12.8 days per worker in all the mills and 10.7 days in the strictly hand-operated bar mills. This tends to confirm the conclusion suggested above, that hand operations have as a rule high frequency, while those of a more mechanical nature may give greater severity. It should not be concluded from this that the introduction of machinery of necessity increases the danger of severe injury. In many cases it greatly reduces hazards; but it is always possible that it will increase them if proper precautions are not taken. A totally wrong impression often prevails with employers on this point. They install a new machine which requires fewer men to attend its operations. At once the number of accidents decreases. It is very easy from this to jump to the conclusion that the machine has improved conditions. When, however, the accidents are compared with the amount of employment, an increased accident rate may appear in frequency or severity, or in both. To prevent this, there should be critical attention to the safety of all machines to be installed and careful study of the results of their operation.

FABRICATING SHOPS.

The accident rates of the fabricating shops are shown in the following table. The relatively small number of 300-day workers shown for 1910, in the group 1910 to 1914, was due to the fact that information was obtainable for only a limited number of plants for that year; but it is believed that those included were entirely representative, and thus that the rates for 1910 may be properly compared with those for the later years.

TABLE 91.—ACCIDENT RATES IN FABRICATING SHOPS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	8,713	1.3	3.8	447.7	452.8	11.4	2.4	5.6	19.9
1911	19,530	.4	4.7	166.1	171.2	3.2	2.3	1.8	7.3
1912	28,988	1.1	4.1	237.7	242.9	9.6	2.1	2.4	14.1
1913	30,470	1.1	3.4	241.8	246.2	9.8	1.9	2.3	13.9
1914	20,837	.6	3.7	196.9	201.1	5.2	2.4	2.0	9.6
Total	108,538	.9	3.9	235.0	239.7	7.8	2.2	2.4	12.4

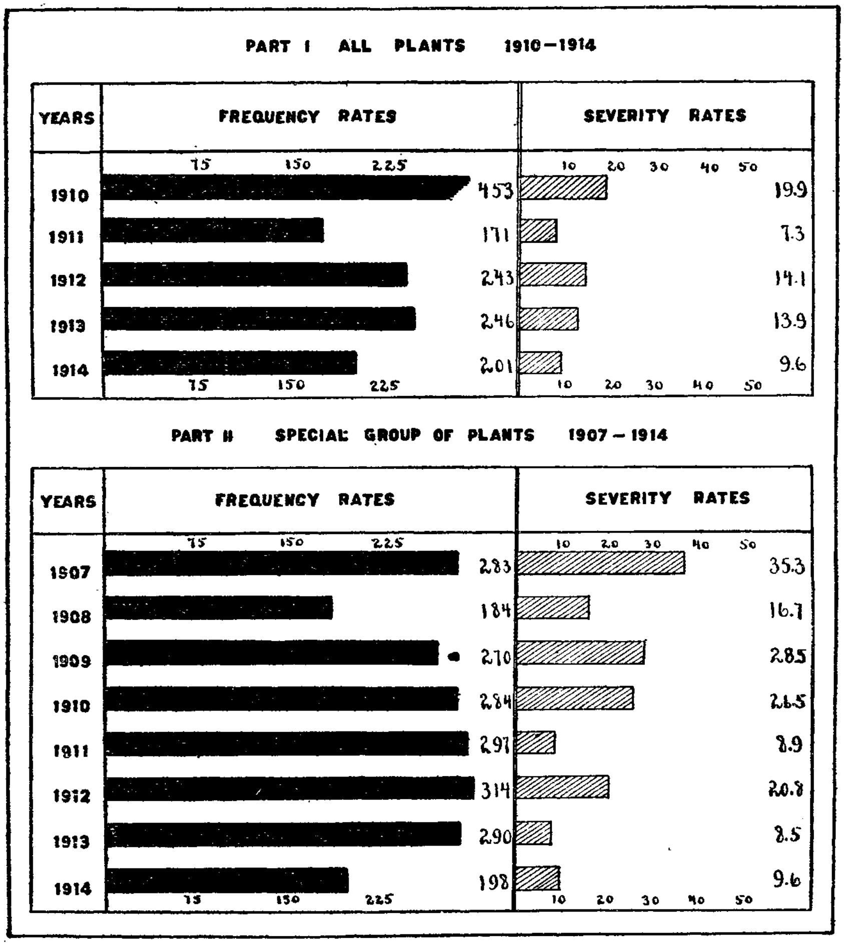
TABLE 91.—ACCIDENT RATES IN FABRICATING SHOPS OVER A SERIES OF YEARS—Concluded.

PART II.—SPECIAL GROUP OF PLANTS, 1907 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,081	2.9	5.8	274.4	283.1	25.9	6.9	2.5	35.3
1908	1,758	1.1	4.0	179.2	184.3	10.2	4.8	1.7	16.7
1909	1,770	2.8	3.4	263.3	269.5	25.4	.8	2.3	28.5
1910	2,074	2.4	5.3	276.3	284.0	21.7	2.2	2.6	26.5
1911	2,203	.5	2.7	294.1	297.3	4.1	2.1	2.7	8.9
1912	2,074	1.4	6.8	306.2	314.4	13.0	4.5	3.3	20.8
1913	2,045	.5	2.9	286.6	290.0	4.4	1.1	3.0	8.5
1914	1,759	.6	7.4	190.4	198.4	5.1	2.3	2.2	9.6
Total	15,764	1.5	4.8	261.9	268.2	13.7	3.1	2.6	19.4

CHART 30.—ACCIDENT RATES IN FABRICATING SHOPS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



The frequency rates of fabricating shops shown in the table—239.7 cases per 1,000 workers in the 1910–1914 group and 268.2 in the 1907–1914 group—are among the highest of the departments of the iron and steel industry. In severity of accident, however, these shops occupy a much lower rank, the severity rates being 12.4 days per worker for the 1910–1914 group and 19.4 days for the 1907–1914 group.

This relation between frequency and severity of accidents conforms to what might be expected from observations of conditions in fabricating shops. The operations carried on therein are of a character to produce a large number of minor injuries and a moderate number of the more severe. The fabricating shops have often been suspected of a very high severity rate because their work is associated, in the minds of many people, with the erection of the structural steel which is fabricated in these shops. But the erection of structural steel (i. e., the building of houses, bridges, etc.) is quite a distinct process, the accident rates of which are shown in a later section of this chapter.

From the above table it appears that for the major group of fabricating shops, covering the period 1910 to 1914, the lowest accident rates, both frequency and severity, occurred in the year 1911, which was, on the whole, a dull year for these shops. The following year, 1912, both frequency and severity rates rose, but during the succeeding two years, 1913 and 1914, the severity rates showed a steady decrease.

Turning attention to the special group of plants, the highest severity rate (35.3 days) is found in 1907, after which it declines by irregular steps to 9.6 days in 1914. The chart illustrating this table (chart 30) shows very strikingly the failure of frequency rates to give a true picture of accident hazard. During the eight-year period frequency rates fluctuated at about the same level, while severity rates showed a marked, although irregular, tendency to decline. The reality of such decline is brought out by contrasting the severity rate of the first four years with that of the last four years of the period. In the first four years the severity rate was 27.2 days. In the second four years it was 12.0 days, a reduction of more than one-half.

FORGE SHOPS.

The rates for forge shops are not presented separately by years, as the number of 300-day workers is hardly sufficient to make such a classification of value. The frequency rate of these shops for the period 1910 to 1914 combined was 177.2 cases per 1,000 300-day workers; the severity rate, 14.9 days per worker.

WIRE DRAWING DEPARTMENT.

The accident rates for the wire drawing departments during the period 1910 to 1914 are as follows:

TABLE 92.—ACCIDENT RATES IN WIRE DRAWING OVER A SERIES OF YEARS, 1910-1914.

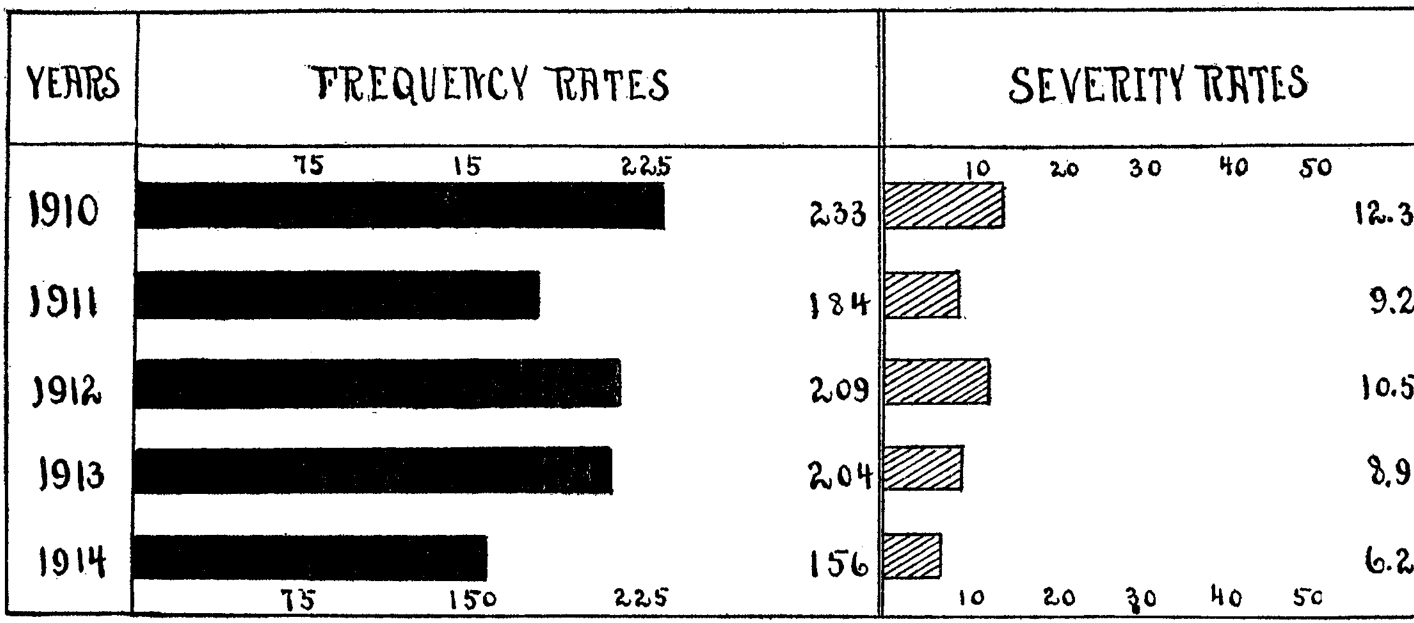
Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	10,370	0.5	8.1	224.0	232.6	4.3	5.9	2.1	12.3
1911	11,819	.3	6.9	177.1	184.3	2.8	4.7	1.7	9.2
1912	13,059	.3	8.0	201.2	209.5	2.8	5.7	2.1	10.5
1913	12,769	.5	4.6	199.1	204.2	4.2	2.6	2.1	8.9
1914	11,468	.2	4.1	151.9	156.1	1.6	3.1	1.6	6.2
Total	59,481	.3	6.3	190.4	197.1	3.0	4.3	1.9	9.3

This department presents another case in which frequency rates are high, ranging from 232.6 in 1910 to 156.1 in 1914, while the severity rates are comparatively low, ranging from 12.3 days in 1910 to 6.2 days in 1914. The figures given show a very considerable reduction in both kinds of rates during the period covered.

It is of interest to note that the wire-drawing department is less affected by industrial fluctuations than are several other departments. One evidence of this is that the number of 300-day workers does not vary from year to year so noticeably as in other cases, such, for example, as in the fabricating shops, which employed 19,530 in 1911, and 30,470 in 1913, an increase of more than 50 per cent. In wire drawing the lowest year is 1910, with 10,370 workers, the highest, 1913, with 13,059 workers, a difference of only 26 per cent. This fact is mentioned for the sake of calling attention, as it is desirable frequently to do, to the very considerable importance of a careful study of the relation of industrial fluctuations to accident occurrence. Earlier in the report (Ch. VII) such facts as have been accumulated upon this subject were presented. But, until such material has been accumulated on a much larger scale than has hitherto been possible and the assembled data are critically studied, many questions of interest and importance must remain unanswered.

CHART 31.—ACCIDENT RATES IN WIRE DRAWING OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



ELECTRICAL DEPARTMENT.

The accident rates of the electrical department of the iron and steel industry for the years 1910 to 1914 are as follows:

TABLE 93.—ACCIDENT RATES IN THE ELECTRICAL DEPARTMENT OVER A SERIES OF YEARS, 1910-1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	1,526	1.3	2.0	184.8	188.1	11.8	2.0	2.0	15.8
1911	2,760	1.1	3.3	129.0	133.4	9.8	2.0	1.6	13.4
1912	3,796	1.6	4.0	137.8	143.4	14.2	3.6	1.6	19.4
1913	4,012	3.5	3.7	123.4	130.6	31.4	2.7	1.5	35.6
1914	2,327	3.4	2.6	129.4	135.4	30.9	2.2	1.6	34.7
Total	14,421	2.3	3.3	135.7	141.3	20.7	2.6	1.6	24.9

This department shows a high fatality rate. In this respect it stands next to the blast furnaces, although its high years are not equal to the high years in blast furnaces and are very far below the experience of special blast furnaces in such years as 1907.

The rather discouraging feature of the showing of the electrical department is that while there has been a fair reduction in frequency, there has been a very marked and serious rise in severity during the last two years of the period. The number of 300-day workers, while well above the limit set for rate computations, is perhaps too small to base general conclusions upon. This is suggested by the discrepancy between the first three years and the last two. The blast furnace figures cover 20,000 300-day workers and upward in each year; the electrical department averages only about 2,800, and this exposure may not be large enough to give typical rates. The average of the five-year period with its 14,421 300-day workers must be regarded, however, as having considerable weight.

It was not possible to subdivide the cases in this department according to occupation. But it may be noted that in a special group of plants for which data are available, electricians, inspectors, linemen, and repairmen suffered 10 out of 13 fatal injuries. It is very noteworthy that but one of these 13 fatalities was from electrical current and this was not among the occupations noted above but was a common laborer who through ignorance approached some high-tension wires.

It would be unsafe to reason very definitely from this small group of fatalities, but both the figures and personal study of mill conditions seem to indicate that the direct electrical hazard is well guarded against. As has been brought out more at length in the study of causes, the chief danger of electrical employees seems to arise from being caught and crushed by unexpected movements when attempting to repair or adjust electrical equipment, and from falls from poles and other elevations. In these latter cases the electric current may play a concealed part. A shock not sufficient in itself to do damage might cause a man to lose his hold and fall from a pole. This concealed factor would in this case be similar in hazard to that of gas about a blast furnace and insecure footing in many locations.

MECHANICAL DEPARTMENT.

The accident rates of the mechanical department are shown in the following table and chart. The second part of the table, covering the special group of plants, carries the rates back to 1905:

CHART 32.—ACCIDENT RATES IN MECHANICAL DEPARTMENTS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]

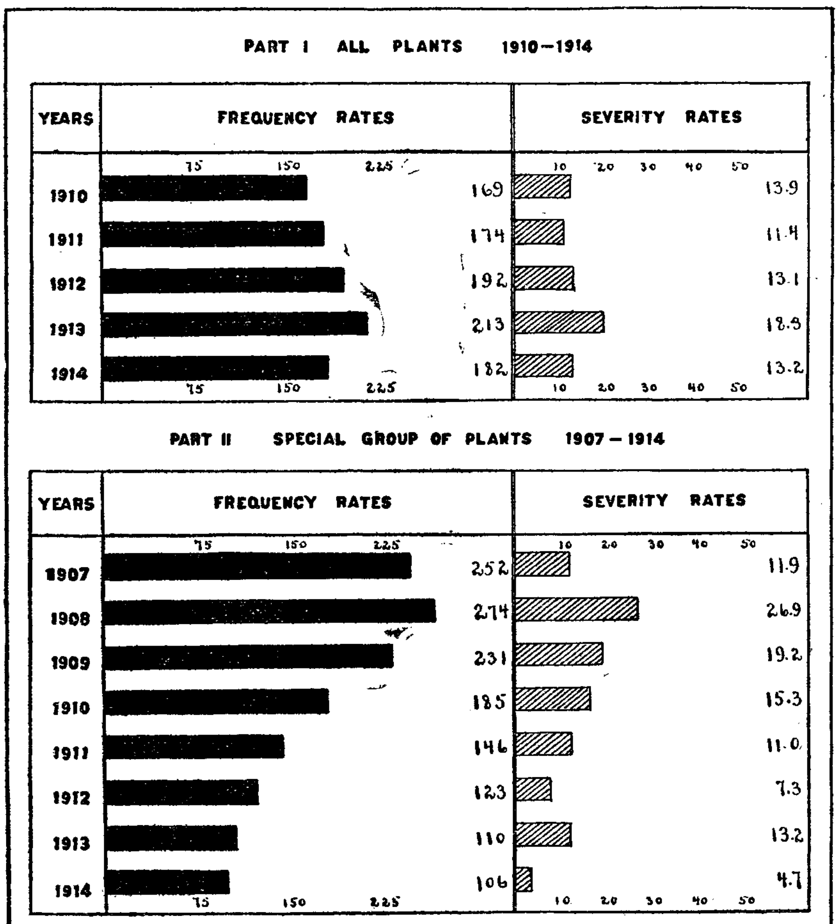


TABLE 94.—ACCIDENT RATES IN MECHANICAL DEPARTMENT OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	15,927	1.1	3.5	164.4	169.1	10.2	2.1	1.6	13.9
1911	17,863	.7	4.5	168.8	174.0	6.6	2.6	2.2	11.4
1912	21,591	.9	4.4	187.1	192.3	7.9	2.7	2.5	13.1
1913	24,009	1.5	4.3	207.1	212.8	13.1	2.4	2.8	18.3
1914	17,772	1.0	3.4	177.2	181.5	8.6	2.4	2.2	13.2
Total	97,161	1.1	4.0	183.1	188.2	9.5	2.5	2.3	14.2

PART II.—SPECIAL GROUP OF PLANTS, 1905 TO 1914.

Year.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1905	1,088	6.4	7.4	375.0	388.8	57.9	8.3	4.1	70.3
1906	1,146	.9	7.0	156.1	164.0	7.9	4.1	2.0	14.0
1907	2,542	.8	1.6	249.7	252.1	7.1	1.3	3.5	11.9
1908	1,619	2.5	4.3	267.3	274.1	22.2	1.5	3.2	26.9
1909	1,977	1.5	4.6	224.6	230.7	13.7	2.7	2.8	19.2
1910	2,223	1.3	1.3	182.2	184.8	12.1	.6	2.6	15.3
1911	2,144	.9	1.4	143.2	145.5	8.4	.6	2.0	11.0
1912	2,362	.4	3.0	119.4	122.8	3.8	1.8	1.7	7.3
1913	2,569	1.2	1.9	107.0	110.1	10.5	1.2	1.5	13.2
1914	1,662	....	5.4	101.1	106.5	....	3.0	1.7	4.7
Total	19,332	1.3	3.3	182.9	187.5	12.1	2.0	2.4	16.5

From 1910 to 1914 no steady decline in rates can be traced. On the other hand, the special group shows definite reduction and indicates possibilities toward which the department may properly work.

Since the department as a whole does not show material decline a very searching inquiry ought to be made to determine whether there may not be factors of the situation now being overlooked which, with proper attention, would bring about further improvement.

Certainly the fatality rates among mechanics are higher than should be the case. One company is using a graded system in ranking its foremen, which directs particular attention to the more serious accidents. Expedients of this kind should be given a thorough trial in the effort to extend the record of reduction.

POWER HOUSES.

It was not practicable to compute accident rates for this department by individual years. For the combined 5-year period 1910 to 1914 a total of 8,083 300-day workers showed a frequency rate of 70.6 cases per 1,000 workers and a severity rate of 10.1 days per worker.

In the study of the machine building industry, recently published by the bureau, power houses in that industry were credited with a low frequency rate (103 cases), but with a rather high severity rate (22.1 days). In the machine building report, the number of 300-day workers concerned was only 877 and a caution was given that this number was too small for the purpose of accurate rate computation. The rates for power houses in the steel industry, based as they are on an experience of 8,083 300-day workers, are probably much more typical of the real hazards of that department and are in accord with the known conditions of such employment. As yearly rates can not be computed it is impossible to determine whether improvement has taken place, but it is easily possible that this department being relatively free from minor accidents, and having no large proportion of serious injuries, has not been examined with the care necessary to produce the best safety results.

YARD DEPARTMENT.

The yard operations of steel plants involve the hazards of transportation—the movement of trains, shifting of cars, loading and unloading of freight, etc. The following table and chart exhibit the accident rates of this department by years. For the special group of plants in the second part of the table data were obtainable as early as 1905.

TABLE 95.—ACCIDENT RATES IN YARDS OVER A SERIES OF YEARS.

PART I.—ALL PLANTS, 1910 TO 1914.

Year.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	15,932	2.5	3.1	128.9	134.5	22.6	2.3	1.6	26.5
1911	9,085	1.2	4.7	147.1	153.0	10.9	4.2	2.0	17.1
1912	11,180	2.1	5.7	173.5	181.3	18.5	3.9	2.3	24.7
1913	11,859	2.4	4.3	155.9	162.6	21.2	2.3	2.1	25.6
1914	7,876	1.3	4.7	123.7	129.7	11.4	3.1	1.7	16.3
Total	55,932	2.0	4.4	145.8	152.1	18.0	3.1	1.9	23.0

PART II.—SPECIAL GROUP OF PLANTS, 1905 TO 1914.

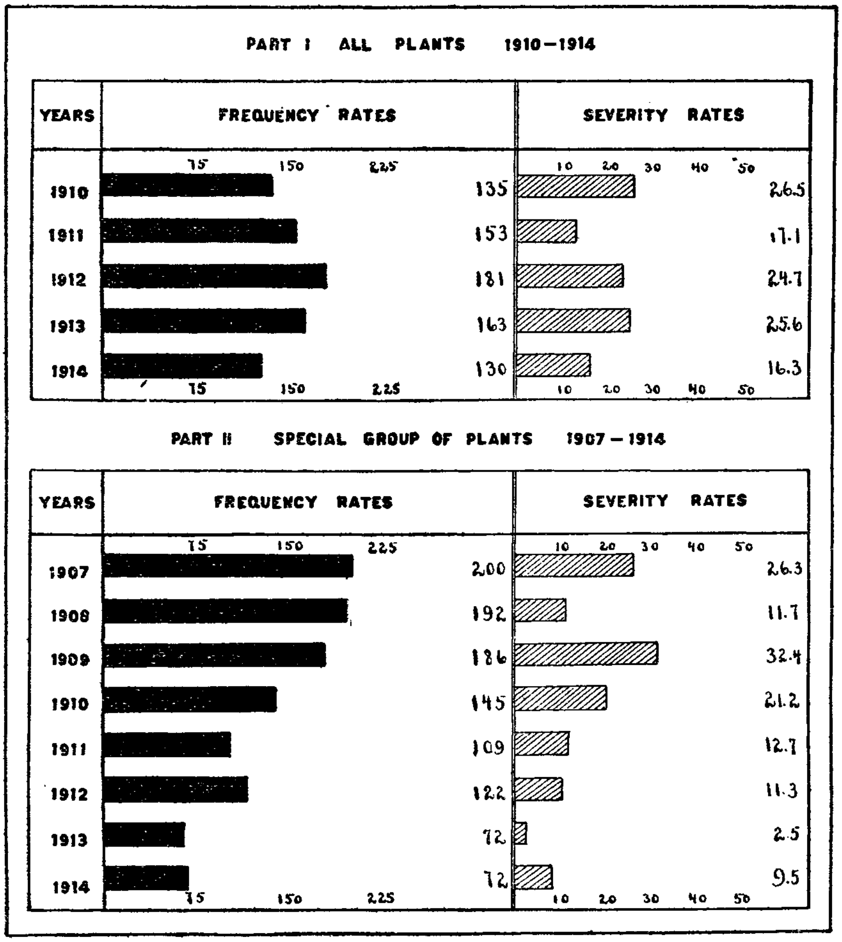
Year.	Number of 300-day workers.	Frequency: Death.	Frequency: Permanent disability.	Frequency: Temporary disability.	Frequency: Total.	Severity: Death.	Severity: Permanent disability.	Severity: Temporary disability.	Severity: Total.
1905	1,185	3.4	5.9	241.4	250.7	30.4	3.9	2.8	37.1
1906	1,136	2.6	5.3	169.0	176.9	23.8	3.8	3.1	30.7
1907	2,618	1.9	3.8	194.4	200.1	17.2	5.9	3.2	26.3
1908	1,522	.7	3.3	187.9	191.9	5.9	2.9	2.9	11.7
1909	1,891	3.2	3.2	179.8	186.2	28.6	.8	3.0	32.4
1910	2,134	1.9	5.2	138.2	145.3	16.9	2.4	1.9	21.2
1911	1,810	1.1	1.1	106.6	108.8	9.9	.7	2.1	12.7
1912	2,078	.5	5.3	116.0	121.8	4.3	4.9	2.1	11.3
1913	2,751	....	2.5	69.4	71.9	....	1.6	.9	2.5
1914	1,356	.7	3.7	67.8	72.2	6.6	1.5	1.4	9.5
Total	18,481	1.5	3.8	142.0	147.3	13.1	2.9	2.3	18.3

In this department the frequency rates for the total group of plants, for the years 1910 to 1914, gave little indication of improved conditions. The highest frequency rate (181.3 cases per 1,000 workers) is in 1912, from which there is a decline to 129.7 cases in 1914. In severity a rate of 26.5 days per worker in 1910 changes to 16.3 days in 1914.

The special group of plants from 1905 to 1914 shows a much more pronounced change: In frequency from 250.7 cases in 1905 to 72.2

CHART 33.—ACCIDENT RATES IN YARDS OVER A SERIES OF YEARS.

[Frequency rate means number of accidents per 1,000 300-day workers; severity rate means number of days lost per 300-day worker.]



in 1914; and in severity from 37.1 days in 1905 to 9.5 days. In 1913 these plants were fortunate enough to entirely escape fatality in their yard operations and consequently the severity rate touched in that year the very low point of 2.5 days.

The contrast between the results secured by the industry as a whole from 1910 to 1914 and by the special plants from 1905 to 1914 is very noteworthy. It is related very directly to more definite and vigorous efforts on the part of the managements of the special plants. By them the yard problem has been more thoroughly studied and the remedies more carefully applied. The result is that for the five-year period, 1910 to 1914, the severity rate in the special plants is 11.1 days as against 23 days for all plants.

COKE OVENS.

Until the introduction of the by-product coke oven the coke used by steel mills was seldom produced at the plants themselves. But the use of the newer process makes it convenient and economical for the larger plants to manufacture their own coke, and this department is steadily becoming a more important element in these plants. The change is indicated by the fact that by-product coke ovens now furnish some 20,000,000 tons of coke annually as against 35,000,000 tons produced by the wasteful "bee hive oven" process.

The coke oven department shows high accident severity rates. The information available is for 13,282 300-day workers during the combined 5-year period 1910 to 1914. The frequency rate for this group was 129.2 cases per 1,000 workers and the severity rate 23.3 days per worker.

The machinery employed and the conditions existing in this work would not seem to warrant such a high severity rate. The work is disagreeable and it may be that the labor employed is of less experience, and as a result subject to greater inherent hazard, than that used elsewhere. If so, the great problem of the safety man would be to make the largest possible effort toward the removal of this ignorance and inexperience.

It is not practicable to compute the accident rates for coke ovens by individual years.

MISCELLANEOUS DEPARTMENTS.

The following table shows the accident experience for the combined period 1910 to 1914 for a few departments which it has not seemed desirable to treat in greater detail, and which are not included in the general summary in Table 76:

TABLE 96.—FREQUENCY AND SEVERITY OF ACCIDENTS, IN MISCELLANEOUS DEPARTMENTS, 1910 TO 1914.

Department.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Armor plate	3,000	1.3	4.0	120.7	126.0	12.0	1.1	2.0	15.1
Axle works	1,326	1.5	3.0	330.3	334.8	13.6	5.0	4.9	23.5
Car wheels	2,367	1.3	6.3	257.3	264.9	11.4	2.0	4.0	17.4
Docks	1,293	2.3	8.5	107.5	118.3	20.9	6.6	2.5	30.0
Erecting of structural steel	2,157	12.1	11.1	342.1	365.3	108.5	14.7	5.4	128.6

Discussion of the above data will be limited to some comments upon the high accident rates in the erection of structural steel. The material upon which such comments are founded came to hand incidentally in the course of the study of the iron and steel industry as a result of the fact that certain of the steel plants were engaged in structural work. Such work lies somewhat outside the limits of the steel industry, strictly defined, but it is of such interest and importance as to warrant the inclusion here of the material referred to. It points to an industrial region which ought to be more thoroughly explored.

The accident rates for structural work, as shown in the table, are based on a group of 2,157 300-day workers. This number, while well above the limit regarded as proper for the calculation of rates, is regrettably small, and the resulting rates may not be typical. On the other hand, the fact that the rates by individual years, although based on too small an exposure to justify presentation, are substantially uniform suggests that the rates for the period as a whole may be taken as fairly typical. So far as known they are the first rates to be determined for structural steel erection, although the work has been recognized as highly hazardous.

All of the rates are very high. Death, with a frequency of 12.0 cases per 1,000 workers, is more than twice that of coal mines, with a frequency rate of 5.83 for the five years 1910 to 1914. Permanent disabilities, with a frequency of 11.1 in structural work, are nearly twice as numerous as in wire drawing, with a rate of 6.3, and lead all the steel departments in this respect. Temporary disabilities, with 342.1 cases per 1,000 workers, are materially in excess of the rate of 269.4 for Bessemer steel works.

In severity of injury, structural steel work has an even more unenviable preeminence. This severity of permanent disability (14.7 days) is more than 3 times that of wire drawing (4.3 days). The severity of temporary disability (5.4 days) is above that of miscellaneous rolling mills, which has the highest rate (3.6 days) of any of the operative departments. The general severity rate (128.6 days) exceeds that so far found for any department except a group of blast furnaces in a year marked by extraordinary fatality.

These figures certainly demand most serious consideration. The operations of the companies whose experience is noted are known to be conducted with as much attention to safety as those of any engaged in this hazardous business. In fact they probably represent, on the average, a greater care than prevails in such operations as a whole. Clearly then the erection of structural steel must be recognized as one of the most, if not the most, hazardous of industrial operations.

With this high intrinsic hazard what can be done in the way of accident prevention? It may be said at once that this is a much more serious and difficult problem than that presented by any other industrial activity. The work is always done under conditions of some pressure. Both contractor and owner desire the completion of the structure at the earliest possible time. All apparatus is installed for temporary use and can scarcely have the solidity and security of permanent structures. Safeguards easily applicable when operations are conducted permanently in a fixed locality are highly difficult when ready removal must be possible. A construction organization can not in the nature of the case form itself in relation to the accident problem as can be done when localized.

With all these difficulties the situation should not be regarded as hopeless. The same principles apply here as in fixed industry and when worked out, as they surely will be under the steady pressure of compensation legislation, a reduction of these high rates may be anticipated.

It is quite common to attribute these rates to the recklessness of the workers. This should be done with great caution. Much that appears reckless is simply the outcome of long experience by which the man walks the slender beam high in air with perfect assurance and perfect safety. His training makes him safe under conditions where the less accustomed would be in peril moment by moment. Such study as it has been possible to make of fatalities in construction work indicates that the great majority of them appear to have some other underlying cause than any chance-taking propensities of the worker.

SUMMARY TABLES.

For convenient reference the following tables are here introduced. They bring together the experience of several of the departments considered in the chapter.

TABLE 97.—SUMMARY OF ALL PLANTS, BY DEPARTMENTS, 1910 TO 1914.

Department.	1910	1911	1912	1913	1914
	NUMBER OF 300-DAY WORKERS.				
Fabricating	8,713	19,530	28,988	30,470	20,837
Bessemer	5,070	5,155	6,521	6,885	4,470
Open hearths	9,739	10,718	17,355	20,604	12,877
Blast furnaces	19,389	21,479	27,154	31,988	26,572
Heavy rolling mills	9,442	12,409	16,258	17,569	11,985
Tube mills	9,767	13,676	17,080	18,909	13,909
Yards	15,932	9,085	11,180	11,859	7,876

TABLE 97.—SUMMARY OF ALL PLANTS, BY DEPARTMENTS, 1910 TO 1914—Concluded.

Department.	1910	1911	1912	1913	1914
	FREQUENCY RATES (PER 1,000 300-DAY WORKERS).				
Fabricating	452.8	171.2	242.9	246.2	201.1
Bessemer	390.7	246.0	297.2	242.3	159.7
Open hearths	319.3	182.1	241.0	218.3	197.2
Blast furnaces	263.3	158.8	182.3	179.5	152.6
Heavy rolling mills	237.6	136.4	150.9	112.9	80.4
Tube mills	167.5	156.0	130.1	88.5	89.2
Yards	134.5	153.0	181.3	162.6	129.7
	SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).				
Fabricating	19.9	7.3	14.1	13.9	9.6
Bessemer	43.0	16.8	19.7	28.0	16.0
Open hearths	35.7	19.7	30.3	20.8	14.9
Blast furnaces	38.4	26.5	29.5	29.1	20.1
Heavy rolling mills	24.4	10.7	14.6	10.8	10.4
Tube mills	5.8	4.2	9.2	10.0	7.2
Yards	26.5	17.1	24.7	25.6	16.3

TABLE 98.—SUMMARY OF A SPECIAL GROUP OF PLANTS, BY DEPARTMENTS, 1907 TO 1914.

Department.	1907	1908	1909	1910	1911	1912	1913	1914
	NUMBER OF 300-DAY WORKERS.							
Fabricating	2,081	1,758	1,770	2,074	2,203	2,074	2,045	1,759
Open hearths	2,987	2,120	2,872	3,138	2,725	3,525	3,603	2,483
Blast furnaces	1,566	1,274	1,486	1,353	1,380	1,749	1,658	1,160
Heavy rolling mills	4,556	3,135	4,210	4,886	4,195	5,226	5,287	3,504
Tube mills	2,007	1,451	1,813	1,792	1,717	2,131	2,101	1,527
Yards	2,618	1,522	1,891	2,134	1,810	2,078	2,751	1,356
	FREQUENCY RATES (PER 1,000 300-DAY WORKERS).							
Fabricating	283.1	184.3	269.5	284.0	237.3	314.4	290.0	198.4
Open hearths	313.4	202.9	230.8	191.2	152.3	156.7	151.3	115.2
Blast furnaces	304.0	222.1	207.9	187.0	126.8	124.6	91.0	75.0
Heavy rolling mills	195.8	171.0	185.1	141.2	139.2	133.2	99.3	57.1
Tube mills	289.0	217.1	254.4	228.3	225.4	168.4	78.6	45.2
Yards	200.1	191.9	186.2	145.3	108.8	121.8	71.9	72.2
	SEVERITY RATES (DAYS LOST PER 300-DAY WORKER).							
Fabricating	35.3	16.7	32.6	26.5	8.9	20.8	8.5	9.6
Open hearths	52.8	7.5	14.6	14.1	9.9	12.6	29.8	11.6
Blast furnaces	64.1	35.2	58.7	27.4	23.2	7.9	20.0	19.6
Heavy rolling mills	19.4	10.3	18.4	15.5	14.4	5.6	7.5	5.4
Tube mills	10.6	4.5	12.6	9.8	3.9	11.8	10.7	3.0
Yards	26.3	11.7	32.4	21.2	12.7	11.3	2.5	9.5

THE PERIOD 1910 TO 1914 AS A STANDARD OF COMPARISON.

The period 1910 to 1914 has a number of features which commend it as a suitable standard for measuring future progress from year to year. By 1910 the movement for safety had gained some headway. During the period it was vigorously promoted and spread rapidly.

It represents therefore a period which had neither the very serious conditions of earlier years such as 1907, nor had it as yet reached the hoped-for goal. It includes enough of good and bad to offer an average standard. It includes also years of high, medium, and low industrial activity, 1910, 1911, and 1912 being only moderately active business years, 1913 being highly active, and 1914 being a year of rather low activity. This admixture of varying degrees of activity also tends to fit the period for service as a point of comparison. Table 99 may therefore be regarded as a ready reference compilation against which the operator of a specific type of mill may match his annual rates in frequency and severity with a feeling that the figures of the table represent a fair average of past experience. A rate above these averages represents possibly misfortune, possibly disgrace; in any event, a condition to be escaped from with all expedition. A rate below them represents a degree of success proportionate to the amount by which it is below and should furnish added incentive to further effort.

TABLE 99.—SUMMARY OF ACCIDENT RATES IN ALL DEPARTMENTS, FOR THE PERIOD 1910 TO 1914.[1]

Department.	Number of 300-day workers.	Accident frequency rates (per 1,000 300-day workers).				Accident severity rates (days lost per 300-day worker).			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Blast furnaces	124,636	2.6	2.9	181.1	186.7	23.4	2.8	2.5	28.7
Steel works:									
Bessemer	28,101	2.0	5.2	262.1	269.3	17.9	3.1	3.8	24.8
Open hearths	71,293	2.0	4.6	218.4	224.9	17.8	3.0	2.9	23.7
Crucible	5,144	.4	4.1	99.0	103.5	3.5	2.1	1.6	7.3
Foundries	95,917	.9	4.7	185.2	190.8	7.9	2.6	2.2	12.7
Rolling mills:									
Heavy rolling mills	67,663	1.1	3.9	133.1	138.0	9.4	2.2	1.9	13.5
Tube mills	73,338	.5	3.4	117.6	121.5	4.5	1.7	1.5	7.7
Plate mills	21,711	.9	4.8	144.1	149.8	7.9	3.0	2.0	12.9
Sheet mills	128,423	.7	2.6	150.0	153.3	6.1	1.4	1.7	9.2
Puddle mills	12,788	.7	4.5	131.5	136.7	6.3	2.0	1.7	10.0
Rod mills	13,244	.6	5.9	153.4	159.9	5.4	4.1	2.0	11.5
Miscellaneous mills	99,809	.8	3.6	215.4	219.9	7.6	2.4	2.8	12.8
Fabricating shops	108,538	.9	3.9	235.0	239.7	7.8	2.2	2.4	12.4
Forge shops	6,249	1.3	3.1	172.8	177.2	11.5	1.4	2.0	14.9
Wire drawing	59,481	.3	6.3	190.4	197.1	3.0	4.3	1.9	9.3
Electrical	14,421	2.3	3.3	135.7	141.3	20.7	2.6	1.6	24.9
Mechanical	97,162	1.1	4.0	183.1	188.2	9.5	2.5	2.3	14.2
Power houses	8,083	.7	2.6	67.3	70.6	6.7	2.5	.9	10.1
Yards	55,932	2.0	4.4	145.8	152.1	18.0	3.1	1.9	23.0
Coke ovens	13,282	2.0	2.9	124.3	129.2	18.3	3.3	1.7	23.3
Armor plate	3,000	1.3	4.0	120.7	126.0	12.0	1.1	2.0	15.1
Axle works	1,326	1.5	3.0	330.3	334.8	13.6	5.0	4.9	23.5
Car wheels	2,367	1.3	6.3	257.3	264.9	11.4	2.0	4.0	17.4
Docks	1,293	2.3	8.5	107.5	118.3	20.9	6.6	2.5	30.0
Erecting structural steel	2,157	12.1	11.1	342.1	365.3	108.5	14.7	5.4	128.6
Total	[2] 1,310,911	1.2	3.9	171.6	176.7	10.5	2.5	2.1	15.1

[1] For a table including severity rates computed on the basis of the scale proposed by the International Association of Industrial Accident Boards and Commissions see Appendix K.
[2] Including 195,553 300-day workers in unclassified plants.

CHAPTER XII.

THE METHODS OF THE SAFETY MAN.

Since the first report of this bureau upon accidents in the iron and steel industry was issued (in 1913), the safety organization has become so standardized and so well known that no more is here necessary than to recapitulate its essential elements. A safety organization to be complete and effective must include the following features:

(1) Compensation; (2) director of safety; (3) superintendents' committees; (4) workmen's committees; (5) medical and surgical care; (6) provision for the retirement of the old and incapacitated.

Compensation has now become so generally a matter of law that its steady pressure is a constantly supporting influence of the very highest importance to the safety man.

The last of the six items listed—provision for the retirement of the old and incapacitated—has reference to the need of some method of removing from industry those who because of age or physical unfitness are particularly subject to accident.

MAINTENANCE OF INTEREST.

The interest of the employer in the problem of safety is assured by the steady pressure of the compensation system. His tendency to become absorbed in the productive aspects of the business is offset by the appearance of compensation charges in his costs. But this influence is not particularly effective with the working force. It is not communicated to them and if it were would hardly excite interest.

The safety man must therefore study the methods of the publicity agent and present the interesting facts of his duty with all the persuasive eloquence which he can command. He may be worthy of all praise in other features of his activities, but if he fails at this point the failure is apt to be serious.

In the following pages are recorded some of the methods which have been evolved out of the experience of safety men in the iron and steel industry.

USE OF RECORDS AND CHARTS.

No safety man can carry on his work very long without feeling the need of recording the accident facts as they develop and of finding some way to present them so that they will convincingly carry their appropriate lesson. This has proved difficult because the essentials of such record keeping and display have not until very recently been worked out and applied. It is hoped that the studies of rate computation, the use of graphic methods, and other features of this report may afford some workable ideas upon this subject.

One method of charting, employed at intervals in this report, has so favorably impressed the practical safety men with whom it has been discussed that at their request it is here presented in detail. The method referred to is that of curve "smoothing," which was used on an extended scale in the study of labor recruiting in Chapter VII.

In most steel plants the month forms the most convenient period for accident tabulation and comparison. But, for diagrammatic purposes, the month is usually too short a period for clear-cut conclusions. Accident rates computed on a monthly basis are liable to such wide fluctuations as a result of temporary and it may be unimportant influences that the general trend of events may be entirely obscured. On the other hand, the full year as a basis of measurement is too long a period for most purposes.

This difficulty may be overcome in very considerable degree by using overlapping 12-month periods as bases for computing rates. For example, instead of computing separately the rates for, say, January, 1915, February, 1915, etc., or for the years 1915, 1916, etc., the rates may be computed for the overlapping 12-month periods ending, respectively, with January, 1915, February, 1915, and so on. The working out of this method can best be explained by means of charts 34 and 35.

Chart 34 plots the accident frequency rates, by individual months, for 5 important departments over the period 1908 to 1914, inclusive, the data being taken from the actual experience of a steel plant. This form of chart has been much used by safety men, and when the fluctuations are slight and the basic data are large in amount it gives a very satisfactory picture of conditions for each month and permits of ready comparison between months. In the case of the data here plotted, however, the fluctuations are so considerable as to make interpretation extremely difficult if not impossible.

Chart 35 presents the same data in the form of rates computed for the series of 12-month periods ending with each month from December, 1908, to December, 1914. With the curves thus smoothed it is possible to follow them readily and thereby to trace the trend of events over the period covered.

In plotting the above chart (chart 35) it will be noted that the true accident rates are used, not relative numbers. Two items of interest are thus brought out: (1) The relation of departments in accident frequency. Thus at the beginning of the period the accident rates for the mechanical department were very much higher than those for the rolling mills, whereas, at the end of the period, this relation was reversed. (2) A changed condition in any department is immediately reflected. For example, beginning with the year ending June, 1915, there is a steady rise in the frequency rates of rolling

CHART 34.—ACCIDENT RATES PLOTTED BY MONTHS.

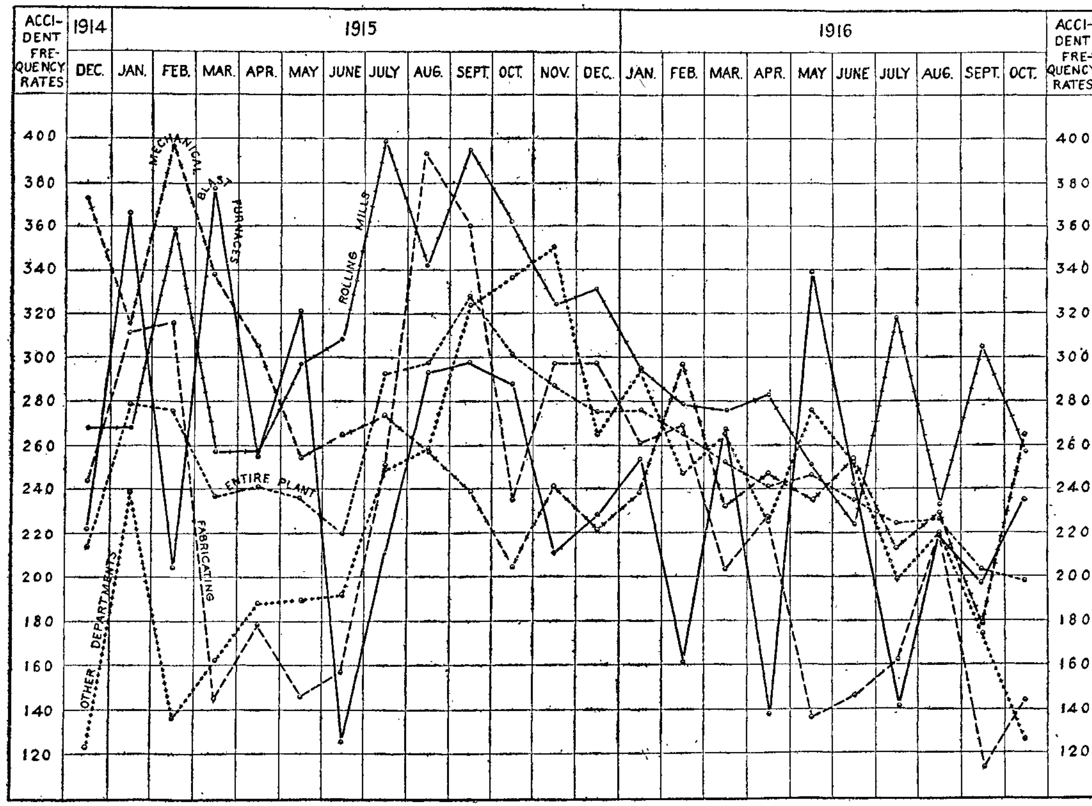
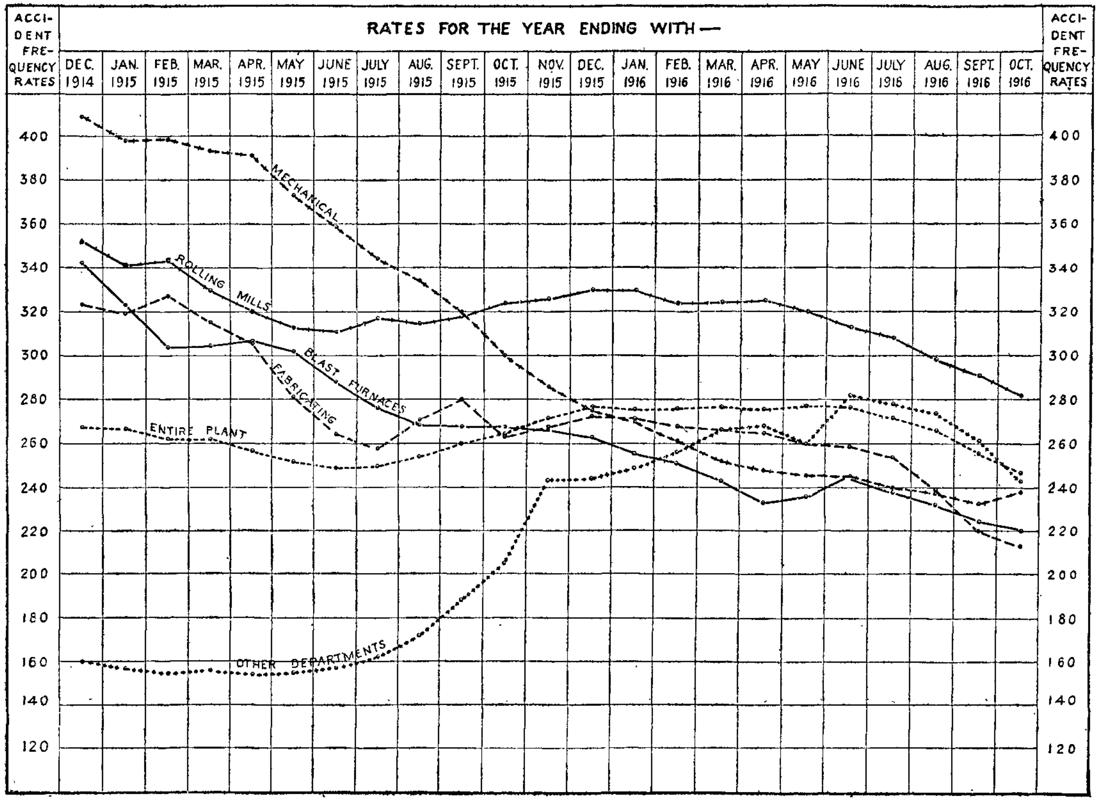


CHART 35.—ACCIDENT RATES PLOTTED BY OVERLAPPING 12-MONTH PERIODS.



mills up to the year ending December, 1915. Such a rise, showing itself on the safety man's chart, would call at once for serious attention.

METHOD OF PREPARING CHARTS.

The following description of the full process of preparing charts of the above character may appear somewhat complicated. But this impression is due to the necessary elaboration of the description and not to the processes involved, which, as a matter of fact, are simple and require little labor. For purposes of description the data for the blast furnaces plotted on charts 34 and 35 will be used.

The detailed steps are as follows: First, a form table must be prepared similar to the following:

[Form for preparing data for charts.]

Month.	Man-hours, by months.			Exposures, by months.			Exposures, by years ending—			Accidents, by months.			Accidents, by years ending—			Rates, by years ending—		
	1914	1915	1916	1914	1915	1916	1914	1915	1916	1914	1915	1916	1914	1915	1916	1914	1915	1916
	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S
January..	195,000	123,000		65	41			718		37	15			232			323	
February	207,000	162,000		69	54			703		30	12			214			304	
March....	204,000	*159,000*		68	*53*			*688*		24	*20*			*210*			*305*	
April.....	198,000			66						17								
May......	198,000			66						24								
June.....	198,000			66						19								
July......	201,000			67						22								
August...	177,000			59						22								
September	177,000			59						18								
October..	177,000			59						17								
November	135,000			45						10								
December	159,000			53			742			14			254			342		
Total.				742						254								

This form of table is arranged to carry data for three years. By additional columns it may be extended to carry data for any greater number of years desired.

Columns "A," "B," and "C" are for the entry of man-hours month by month. Using the formula, Total man-hours $\div$ 3000 = 300-day workers, the figures in column "D" are obtained. These represent the amount of monthly exposure expressed in terms of 300-day workers. Summing up column "D" gives 742 as the number of exposures for the year ending with December, 1914. This item is then entered in column "G" opposite December. In column "K" are entered the accidents for each month of 1914. The sum of these gives 254, entered in column "N" opposite December. Applying now the formula, Number of accidents ÷ Number of 300-day workers × 1000 = Accident frequency rate per 1,000 300-day workers, gives (254 ÷ 742 × 1000 =) 342, which figure is then entered in column "Q" opposite December. This rate (342) for the year ending with December, 1914, may now be plotted, giving point 1, in the curve for blast furnaces, on chart 34 above.

For the determination of later points in the curve the procedure is quite similar. Take March, 1915, for example. The number of man-hours is 159,000. This divided by 3,000 gives 53 300-day workers, entered in column "E" as the monthly exposure for March, 1915. For the 12-month period ending with March the total exposure would be this item (53) plus the corresponding items for the preceding 11 months. This would be 688, as shown in column "H." The number of accidents for the period may be determined in the same manner, the result being 210. Dividing this number (210) by the amount of exposure (688) and multiplying by 1,000 gives (210 ÷ 688 × 1000 =) 305, as the frequency rate per 1,000 300-day workers for the year ending March, 1915. This when plotted gives the entry in column 4 (March, 1915) of chart 35 above.[1]

Whenever the man hours and the number of accidents are obtained for a new month the table and the chart can be filled for that month. As has been said, such a chart gives a picture of the changes of the month so modified that it is not distorted unreasonably by local and temporary events.

THE CHARTING OF ACCIDENT CAUSES.

In precisely the same way as just described for departmental rates (as shown in chart 36), the rates for accident causes may be charted. One modification, however, will be found convenient—namely, the use of relative numbers instead of the actual accident rates. This is so, simply because cause rates vary so greatly that satisfactory plotting is difficult. By the use of relative numbers, however, it is possible to relate all the curves to the same base and thus to show how the different causes are varying with relation to each other.

Thus, it will be found convenient to reduce all of the rates to a basis of 100 for the initial year, and then to compute the later years as relatives with the first year as the base. As an example, the following

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[1] Formulas for determining exposures and accidents for years ending with given months may be formed as follows:

For exposures, let E=exposure for year next earlier than desired year, E′=exposure for desired year, e=exposure for corresponding month of preceding year, e′=exposure for current month. The formula will read $(E-e)+e'=E'$. Applying this to March, 1915, E=703, e=68, e′=53, $(703-68)+53=688$.

For accidents, let A=accidents for year next earlier than desired year, A′=accidents for desired year, a=accidents for corresponding month of preceding year, a′=accidents for current month. The formula will read $(A-a)+a'=A'$. Applying for March, 1915, A=214, a=24, a′=20; $(214-24)+20=210$.

CHART 36.—TREND OF ACCIDENT RATES IN PRINCIPAL CAUSE GROUPS.

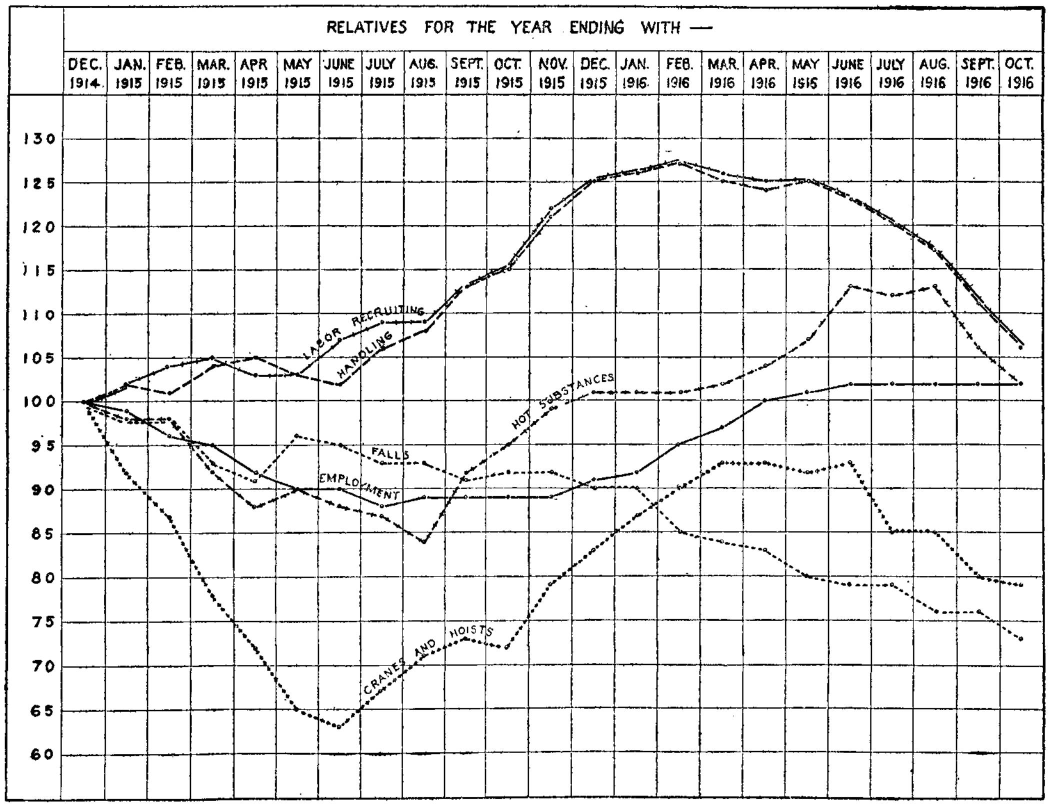

table shows the actual frequency rates for one cause of accident—handling tools and objects—and also shows the resulting relatives when the first year is taken as a base:

ACTUAL AND RELATIVE FREQUENCY RATES FOR HANDLING TOOLS AND OBJECTS. (YEAR ENDING DEC., 1914=100.)

Year ending with—	Frequency rates.			Relatives.		
	1914	1915	1916	1914	1915	1916
January	....	79.1	97.9	....	101.7	125.8
February	....	78.5	98.8	....	100.9	127.0
March	....	80.5	97.4	....	103.5	125.2
April	....	81.3	96.6	....	104.5	124.2
May	....	80.1	97.2	....	103.0	124.9
June	....	79.4	95.9	....	102.1	123.3
July	....	82.7	93.4	....	106.3	120.1
August	....	84.3	90.9	....	108.4	116.8
September	....	87.6	86.2	....	112.6	110.8
October	....	89.8	82.4	....	115.4	105.9
November	....	94.4	....	....	121.3	....
December	77.8	97.4	....	100.0	125.2	....

These relatives may thereupon be plotted, as is done in chart 36, for "handling tools and objects" as well as for three other causes. In addition, the curves for labor recruiting and employment are similarly plotted. If this chart were drawn with the rate for each month plotted separately, it would appear more confused even than chart 34 above.

Examination of chart 36 will show that at the beginning of the period all the curves were declining except those for labor recruiting and handling tools and objects. The decline of employment must have been due either to men leaving in excess of men hired, or to shortened hours of labor, or to both these factors. The decline in all cause groups except one may be explained by lessened industrial tension and by "selective discharge." Of the men leaving a large proportion would under such circumstances be the younger and less experienced men. The average quality of the force would be improving in the matter of experience. It is probable that the new men coming in were assigned largely to tasks involving handling of material, this accounting for the fact that the frequency rates for that cause did not decline as did the other cause groups.

With minor fluctuations the general decline goes on until about the year ending with July, 1915. Then labor recruiting begins an upward trend followed shortly by employment. As long as labor recruiting continues to rise the frequency rates for all the cause groups go up, with the exception of the rate for falls of worker.

Since hot substances and cranes and hoists are the groups known to have high severity, such increased frequency rates for these causes as appear on the chart from the year ending with June, 1915, and the year ending with August, 1915, would excite serious attention. An exception to the general rule appears in the case of falls of worker. This is very interesting in view of the fact that throughout the period an active campaign was in progress to improve the condition of the plant from the standpoint of cleanliness, condition of stairways and ladders, and other items likely to influence the occurrence of falls. This reinforces the point made earlier (Chapter VII) that in many cases the natural influence of increased labor recruiting may be entirely overcome by special effort.

By using colors a larger number of departments and causes can be introduced on the charts and so a very complete picture of conditions and their fluctuation can be constantly maintained for reference and study. The cause chart is particularly effective in determining whether a particular effort is bearing fruit. It is believed that safety men will find the labor of producing charts by this method fully repaid by the clearer and more reliable knowledge which they will obtain of the facts and the underlying influences at work.

AWARDS AND BONUS PLANS.

The pressure of compensation costs and the presentation of facts by means of records and charts as just described will usually keep superintendents alive to the importance of accident-prevention effort. But these will not suffice for the maintenance of an effective interest among the working force.

There is, accordingly, resort to various plans, among which awards and bonus payments play a prominent part. A simple award widely and effectively used has been the safety button. The receipt of such a distinction may be conditioned upon a certain amount of service on a safety committee or upon proof by examination of familiarity with safety rules. Experience shows, however, that the more vigorously such a campaign is pushed the more quickly does it lose its novelty and with it some of its effectiveness. Need arises very soon for some more permanent method of appeal. The interval of usefulness of minor awards may be considerably prolonged by ingenuity in varying the award or the method of deciding how it shall be given. Finally, however, it in a measure loses its significance. Rather instinctively the safety man will turn to something in the nature of a bonus. This is more likely to be true if he is a practical mill man. The bonus is perfectly familiar to him as a means of stimulating production, and he naturally looks in that direction when he needs a continuous motive to keep his safety work going among the men.

It should be pointed out that many of the very best and most effective safety men have regarded the bonus with disfavor. They hold that the humane motive should be sufficient and that an appeal on the ground of economic advantage lowers the standards which should exist. On the other hand, those who favor such methods argue that the appeal on humane grounds is left untouched, while an element is added likely to keep the matter freshly in the minds of foremen just as compensation cost does with the employer.

No attempt is here made to justify either view. The fact is simply recorded that in the search for some means of exercising a continuous pressure for the maintenance of interest among the foremen an increasing number of safety men are experimenting with some form of bonus.

As observed in practice the commonest form of such a scheme seems to be one directed to the foremen, though some cases were found of plans similar to that described in the machine-building report [1] in which one or two days' extra pay is given to the entire force of a successful department.

In installing a bonus plan a study is made of the records of previous years and rates are prepared for each department of the organization. These may be simple frequency rates or a plan of classification may be used which will give greater weight to the more severe accidents. Such rates are in principle like the severity rates of this report.

After the determination of basing rates some amount will be determined upon per man under the supervision of a foreman, such, for example, as $2. Thus a foreman having 100 men under his supervision would receive $200 if he had no accidents during a year. Suppose that a foreman is in a department whose basing rate is 80 and he comes through the year with a rate of 60. This is 25 per cent of a possible reduction of his basing rate to zero. He would receive 50 cents per man under his supervision. If there were an average of 60 men his bonus would be $30.

No attempt can safely be made to introduce the question of responsibility. To do so leads to endless difference of opinion tending to obscure the real issue. Each accident is charged up to the foreman under whom the man works.

Monthly the records are cast up. The safety office transmits to the accounting department a record of all accidents and of the foremen to whose accounts they are chargeable. A regular blank form is usually provided on which is entered the complete accident record and the standing of each foreman both for the month and cumulative to date. These reports are distributed to various interested parties, such as the general superintendent, each departmental superintendent, and the safety office. Each foreman has his own record for the month and for the year to date.

It is to be noted that it is the year's record which counts. Each month the foremen have a reminder of their duty and opportunity in the matter.

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[1] Bulletin of Bureau of Labor Statistics, No. 216.

It is probably too soon to reach any conclusion regarding the effectiveness of this method. This much is certain, for the swarm of minor injuries for whose reduction personal care is the only remedy the bonus plan seems to have had a very marked success. This is in considerable degree due to the care which it induces the foremen to take in breaking in new men and instructing them both in the dangers of the work and in safe methods.

BULLETIN BOARDS AND DISPLAYS.

As a means of direct appeal something which can be seen has great force. Quite early in the movement a great many companies used with good effect illuminated bulletins at the entrances to their plants. The extension of this system to bulletins in all parts of the works, supplied with fresh material from time to time, has been a very potent influence. An important modification has been the use of a projection lantern. Its use is sometimes confined to strictly safety matter, but very commonly other material of interest is interspersed which serves to emphasize the pictures related to safety when they are displayed.

COOPERATION WITH COMMUNITY AGENCIES.

Among such agencies which different safety men have used effectively are the school, the community associations, visiting nurses' organizations, and the church.

The importance of such forms of activity for the long future of the safety movement can not be overestimated. Their immediate results may not be measurable by any assembly of rates but they serve to establish that foundation of appreciation and intelligence which is essential if sound progress is to continue.

COOPERATION OF ENGINEERS.

Elsewhere it has been pointed out that industrial death must be eliminated, if at all, by thorough engineering revision. Naturally from the nature of the development of the safety movement many safety men are not engineers. They can not look upon their problems with the thoroughgoing understanding of the trained engineer. This should be a warning. Unless safety men bring to their aid every resource of engineering method to a much larger degree than they have already done the end of their progress is in sight. With generous and unstinted use of engineering skill, industrial death may be reduced to a degree not yet even faintly appreciated. Without such emphasis upon, and extension of engineering effort there is little hope of getting much beyond the sorry makeshift of compensating for the worker's death.

APPENDIX A.—SAFETY CODE FOR HOISTING CHAINS.[1]

(*Bulletin of National Safety Council.*)

The following recommendations are made for operations requiring the use of chains as hoisting accessories:

1. Material.

Decide upon the material desired for manufacturing the chain. Low carbon open hearth steel and wrought iron are both used by reliable manufacturers. Some engineers favor the use of the best quality of iron, such as Norway or Swedish, claiming it will lend itself to a better weld, has a greater ductility, which allows it to yield under an overload rather than snap, and is less liable to injury than steel if worked at improper temperatures. A suitable quality of iron should be tough and produce a silky, fibrous fracture; it should be uniform throughout, free from laminations caused by layers of slag between the fibers, and be free from an excess of phosphorous and sulphur, which would cause cold and red shortness.

2. Specifications.

Prepare a rigid set of specifications to govern the purchase of all chains, and insist that the purchasing department buy on quality and reputation of manufacturer, rather than price. The following points should be covered by a good set of specifications:

(a) Material.—Insist on material passing physical tests in accordance with the standards adopted by the American Society for Testing Materials.

(b) Workmanship.—Links should have a smooth, workmanlike finish, and be free from cracks and scars of such a nature as to cause a material reduction in the net cross-sectional area. Links should be formed by the three-heat process; that is, first heat, bending the stock bar to U shape; second heat, scarfing the ends; and third heat, driving home the weld. Insist on hand-made links with long lap welds, so finished as not to cause a bulging or any material increase of the section at the weld. Machine-made or so-called coil-wound links are not acceptable, because such severe initial internal stresses are set up in the stock bar, due to being bent around so short a radius while cold. Such links also have the additional disadvantage of a short-lap weld. Variation in the diameter of the stock bar used in the link at any section should be limited to one-twentieth of an inch. The stock bars should be as nearly circular in section as possible, because any irregularities will cause an unevenness of bearing between the finished links. The method of closing a weld with a "foot dolly" is not objectionable, provided the chainmaker is careful not to hammer the link after it has lowered in temperature, as such a procedure will undoubtedly harm the weld. In an attempt to make a weld have a good shape; chainmakers often make the serious mistake of hammering the weld until it is cold. Such a process tends to harden the metal and reduces its ductility. Great care should also be taken by the chainmaker to see that the scarfs are free from grit and dirt before bonding them.

(c) Proportions of links.—The major and minor axes of a link should be as small as possible, as it not only gives a greater flexibility to the chain, but also keeps the

[1] By Earl B. Morgan, Safety Engineer, Norton Co., Worcester, Mass.

bending stresses in the link down to a minimum. The following dimensions are recommended:

Diameter of section.	Inside minor axis.	Inside major axis.
$\frac{3}{8}$ inch.	$\frac{9}{16}$ inch.	$1\frac{1}{8}$ inches.
$\frac{7}{16}$ inch.	$\frac{5}{8}$ inch.	$1\frac{1}{4}$ inches.
$\frac{5}{8}$ inch.	$\frac{7}{8}$ inch.	$1\frac{3}{4}$ inches.
$\frac{9}{16}$ inch.	$\frac{3}{4}$ inch.	$1\frac{5}{8}$ inches.
$\frac{3}{4}$ inch.	1 inch.	2 inches.
$\frac{7}{8}$ inch.	$1\frac{1}{4}$ inches.	$2\frac{3}{8}$ inches.
1 inch.	$1\frac{3}{8}$ inches.	$2\frac{5}{8}$ inches.
$1\frac{1}{4}$ inches.	$1\frac{5}{8}$ inches.	$3\frac{3}{8}$ inches.

(d) Proof test.—The most important function in testing a chain is the detection of defective welds and deformed links. This necessitates a careful examination after the application of a load in tension equal to the safe working load. It is also recommended that one short sample of at least three links be tested to destruction, and during the application of this loading the point at which the sides of the links begin to collapse should be carefully noted, as this is really the critical strength of the chain. (Analagous to elastic limit of a test bar.)

3. Safe Loads.

Prepare a table of safe loads, based upon the maximum permissible stress of the material that is used in the manufacture of the link. The following formula is recommended as amply safe, and, although it gives loads that are much smaller than those recommended by well-known manufacturers, the users of such loads can feel reasonably assured that the material has not been stressed beyond the elastic limit:

FORMULA.[1]

$P=0.4\ fd^2 \times f \times d^2$

Where P=the safe load, and

f=the permissible fiber stress of the material in the link, and

d=the diameter of the stock used in the links.

Generally the strength of a chain link is calculated from the direct internal stresses produced in the cross section of the link by the loading and neglecting the bending stresses which are undoubtedly present. The formula cited above takes into consideration the stresses produced by the bending movement, which accounts for the lower value of the safe loads.

Insisting on proper loading of chains is a most important precaution, as overloading will cause fatigue or so-called crystallization by reducing the ductility or hardening the material, and annealing after such a state is reached does not restore the ductility completely, although it does remedy the condition.

Annealing chains once before they go into service is good practice as any internal stresses that may have been set up during the manufacture of the chain are thereby relieved. This annealing should be carefully done by the closed process. Open annealing gives the oxygen of the air a chance to act and will cause scaling. Do not attempt to anneal without an accurate pyrometer, and treat at least 30 minutes (to get complete saturation) to not less than 1,700° F. The best success can be obtained by using a gas or oil furnace.

4. Marking and Records.

Mark each chain by stamping some identifying letter or number on the connecting ring. This mark should refer to a card record containing the following information:

[1] This formula developed by experimental station, University of Illinois.

(1) Description of the material used in manufacture; (2) dimensions of the chain; (3) class of work for which it is used; (4) proof test; (5) safe working load; (6) date issued for service; (7) date of repair and nature and extent of same.

5. INSPECTION DURING SERVICE AND AFTER REPAIRS.

Inspection should be made at least once a week, and oftener if the chain is in constant use, by a competent and experienced man to detect any appreciable reduction of section in the links due to wear or abrasion, any deformation of the links due to overloading, and visible flaws in the welds. Chains which have been overloaded to such a point as to cause fatigue can be detected by a characteristic ring, which is yielded when struck a sharp blow with a hammer. Further proof of such condition can be obtained by placing the link edgewise on an anvil and striking it several sharp blows with a sledge. If it is fatigued it will fracture sharply with a decided crystalline appearance. In case a chain is found to contain a link of such a nature the safe thing to do is to discard the entire chain for all overhead lifting purposes where life is in danger.

6. RINGS.

Be sure the connecting ring is designed to resist the same safe load as the chain. The following formula is recommended:

$$P=\frac{0.617\, fd^3}{D}$$

Where P=the safe load,
f=the fiber stress of the material used,
d=the diameter of the stock in the ring, and
D=the main diameter of the ring.

7. HOOKS.

Be sure the hook is properly designed by a competent engineer. The common practice in designing hooks seems to neglect the fact that it is a matter of strength in a curved beam rather than a straight beam, and therefore gives a load far too large for safety.

This subject is too complicated to go into detail, but any further information that is desired will be gladly furnished by the council upon request.

Most important of all—do not overload the chain, and in case it has been overloaded do not resort to annealing as a remedy, for annealing positively will not restore the original physical qualities of the material used in the chain. If chains, hooks, or rings have been overloaded, scrap them.

APPENDIX B.—ACCIDENT CAUSES, BY DEPARTMENTS.

In Chapter II there is presented an analysis and discussion of accident causes in the various departments of the industry. The following tables offer some supplementary information of considerable interest. They are presented here because of the fact that the system of cause classification available is somewhat different from that followed in the text presentation.

Table 100, consolidating a three-year experience, presents the contrast between the rates for the different causes which prevail under the various conditions incident to the manufacture of different products. For example, "cranes" had a frequency rate of 8.3 cases per 1,000 300-day workers in companies manufacturing miscellaneous steel products, while for the companies manufacturing fabricated products the rate was 25.0. The second and third columns of Table 100 show that mills largely modern and thoroughly organized for safety have a measurable advantage over mills of older type and organized more recently.

Table 101 presents the same material as the preceding table for each of the three years. A very constant downward trend is observable. All rates showing an increase over the rates of the previous year are printed in italics. Frequency rates for the entire group of plants ran as follows in the three years: 1913, 174.5 cases per 1,000 300-day workers; 1914, 124.7 cases; 1915, 124.3 cases. The severity rates for the same period (which can not be shown in the detailed table because known only for the totals) are: 1913, 15.45 days lost per 300-day worker; 1914, 11.44 days; 1915, 11.10 days.

Table 102 presents the experience of a large plant for two years after safety organization was effected. Four of six departments show marked decline in the frequency rate for the period. The italic type indicates the cases where the rate increased.

In addition, by comparing the total column of Table 102 with the total column of Table 100 emphasis is again laid on the progressive possibilities of accident prevention. Table 100 shows a total frequency rate of 143.7. This is the experience of a very large group of plants which have been for varying lengths of time engaged upon the safety problem, all of them organized some years prior to the company represented by Table 102, for which the total frequency rate is 311.9. When the subtotals for the main cause groups are examined it will be found that almost without exception Table 102 shows the higher rates, such, for example, as falling objects with a rate of 58.9 cases as against a rate of 29.4 cases for Table 100.

TABLE 100.—ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS) IN PLANTS PRODUCING SPECIFIED PRODUCTS, BY CAUSES, FOR THE PERIOD 1913 TO 1915.

Cause.	Miscellaneous steel products.		Manufacture of tubes.	Manufacture of wire.	Fabricated products.	Manufacture of sheets.	Total.
	Company A (safety work begun early).	Company B (safety work begun more recently).					
Gas (asphyxiating)	0.7	1.3	0.1	0.2	(1)	....	0.6
Hot substances:							
Electricity	1.2	2.0	.4	.6	1.2	0.3	1.1
Hot metal	9.5	13.1	4.4	6.0	4.4	4.1	8.2
Hot water, etc	2.3	4.0	1.0	5.1	.7	6.2	3.2
Total	13.0	19.0	5.8	11.7	6.3	10.6	12.9
Flying objects:							
From tools, not striking eye	.2	.6	.1	.4	2.1	.3	.5
From other sources, not striking eye	1.1	2.8	.6	1.9	5.4	1.1	2.0
Striking eye	6.9	8.1	2.7	4.4	16.0	5.7	6.6
Total	8.2	11.5	3.4	6.7	23.5	7.1	9.1
Cranes:							
Overhead	7.2	8.9	3.6	2.1	22.4	5.1	6.9
Locomotive	.7	1.2	.4	.7	.4	....	.7
Other hoisting apparatus	.4	1.5	.4	1.1	2.2	.1	.7
Total	8.3	11.6	4.4	3.9	25.0	5.2	8.3
Falling material:							
Dropped in handling	20.7	39.5	11.2	19.1	44.1	22.1	26.7
Other	1.2	3.9	.8	2.8	5.9	1.7	2.7
Total	21.9	43.4	12.0	21.9	50.0	23.8	29.4

1 Less than 0.005.

TABLE 100.—ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS) IN PLANTS PRODUCING SPECIFIED PRODUCTS, BY CAUSES, FOR THE PERIOD 1913 TO 1915—Concluded.

Cause.	Miscellaneous steel products. Company A (safety work begun early).	Miscellaneous steel products. Company B (safety work begun more recently).	Manufacture of tubes.	Manufacture of wire.	Fabricated products.	Manufacture of sheets.	Total.
Falls:							
From ladders	0.6	0.7	0.4	0.7	0.8	0.3	0.6
From scaffolds	.7	.9	.2	.6	1.7	.2	.7
Into openings	.5	.9	.2	.3	.2	.3	.5
Due to insecure footing	6.0	13.2	3.4	10.5	18.4	12.7	10.5
Total	7.8	15.7	4.2	12.1	21.1	13.5	12.3
Heat, cramps, and exhaustion	1.0	2.9	.4	.8	.7	5.7	2.1
Handling tools and objects:							
Caught between	7.0	10.9	3.0	7.1	27.5	4.7	8.7
Operating trucks	1.4	3.1	2.0	9.1	4.6	6.8	4.5
Hand tools	5.3	11.0	3.4	7.0	22.6	11.1	9.0
Slivers and edges	2.6	7.0	2.1	22.5	6.7	21.4	10.7
Lifting	3.0	8.9	2.0	13.4	5.4	5.4	7.3
Total	19.3	40.9	12.5	59.1	66.8	49.4	40.2
Machinery:							
Caught by	3.5	4.2	2.5	11.5	11.6	6.4	6.1
Breakage	.2	.3	.2	.7	.3	.3	.4
Moving material in	1.5	2.9	1.7	6.1	.7	1.0	2.8
Total	5.2	7.4	4.4	18.3	12.6	7.7	9.3
Power vehicles:							
Collisions	(1)	.5	.1	.1	.2	(1)	.2
Coupling	1.0	1.6	.5	.5	.5	.2	.9
Falls from car, etc	.4	1.4	.4	.4	.7	.2	.7
Working in or about	.3	2.0	.1	.5	.3	.2	.8
Other	1.3	6.3	.8	1.5	2.1	1.5	2.9
Total	3.0	11.8	1.9	3.0	3.8	2.1	5.5
Unclassified	8.9	13.1	5.2	20.9	11.9	20.9	13.8
Grand total	97.4	178.7	54.1	158.4	221.6	146.2	143.7
Number of 300-day workers	*56,078*	*123,294*	*54,154*	*77,296*	*24,296*	*52,375*	*387,265*
Total accidents	*5,464*	*22,031*	*2,928*	*12,244*	*5,333*	*7,655*	*55,655*

(1) Less than 0.005.

TABLE 101.—ACCIDENT FREQUENCY RATES (PER 1000 300-DAY WORKERS) IN

Cause.	Miscellaneous steel products.						Manufacture of tubes.		
	Company A (safety work begun early).			Company B (safety work begun more recently).					
	1913	1914	1915	1913	1914	1915	1913	1914	1915
Gas (asphyxiating)	0.7	0.9	0.5	1.7	1.2	0.9	0.2	0.1	0.1
Hot substances:									
Electricity	1.6	1.6	.6	2.5	1.8	1.5	.8	.1	.2
Hot metal	12.1	9.6	6.0	16.6	8.8	12.8	6.7	2.9	2.6
Hot water, etc	2.9	2.1	1.8	4.7	3.2	3.8	1.0	1.2	.9
Total	16.6	13.3	8.4	23.7	13.8	18.1	8.5	4.2	3.7
Flying objects:									
From tools, not striking eye	.1	.3	.2	.7	.7	.6	.1	.1	.1
From other sources, not striking eye	.9	.9	1.4	3.1	3.8	2.7	.5	.8	.5
Striking eye	7.3	6.2	6.9	10.6	9.6	6.6	4.8	1.8	.8
Total	8.3	7.4	8.5	14.4	14.1	9.9	5.4	2.7	1.4
Cranes:									
Overhead	9.3	6.9	4.6	8.6	7.9	10.1	5.1	2.7	2.3
Locomotive	.8	.4	.8	2.0	.7	.7	.6	.1	.6
Other hoisting apparatus	.5	.3	.3	1.4	.8	.7	.4	.5	.2
Total	10.6	7.6	5.7	12.0	9.4	11.5	6.1	3.3	3.1
Falling material:									
Dropped in handling	25.2	19.9	15.1	47.8	30.3	37.1	15.7	8.4	7.8
Other	1.8	.5	.9	6.2	2.7	2.2	1.3	.5	.4
Total	27.0	20.4	16.0	54.0	33.0	39.3	17.0	8.9	8.2
Falls:									
From ladders	.8	.7	.2	.8	....	.5	.5	.3	.2
From scaffolds	.4	.9	.8	1.1	.9	.6	.2	.2	.4
Into openings	.6	.5	.3	1.4	.6	.7	.3	.2	.1
Due to insecure footing	5.2	7.8	5.7	14.7	13.1	11.5	3.8	3.9	2.3
Total	7.0	9.9	7.0	18.0	15.5	13.3	4.8	4.3	3.0
Heat cramps and exhaustion	1.4	1.5	....	3.5	2.8	2.2	.5	1.4	.2
Handling tools and objects:									
Caught between	9.8	5.9	4.2	12.1	9.9	10.3	4.6	1.9	1.9
Operating trucks	1.6	1.1	1.3	3.7	2.2	3.2	3.4	1.1	.9
Hand tools	6.5	5.5	3.7	11.6	9.8	11.1	6.0	1.4	1.7
Slivers and edges	3.9	1.6	1.6	8.0	6.2	6.4	3.9	1.1	.8
Lifting	4.0	2.6	2.2	9.1	8.2	9.3	3.4	2.1	.7
Total	25.8	16.7	13.0	44.5	36.3	40.3	21.3	7.6	6.0
Machinery:									
Caught by	4.3	2.9	2.7	5.2	4.1	3.1	3.7	1.5	2.1
Breakage	.3	.1	.3	.3	.2	.3	.3	.3	.2
Moving material in	2.2	1.1	1.1	3.2	2.4	3.0	2.7	.7	1.4
Total	6.8	4.1	4.1	8.7	6.7	6.4	6.7	2.4	3.7
Power vehicles:									
Collisions	....	.1	....	.7	.4	.3	.1	....	.1
Coupling	1.4	.5	.8	2.2	1.2	1.3	.4	.3	.1
Falls from cars, etc	.5	.2	.7	2.0	1.5	.6	.3	.2	.1
Working in or about	.5	.1	.1	2.1	2.1	1.8	.1	....	.1
Other	2.3	3.1	1.0	8.1	5.8	4.6	1.1	.4	.7
Total	4.7	4.0	2.6	15.1	11.0	8.6	2.0	1.1	1.1
Unclassified	14.2	5.0	4.3	17.2	12.8	11.5	9.1	2.9	1.7
Grand total	123.1	90.8	70.2	212.8	156.6	162.0	81.6	38.2	32.3

PLANTS PRODUCING SPECIFIED PRODUCTS, BY CAUSES AND YEARS, 1913 TO 1915.

Manufacture of wire.			Fabricated products.			Manufacture of sheets.			Total.		
1913	1914	1915	1913	1914	1915	1913	1914	1915	1913	1914	1915
0.3	0.1	0.2	0.1	....	....	....	....	....	0.8	0.5	0.4
.6	.9	.2	1.6	1.1	1.0	0.4	0.3	0.2	1.4	1.1	.7
7.9	5.5	4.6	5.8	2.5	4.3	4.7	4.4	2.7	10.7	6.4	6.7
4.2	4.7	6.3	.9	.4	.7	8.8	5.2	4.5	4.0	3.2	3.6
12.7	11.1	11.1	8.3	4.0	6.0	13.9	9.9	7.4	16.1	10.7	11.0
.6	.1	.4	2.5	2.3	1.3	.4	.2	.2	.6	.4	.4
1.6	1.9	2.0	9.9	3.6	1.2	2.4	.6	.3	2.4	1.8	1.7
5.1	3.6	4.3	23.3	11.2	11.0	8.8	4.7	3.2	8.8	5.3	5.2
7.3	5.6	6.7	35.7	17.1	13.5	11.6	5.5	3.7	11.8	7.5	7.3
2.5	2.1	1.6	31.3	15.5	17.2	7.1	4.2	3.9	8.4	5.8	6.0
.4	.6	1.0	.6	.3	.3	....	....	....	1.0	.4	.6
1.1	.7	.6	4.1	1.3	.3	.3	....	.1	1.1	.6	.4
4.0	3.4	3.2	36.0	17.1	17.8	7.4	4.2	4.0	10.5	6.8	7.0
22.4	16.6	17.3	59.8	33.8	33.2	31.9	19.1	14.6	33.7	21.7	22.7
3.5	1.5	3.2	7.0	5.3	5.1	1.2	2.3	1.6	3.7	2.0	2.1
25.9	18.1	21.0	66.8	39.1	38.3	33.1	21.4	16.2	37.4	23.7	24.8
1.0	.6	.4	1.3	.5	.4	.5	.3	.2	.8	.6	.3
.6	.5	.6	1.1	1.5	1.3	.4	.2	....	.7	.7	.5
.4	.1	.3	.5	.1	....	.3	.3	.3	.7	.4	.4
10.4	10.2	10.8	19.9	19.0	15.6	16.0	13.6	8.6	11.3	11.0	9.2
12.4	11.4	12.1	22.8	21.1	17.3	17.2	14.4	9.1	13.5	12.7	10.4
1.1	.9	.5	1.0	.5	.3	8.2	6.7	2.3	2.7	2.3	1.2
8.5	5.6	7.0	33.5	24.2	22.5	2.5	6.4	5.6	10.2	7.8	7.7
11.0	6.9	9.1	7.1	2.7	3.0	11.1	3.9	4.8	5.8	3.1	4.1
7.5	6.4	6.9	33.9	17.5	12.1	14.4	10.2	8.5	11.1	7.9	7.7
26.1	18.6	22.5	10.1	5.5	3.2	16.4	26.1	29.5	11.3	10.1	10.6
13.5	11.4	14.9	6.6	4.8	4.2	5.5	6.4	4.4	7.7	6.7	7.4
66.6	48.9	60.4	91.2	54.7	45.0	49.9	53.0	45.8	46.1	35.6	37.5
14.8	9.4	10.1	14.0	9.4	10.5	8.0	7.3	4.1	7.5	5.5	5.0
.7	.7	.6	.7	....	.1	.5	.5	.2	.4	.3	.3
7.6	5.6	5.2	1.9	....	....	2.6	.1	.1	3.6	2.3	2.4
23.1	15.7	15.9	16.6	9.4	10.6	11.1	7.6	4.4	11.5	8.1	7.7
.1	.1	....	.4	....	....	.1	....	.1	.3	.2	.1
.7	.2	.7	.7	.1	.7	.4	.1	.3	1.2	.5	.8
.5	.3	.4	.7	.1	1.2	.3	.3	.1	1.0	.6	.5
.7	.4	.4	.1	.5	.3	.1	.7	....	.9	.9	.7
1.6	.9	1.9	2.4	1.2	2.7	1.0	1.3	2.3	3.8	2.4	2.6
3.6	1.9	3.4	4.3	1.9	4.9	1.9	2.4	2.8	7.2	4.6	4.7
20.7	20.1	21.1	18.1	9.3	8.0	30.6	15.7	15.8	16.9	12.2	12.8
177.7	136.3	155.6	300.9	174.2	162.0	184.9	140.8	111.8	174.5	124.7	124.3

TABLE 102.—ACCIDENT FREQUENCY RATES (PER 1,000 300-DAY WORKERS) IN A LARGE STEEL PLANT, BY CAUSES, AND BY DEPARTMENTS. FOR A 2-YEAR PERIOD AFTER INTRODUCING SAFETY ORGANIZATION.

Cause.	Blast furnaces.		Rolling mills.		Wire mills.		Mechanical departments.		Fabricated products.		Yards.		Total (1914 and 1915).
	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	
Gas (asphyxiating)	1.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.1
Hot substances:													
Electricity	2.7	1.5	0.7	0.6	.....	.....	4.5	1.5	3.3	2.2	.....	1.1	1.8
Hot metal	70.1	44.4	21.9	22.1	28.1	12.1	20.1	20.2	10.7	13.9	.....	5.6	20.8
Hot water, etc	12.1	7.7	2.0	2.9	6.5	4.0	7.6	5.0	.....	1.5	8.1	.....	4.4
Total	84.9	53.6	24.6	25.6	34.6	16.1	32.3	26.7	14.0	17.6	8.1	7.7	26.9
Flying objects:													
From tools, not striking eye	4.0	1.5	.3	.3	.....	.....	3.7	1.5	.8	.7	3.5	.....	1.4
From other sources, not striking eye	2.7	4.6	1.3	2.6	6.5	4.0	11.6	7.4	10.7	2.2	3.5	5.6	5.6
Striking eye	8.1	13.8	4.6	5.5	19.4	9.4	13.0	6.5	13.2	5.9	10.4	4.4	8.3
Total	14.8	19.9	6.3	8.4	25.9	13.4	28.3	15.4	24.8	8.8	17.4	10.0	15.4
Cranes:													
Overhead	5.4	.....	11.0	16.1	4.3	.....	8.5	5.0	22.3	10.3	2.3	4.4	9.3
Locomotive	.....	1.5	.....	.....	.....	.....	1.4	.....	.....	.....	1.2	.....	.3
Other hoisting apparatus	2.7	.....	.....	.....	2.2	1.3	3.7	.....	.....	1.5	.....	.....	.9
Total	8.1	1.5	11.0	16.1	6.5	1.3	13.6	5.0	22.3	11.7	3.5	4.4	10.5
Falling material:													
Dropped in handling	59.3	38.3	47.8	76.2	43.2	22.8	38.0	21.1	53.6	54.2	33.4	54.4	45.9
Other	28.3	24.5	4.3	7.9	2.2	1.3	33.7	14.2	7.4	2.9	1.2	3.3	13.0
Total	87.6	62.8	52.1	84.1	45.4	24.1	71.7	35.3	61.0	57.1	34.6	57.7	58.9
Falls:													
From ladder	4.0	1.5	.....	1.2	4.3	.....	11.0	3.9	.8	.7	.....	.....	3.2
From scaffold	4.0	1.5	.....	.6	.....	.....	11.9	6.8	.....	.7	1.2	.....	3.6
Into openings unguarded	.....	.....	.....	.....	.....	.....	1.7	.3	.8	.7	1.2	1.1	.5
Due to insecure footing	24.3	23.0	21.2	26.6	34.6	16.1	31.7	21.6	22.3	18.3	23.0	26.7	24.5
Total	32.3	26.0	21.2	28.4	38.9	16.1	56.4	32.6	23.9	20.5	25.4	27.8	31.8
Heat, cramps, and exhaustion	2.7	3.1	1.3	.....	.....	.....	3.7	1.2	.....	.....	.....	.....	1.3
Handling tools and objects:													
Caught between	22.9	15.3	31.5	42.6	28.1	25.5	38.0	21.1	47.0	43.2	24.2	38.9	33.4
Operating trucks	.....	7.7	12.9	9.9	43.2	18.8	7.6	7.1	11.6	9.5	2.3	2.2	9.6
Hand tools	25.6	18.4	15.9	23.9	13.0	14.8	32.0	27.3	29.7	41.0	18.4	10.0	24.6
Slivers and edges	6.7	6.1	13.6	21.0	105.8	72.5	19.3	13.9	10.7	12.5	8.1	7.8	18.9
Lifting	8.1	16.8	13.9	16.4	36.7	25.5	16.4	23.1	15.7	19.0	16.1	21.1	18.0
Total	63.3	64.3	88.0	114.0	226.8	157.1	113.3	92.5	114.7	125.3	69.1	80.0	104.5
Machinery:													
Caught by	6.7	3.1	6.6	5.5	38.9	20.1	9.3	8.0	21.5	5.1	1.2	.....	8.5
Breakage	.....	.....	2.3	3.2	.....	.....	1.4	.6	.8	.....	1.2	.....	1.4
Moving material in	1.3	.....	16.3	13.7	75.6	25.5	3.4	2.7	11.6	2.9	.....	.....	9.4
Total	8.0	3.1	25.2	22.4	114.5	45.6	14.2	11.3	33.8	9.5	2.4	.....	19.3
Power vehicles:													
Collisions	.....	.....	.....	.....	.....	.....	.....	.....	.8	.....	2.3	2.2	.4
Coupling	.....	3.1	2.3	.6	.....	.....	.3	.3	.....	.7	13.8	7.8	1.6
Falls from cars, etc	6.7	1.5	1.3	1.7	2.2	.....	1.1	1.2	2.5	1.5	6.9	12.2	2.3
Working in or about	.....	.....	.....	.....	.....	.....	.3	.....	.8	.....	2.3	.....	.2
Other	18.9	10.7	7.0	6.1	6.5	1.3	6.2	5.3	3.3	.7	25.3	12.2	7.1
Total	25.6	15.3	10.6	9.3	8.7	1.3	7.9	6.8	7.4	2.9	50.7	34.4	11.7
Unclassified	13.5	13.7	12.6	20.7	34.6	20.1	67.7	48.3	22.3	18.3	5.8	22.2	31.5
Grand total	342.3	263.4	252.9	329.3	535.6	295.3	409.7	275.2	324.3	272.5	216.6	243.3	311.9
Number of 300-day workers	742	653	3,013	3,422	463	745	3,680	3,372	1,212	1,365	868	900	20,285
Total accidents	254	172	762	1,127	248	220	1,444	928	393	372	188	219	6,327

APPENDIX C.—ACCIDENT CAUSES IN BLAST FURNACES.

TABLE 103.—DETAILS OF ACCIDENT FREQUENCY RATES IN BLAST FURNACES, FOR CERTAIN CAUSES SHOWN IN TABLE 33.

Cause.	Accident frequency rates (per 1,000 300-day workers).										
	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	Total.
Cranes and hoists:											
Skip hoist	......	0.8	......	......	1.3	......	0.7	......	......	......	0.7
Other	6.2	15.1	8.3	9.4	14.8	5.2	6.5	4.6	6.0	2.6	7.9
Falling objects:											
Ore and coke from stock	18.7	7.9	2.6	2.4	1.3	2.2	.7	2.3	1.2	.9	3.5
Ore and coke from skip	......	.8	......	......	......	......	......	......	......	.9	.1
Other sources	96.8	55.5	53.0	38.5	35.0	40.7	15.9	17.7	17.5	7.8	35.6
Falls of worker:											
Into pockets and bins	2.1	......	1 3	.8	2.0	.7	......	1.1	......	1.7	.9
From transfer and larry cars	1.0	.8	......	......	......	.7	.7	1.1	......	......	.4
Other falls	19.8	23.0	21.1	25.1	12.1	22.1	9.4	14.8	7.8	11.2	16.2
Number of 300-day workers	*961*	*1,262*	*1,566*	*1,274*	*1,486*	*1,353*	*1,380*	*1,749*	*1,658*	*1,160*	*13,849*

APPENDIX D.—ACCIDENT CAUSES IN OPEN HEARTHS.

TABLE 104.—DETAILS OF ACCIDENT FREQUENCY RATES IN OPEN HEARTHS, FOR CERTAIN CAUSES SHOWN IN TABLE 36.

Cause.	Accident frequency rates (per 1,000 300-day workers).								
	1907	1908	1909	1910	1911	1912	1913	1914	Total.
Working machines:									
Charging machines	1.7	....	2.4	1.9	2.2	0.6	0.8	0.8	1.3
Objects flying from machines	.3	0.9	....	....	....	....	....	....	.1
Unclassified	2.7	.5	.7	1.3	....	.9	....	.4	.8
Cranes and hoists:									
Hot metal	3.3	.5	1.0	1.3	.7	....	.3	.4	.9
Scrap	5.7	.9	.3	2.9	....	.6	.8	....	1.4
Unclassified	29.1	24.1	20.2	18.2	18.3	13.3	11.1	12.5	18.0
Handling tools and objects:									
Objects flying from tools	2.0	.9	....	.6	.7	....	....	1.2	.6
Unclassified	43.2	22.6	35.5	32.8	23.9	25.2	23.3	21.3	28.7
Power vehicles:									
Ladle cars	.3	.5	.3	....	....	....	....	.4	.2
Ingot cars	2.3	....	....	....	....	.3	....	....	.4
Scrap cars	....	.5	.7	1.0	.4	.3	1.1	.1	.6
Other cars	14.1	6.6	9.1	7.3	6.6	11.9	13.6	2.0	9.3
Number of 300 day workers	*2,987*	*2,120*	*2,872*	*2,138*	*2,725*	*3,525*	*3,603*	*2,483*	*23,453*

APPENDIX E.—ACCIDENT CAUSES IN ROLLING MILLS.

TABLE 105.—DETAILS OF ACCIDENT FREQUENCY RATES IN ROLLING MILLS, FOR SPECIFIED CAUSES, SHOWN IN TABLES 40, 41, 43, AND 44.

HEAVY ROLLING MILLS.

Cause.	Accident frequency rates (per 1,000 300-day workers).							
	1907	1908	1909	1910	1911	1912	1913	1914
Working machines:								
Charging cranes and pushers	0.2	....	....	0.4	....	0.2	....	0.3
Roll tables	.2	....	0.2	.4	....	....	0.2	.9
Rolls	2.0	2.9	1.7	1.0	3.1	2.5	2.3	2.3
Transfer tables	.2	.6	....	....	....	....	....	.3
Hot beds	.9	.6	.5	.2	....	....	.2	.3
Shears	1.3	.3	.7	.2	.7	.8	....	.3
Straighteners	.9	1.6	1.7	.8	.7	.4	.4	....
Objects flying from machines	2.9	3.8	3.3	1.4	1.7	.4	.9	.9
Other machines	8.1	2.2	5.2	5.5	5.2	3.8	5.2	2.0
Hot substances:								
Metal in rolls	.9	1.0	.2	....	.5	....	.2	.6
Scale	1.5	1.6	2.1	.4	1.0	1.1	1.5	1.4
Other	13.6	9.3	12.1	11.5	8.6	10.1	7.2	5.4
Number of 300-day workers	*4,556*	*3,135*	*4,210*	*4,886*	*4,195*	*5,226*	*5,287*	*3,504*

TUBE MILLS.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
Working machines:								
Charging cranes and pushers	8.5	5.5	1.7	1.1	3.5	1.9	1.0	0.7
Rolls	4.5	2.8	2.2	1.1	2.9	.5	....	....
Shears	....	....	1.1	.6	.6	....	....	....
Straighteners	....	....	1.1	.6	.6	....	....	....
Threaders	5.0	9.0	11.6	4.5	4.1	1.4	.5	....
Objects flying from machines	12.0	9.6	7.2	5.0	11.1	7.0	5.7	1.3
Other machines	18.9	19.3	18.8	19.0	12.8	8.9	3.3	.7
Number of 300-day workers	*2,007*	*1,459*	*1,813*	*1,792*	*1,717*	*2,131*	*2,101*	*1,527*

PLATE MILLS.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
Working machines:								
Charging cranes	1.0	....	....	2.1	....	3.5	0.5	....
Roll tables	1.0	....	....	.5	....	....	.5	....
Rolls	1.0	2.6	0.6	4.8	4.9	....	3.5	0.7
Transfer tables	.5	....	....	....	.6	....	....	....
Hot beds	1.0	....	1.2	....	....	....	....	....
Shears	5.2	3.4	5.5	3.7	3.6	4.5	3.5	2.2
Straighteners	....	....	....	....	....	.5	....	....
Objects flying from machines	2.6	4.3	3.1	1.6	3.6	1.5	....	.7
Other machines	8.4	6.8	2.4	1.6	1.8	1.5	2.0	.7
Hot substances:								
Scale	.5	1.7	3.1	....	1.2	.5	2.0	1.5
Other	20.4	15.3	17.1	16.0	12.8	16.1	14.4	5.8
Number of 300-day workers	*1,916*	*1,173*	*1,634*	*1,872*	*1,645*	*1,992*	*2,013*	*1,379*

SHEET MILLS.

Cause.	1907	1908	1909	1910	1911	1912	1913	1914
Working machines:								
Doublers	0.5	0.5	....	0.4	0.8	0.3	0.4	....
Rolls	1.4	3.1	2.5	5.3	7.8	8.2	11.5	13.6
Shears	5.4	5.6	7.2	2.7	5.8	5.1	4.1	2.1
Objects flying from machines	.9	2.6	....	1.1	1.2	....	1.1	.5
Other machines	5.0	4.1	1.3	3.4	3.7	4.1	2.6	2.1
Hot substances:								
Sheets being handled	.5	.5	.8	.4	....	....	....	.5
Falls on hot sheets	11.3	5.6	3.8	.8	1.6	2.7	1.1	2.1
Other	10.0	5.1	3.8	3.8	2.9	4.8	1.9	4.2
Handling tools and objects:								
Opening packs	12.2	14.4	5.5	2.7	9.5	17.8	8.2	.5
Other	27.1	23.6	26.2	11.4	21.4	37.9	29.4	17.3
Number of 300-day workers	*2,211*	*1,951*	*2,366*	*2,637*	*2,433*	*2,925*	*2,691*	*1,905*

APPENDIX F.—WORKING MACHINES AS A CAUSE OF ACCIDENTS IN MECHANICAL AND FABRICATING DEPARTMENTS.

The following table presents the frequency of accidents in mechanical departments and fabricating shops, caused by the various working machines. It was not practicable to compute severity rates, which would have been of even greater interest and value.

TABLE 106.—ACCIDENT FREQUENCY RATES FROM WORKING MACHINES IN MECHANICAL AND FABRICATING DEPARTMENTS, 1907 TO 1914, BY YEARS.

Cause.	Accident frequency rates (per 1,000 300-day workers).								
	1907	1908	1909	1910	1911	1912	1913	1914	Total.
MECHANICAL DEPARTMENTS.									
Bending rolls	0.4					0.4			0.1
Boring mills							0.4		.1
Drills	3.9	1.9	2.0	5.8	2.3	.4			2.1
Lathes	2.0	1.2	4.0	1.8	3.3	2.1			1.8
Millers			.5						.1
Planers	1.2	1.9	1.0	1.3	1.4	.4	1.2		1.1
Presses and punches		1.9				3.0		0.6	.6
Reamers	.4		.5	.4					.2
Riveters	1.2	.6	1.0			.8	1.2	.6	.7
Shapers	.4		.5	.9			.4		.3
Grinding wheels	1.2	.6	2.0	.9	3.7	1.7		1.8	1.5
Objects flying from machines	18.9	22.9	14.7	8.1	12.6	8.9	2.3	4.8	11.3
Other working machines	13.8	9.3	16.2	10.3	7.0	6.4	4.3	5.4	9.1
Number of 300-day workers	*2,542*	*1,619*	*1,979*	*2,223*	*2,144*	*2,362*	*2,569*	*1,662*	*17,098*
FABRICATING DEPARTMENTS.									
Bending rolls			1.1	1.0	0.5	0.5	0.5	0.6	0.5
Boring mills	1.0					1.0		.6	.3
Drills	1.9	1.1	1.1	1.0	.9	.5	.5	2.3	1.1
Lathes		.6	1.1	2.4	1.4	1.4	1.0	.6	1.1
Planers	1.0			1.0		1.4	.5	1.1	.6
Presses and punches	1.4	1.7	6.2	3.9	4.1	7.2	3.9	3.4	4.0
Reamers	6.2	2.8	7.3	7.2	6.8	6.8	8.3	3.4	6.2
Riveters	5.8	2.3	2.3	4.8	2.7	3.4	3.9	1.1	3.4
Shears		1.7	2.8	1.4	3.6	1.4	2.0	1.1	1.8
Slotters	1.0	1.1							.3
Grinding wheels	1.0		1.1		1.4	1.9	.5	1.1	.9
Objects flying from machines	12.5	10.2	16.9	19.3	27.7	37.6	36.7	18.8	22.9
Other working machines	10.6	7.4	7.9	6.3	9.1	11.6	5.9	2.8	7.8
Number of 300-day workers	*2,081*	*1,758*	*1,770*	*2,074*	*2,203*	*2,074*	*2,045*	*1,914*	*15,674*

The rates of the above table must not be mistaken for the rates for the operators of such machines. It was not possible satisfactorily to isolate the occupations. As was pointed out in the text, working machines, while not contributing largely to the general severity rates for the department as a whole, probably show a high rate for those who operate them.

Comparing the two sections of the table it will be observed that mechanical departments have distinctly higher frequency rates upon the characteristic machine shop equipment such as boring mills, drills, lathes, and planers. Fabricating shops are higher when presses, punches, reamers, and riveters are considered. This may represent greater use in the respective departments and does not certainly indicate relative hazard of these machines. Determination of relative hazard would require occupational rates.

One further point deserves comment. Objects flying from machines have declining frequency rates in the mechanical department but show no such tendency in the fabricating shops. This is undoubtedly due to greater effort and success in the mechanical departments in introducing the use of protective goggles.

APPENDIX G.—POWER VEHICLES AS A CAUSE OF ACCIDENTS IN YARDS.

TABLE 107.—ACCIDENT FREQUENCY RATES FROM POWER VEHICLES IN YARDS, 1907 TO 1914, BY YEARS.

Cause.	Accident frequency rates (per 1,000 300-day workers).							
	1907	1908	1909	1910	1911	1912	1913	1914
Falls from moving cars or engines	1.5	0.6	1.1	4.7	3.3	1.9	0.7	0.7
Run over by moving cars or engines	3.4	1.3	2.6	.5	.6	.5	......	.7
Struck by moving cars or engines	5.0	......	3.2	4.2	1.7	.5	.7	1.5
Unsignaled movement	1.9	1.3	.5	.9	......	2.9	1.5	.7
Operation of engine	1.9	......	.5	2.3	......	1.4	1.1	1.5
Getting on or off	3.8	2.0	1.6	4.7	1.7	3.4	3.6	2.2
Operation of switches	3.1	1.3	.5	4.2	1.7	3.4	.7	3.7
Caught in frogs or switches	......	......	......	.5	......	......	......	......
Locomotive cranes moving	.8	......	......	......	.6	.5	......	......
Coupling and uncoupling	14.9	3.9	6.9	9.8	8.8	7.7	6.5	9.6
Derailments	.4	1.3	1.6	.5	1.1	1.4	.4	.7
Other	4.6	4.1	4.8	4.7	4.3	10.1	4.8	.8
Total	41.3	15.8	23.3	37.0	23.8	33.7	20.0	22.1
Number of 300-day workers	*2,618*	*1,522*	*1,891*	*2,134*	*1,810*	*2,078*	*2,751*	*1,356*

APPENDIX H.—NATURE OF INJURY, BY DEPARTMENTS.

TABLE 108.—ACCIDENT FREQUENCY RATES, BY NATURE OF INJURY AND BY DEPARTMENTS.

Nature of injury.	Accident frequency rates (per 1,000 300-day workers).										
	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
Asphyxia	4.8	0.3	0.7	......	......	0.2	0.2	......	......	0.8	0.3
Bruises, cuts, and lacerations—											
Of abdomen	.5	.7	.4	0.5	0.8	.6	.9	0.2	0.6	.5	.6
Of arm or arms	4.3	4.4	4.7	2.3	5.0	3.2	9.2	10.9	7.6	4.5	3.4
Of trunk	7.0	5.1	8.5	2.8	2.9	4.4	4.7	1.1	5.1	7.9	5.9
Of foot or toes	23.3	24.1	44.1	21.9	20.9	24.3	43.5	21.5	40.9	25.8	26.3
Of hand or fingers	24.8	40.1	49.5	37.2	51.3	34.6	53.9	30.3	75.1	50.1	34.1
Of head or neck	16.0	16.7	14.9	9.3	10.9	9.9	16.9	3.8	19.3	14.9	12.6
Of leg or legs	10.1	9.3	12.1	9.1	8.5	12.4	22.2	9.7	19.9	7.6	12.1
Unclassified	3.0	3.9	1.9	1.8	2.4	2.3	2.0	.4	.3	5.4	2.4
Total	89.0	104.4	136.2	85.0	102.9	91.6	153.4	78.1	168.9	116.7	97.3
Burns—											
By electricity	.7	.8	.1	.4	1.3	1.3	2.2	.3	1.2	1.4	.1
By gas	3.4	4.0	.4	1.0	.9	.7	1.5	1.2	.4	.2	.2
By hot metal	18.4	21.1	34.7	12.4	10.8	2.1	7.7	4.8	1.3	1.0	1.4
By hot water and steam	4.4	2.1	1.9	.2	1.2	1.0	.6	.3	.2	2.7	1.7
Unclassified	17.7	10.1	13.2	3.7	1.0	4.2	2.6	1.5	.9	4.3	3.1
Total	44.6	38.1	50.3	17.7	15.3	9.4	14.6	8.1	4.0	9.8	6.4
Crushing injuries—											
Of abdomen	.1	.2	......	.1	.1	.1	.6	.1	.1	......	.1
Of arm or arms	......	(1)	.1	.1	.1	......	.2	.1	.1	......	.1
Of chest	.2	.3	......	.2	......	.1	......	.1	.1	.2	.1
Of foot or toes	1.0	1.5	1.9	.9	.7	.6	.7	1.3	.6	.4	.9
Of hand or fingers	2.4	3.8	3.8	4.6	3.0	3.4	4.0	5.1	3.6	1.6	2.9
Of head	.2	.1	.1	.1	.1	.1	.1	.1	.1	......	.1
Of leg or legs	.3	.5	.5	.2	.1	......	.3	.2	.5	.1	.3
Unclassified	.6	(1)	.5	.1	.2	(1)	.1	.4	.8	.1	.2
Total	4.8	6.5	7.1	6.5	4.3	4.3	5.9	7.2	5.8	2.3	4.5

[1] Less than 0.05.

TABLE 108.—ACCIDENT FREQUENCY RATES, BY NATURE OF INJURY AND BY DEPARTMENTS—Concluded.

Nature of injury.	Accident frequency rates (per 1,000 300-day workers).										
	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Fabricating.	Mechanical.	Yards.
Dislocations and sprains—											
Of ankle	4.0	3.5	5.3	1.5	3.6	4.0	6.6	4.1	3.2	3.9	5.1
Of back	2.7	3.8	9.1	1.7	3.3	2.6	5.3	.8	2.6	3.7	3.1
Of elbow	.4	.3	.4	......	.5	.1	......	.1	.3	.7	.4
Of foot or toes	.5	.6	.8	.1	.3	.6	.6	.1	1.3	.6	.4
Of hand or fingers	.4	.3	.4	.3	1.1	.4	.5	.1	1.1	.4	.5
Of knee	.9	.7	1.0	1.0	.7	.8	.9	.6	1.0	1.0	.9
Of shoulder	.4	.4	1.2	.1	.5	.4	.5	.2	.6	.8	.5
Of wrist	1.8	1.2	2.0	.7	2.7	1.1	2.5	.5	2.0	2.9	1.7
Unclassified	.1	.2	1.0	.7	.7	.4	1.0	.3	.5	.3	.4
Total	11.1	11.0	21.3	6.2	13.6	10.5	17.8	6.7	12.6	14.2	12.9
Electric shock	.1	......	......	......	......	.1	......	......	......	......	.1
Eye injuries	16.5	12.6	27.5	32.5	22.1	11.6	12.0	3.4	38.8	27.9	10.1
Fractures—											
Of arm	1.1	1.1	1.3	.1	.3	.6	.7	.2	.8	.6	.6
Of both arms	......	......	.1	.1	......	......	......	......	......	......	......
Of collar bone	.2	.3	.3	.3	.1	.1	.2	.2	.2	.3	.4
Of face	.2	.3	.3	......	.1	.4	.2	.1	.6	.4	.3
Of foot or toes	1.9	3.4	3.5	2.3	1.8	3.7	5.4	2.1	12.8	2.7	3.3
Of hand or fingers	3.3	4.2	2.6	3.5	2.1	3.8	4.7	1.8	14.4	3.3	3.1
Of leg	1.5	1.9	1.9	2.0	.5	2.0	1.3	1.2	3.7	1.0	1.1
Of both legs	.1	.1	.1	......	......	......	......	......	......	.1	.1
Of pelvis	.1	.1	.1	......	.1	.1	.1	.1	......	......	.1
Of ribs	.6	.9	1.4	.7	.5	.5	.6	.3	1.6	.5	.4
Of skull	1.2	.5	1.4	.2	.1	.6	.1	.2	.9	.8	.5
Unclassified	.2	.1	.4	......	......	.1	.1	......	.1	2	.1
Total	10.2	12.8	13.5	9.1	5.7	11.7	13.3	6.0	35.2	9.8	10.1
Heat exhaustion	.1	1.5	.1	.2	.4	.3	1.6	1.6	.6	.1	.2
Infections	8.0	4.7	7.1	2.3	15.0	3.5	5.2	.6	.8	4.4	3.7
Unclassified	1.6	.8	1.8	.8	2.5	.9	1.1	.7	1.5	1.4	1.0
Grand total	190.5	192.7	265.7	160.3	181.8	144.1	226.3	112.4	268.2	187.5	147.3
Number of 300-day workers	*19,425*	*26,011*	*7,329*	*13,710*	*16,443*	*37,464*	*14,346*	*19,498*	*15,764*	*19,332*	*18,481*

APPENDIX I.—RESULT OF INJURY, BY DEPARTMENTS.

TABLE 109.—ACCIDENT FREQUENCY RATES, BY RESULTS OF INJURY AND BY DEPARTMENTS, ALL PLANTS, 1910 TO 1914.

[For number of accidents on which these rates are based see Appendix K.]

Result of injury.	Accident frequency rates (per 1,000 300-day workers).										
	Blast furnaces.	Open hearths.	Bessemer.	Foundries.	Tube mills.	Heavy rolling mills.	Plate mills.	Sheet mills.	Mechanical.	Fabricating.	Yards.
Death	2.60	1.98	1.99	0.88	0.50	1.05	0.88	0.68	1.04	0.87	2.00
Permanent disability:											
Loss of—											
Great toe	.06	.17	.14	.18	.12	.16	.09	.06	.03	.08	.04
1 joint great toe	.02	.06	......	.06	.07	.01	.05	.03	.08	.07	.05
Other toe or toes	.07	.14	.14	.16	.05	.19	.32	.08	.15	.06	.21
1 joint other toe or toes	.05	.11	.14	.07	......	.10	......	.03	.08	.05	.11
Foot	.06	.25	.14	.13	.03	.16	.18	.04	.06	.06	.20
Both feet	.01	.01	......	......	......	......	.05	......	......	......	......
Total, feet and toes	.27	.74	.52	.60	.27	.62	.69	.24	.40	.32	.61
Leg	.11	.18	.11	.05	.01	.07	......	.04	.06	.06	.30
Both legs	......	......	......	......	......	......	......	......	......	......	......
Thumb	.03	.18	.14	.08	.20	.12	.09	.09	.10	.17	.09
1 joint thumb	.06	.21	.32	.35	.26	.15	.09	.18	.17	.20	.27
1 joint finger or fingers	.57	1.29	1.21	1.31	.94	1.05	1.47	1.01	.98	1.08	.86
1st finger	.26	.56	.60	.41	.34	.74	.64	.26	.42	.57	.45
2d finger	.15	.24	.11	.11	.22	.18	.32	.14	.19	.14	.18
3d finger	.08	.14	.18	.16	.14	.12	.28	.09	.14	.23	.16
4th finger	.15	.15	.21	.20	.12	.04	.23	.10	.11	.30	.23
Hand	.10	.10	......	.04	.03	.07	.14	.11	.09	.06	.02
Both hands	......	......	......	......	......	......	......	.01	......	......	......
Total hands and fingers	1.40	2.87	2.77	2.66	2.25	2.47	3.26	1.99	2.20	2.75	2.26
Arm	.07	.07	......	.04	.04	.04	.09	.05	.03	.03	.05
Both arms	......	......	......	......	......	......	......	......	......	.02	......
Eye	.36	.20	.75	.45	.12	.25	.27	.12	.48	.43	.25
Both eyes	.06	......	......	......	......	......	......	......	......	......	......
Other	.64	.51	.96	.90	.68	.38	.51	.16	.83	.26	.89
Total permanent disability	2.92	4.60	5.16	4.70	3.38	3.86	4.84	2.64	4.03	3.88	4.36
Temporary disability:											
Terminating in—											
1st week	89.85	108.51	116.83	108.92	59.21	65.93	70.60	82.07	95.60	137.85	75.29
2d week	38.00	48.35	60.75	33.12	27.19	26.38	31.46	36.31	41.38	48.82	31.57
3d week	18.52	21.87	29.28	15.79	12.78	13.42	15.80	12.54	17.03	19.16	13.78
4th week	9.48	13.47	18.64	7.99	6.45	7.77	9.12	6.71	9.38	10.15	7.29
5th week	6.61	7.52	10.50	5.19	3.89	5.38	5.11	3.75	5.63	7.03	5.29
6th-13th week	11.71	13.88	21.84	8.92	6.55	9.58	9.25	6.08	10.90	10.34	9.82
14th week and later	3.05	2.90	3.20	2.69	1.34	2.45	2.34	1.85	2.41	1.47	1.93
Unknown	3.92	1.83	1.06	2.60	.18	2.17	.41	.57	.80	.15	.79
Total	181.14	218.35	262.13	185.22	117.58	133.09	144.12	149.97	183.03	234.99	145.77
Grand total	186.66	224.93	269.28	190.80	121.46	138.00	149.84	153.29	188.22	239.73	152.13
Number of 300-day workers	*124,636*	*71,293*	*28,101*	*95,917*	*73,338*	*67,663*	*21,711*	*128,423*	*97,162*	*108,538*	*55,932*

APPENDIX J.—DATA UPON WHICH CHARTS 11, 12, AND 13 (RELATION OF EMPLOYMENT AND OUTPUT TO ACCIDENT OCCURRENCE) ARE BASED.

TABLE 110.—DATA UPON WHICH CHART 11 IS BASED.[1]

PART I.—NUMBER OF 300-DAY WORKERS.

Month.	1908	1909	1910	1911	1912	1913	1914
January	451	391	672	370	482	678	428
February	390	447	695	445	558	685	469
March	424	470	674	467	595	665	502
April	377	474	704	466	597	671	453
May	360	495	705	475	622	685	429
June	361	534	684	458	650	690	416
July	367	541	634	510	647	690	436
August	336	549	592	513	633	668	418
September	358	553	603	480	649	612	398
October	373	573	543	502	646	569	304
November	380	605	607	545	642	539	238
December	398	583	529	543	675	410	250
Total	4,575	6,215	7,642	5,774	7,396	7,562	4,741

PART II.—NUMBER OF ACCIDENTS.

Month.	1908	1909	1910	1911	1912	1913	1914
January	53	65	128	32	84	88	37
February	73	72	122	32	91	54	35
March	69	70	117	42	100	114	38
April	65	62	125	28	117	84	41
May	44	88	89	44	126	76	26
June	47	81	79	56	118	71	33
July	52	96	83	90	109	90	41
August	55	121	73	67	89	112	44
September	65	97	63	53	81	68	22
October	53	116	59	66	85	32	12
November	54	92	41	62	55	45	8
December	55	124	41	68	79	32	12
Total	685	1,084	1,020	640	1,134	866	349

PART III.—NUMBER OF NEW MEN EMPLOYED.

Month.	1908	1909	1910	1911	1912	1913	1914
Jan. 1	318	197	560	20	325	571	19
Feb. 2	197	278	332	29	649	369	19
Mar. 3	61	268	793	65	635	439	28
Apr. 4	25	327	638	66	1,150	728	10
May 5	63	409	461	71	988	659	9
June 6	39	643	324	153	667	439	24
July 7	53	648	190	597	664	418	40
Aug. 8	30	1,008	233	365	549	273	9
Sept. 9	94	712	173	107	454	172	5
Oct. 10	93	563	154	242	426	134	3
Nov. 11	134	794	133	344	471	55	4
Dec. 12	147	457	35	196	490	23	9
Total	1,254	6,304	4,026	2,255	7,468	4,280	179

[1] Data relative to tonnage were furnished as confidential and so are not included in this table.

TABLE 111.—DATA UPON WHICH CHART 12 IS BASED.[1]

PART I.—NUMBER OF 300-DAY WORKERS.

Month.	1908	1909	1910	1911	1912	1913	1914
January	120	418	430	419	416	545	446
February	202	393	455	445	440	494	440
March	248	399	491	478	480	512	519
April	280	365	476	463	480	523	490
May	254	428	496	483	496	558	352
June	463	462	468	455	460	508	360
July	471	473	440	428	474	507	403
August	537	525	476	468	510	517	345
September	520	534	451	440	488	527	309
October	381	541	467	453	538	540	296
November	385	516	437	426	515	452	231
December	360	473	374	363	468	415	234
Total	4,221	5,527	5,461	5,321	5,765	6,098	4,425

PART II.—NUMBER OF ACCIDENTS.

Month.	1908	1909	1910	1911	1912	1913	1914
January	45	138	137	85	83	78	27
February	48	75	139	74	123	66	21
March	65	101	131	99	97	55	35
April	83	83	151	83	71	51	20
May	63	127	117	103	69	28	14
June	117	122	109	126	58	20	19
July	128	149	107	99	55	40	17
August	155	176	89	112	79	25	10
September	121	160	92	91	70	33	14
October	100	164	119	101	99	30	5
November	105	139	99	61	92	23	6
December	116	154	75	67	63	24	10
Total	1,146	1,588	1,365	1,101	959	473	198

PART III.—NUMBER OF NEW MEN EMPLOYED.

Month.	1908	1909	1910	1911	1912	1913	1914
January	....	168	199	59	330	390	70
February	18	32	308	109	687	334	168
March	3	67	614	175	481	338	176
April	1	68	586	329	618	464	12
May	3	332	203	281	391	534	....
June	52	426	98	135	406	526	19
July	227	520	299	113	529	177	18
August	75	570	126	188	667	104	....
September	115	320	354	254	519	114	....
October	74	388	301	281	441	61	....
November	100	246	59	44	387	8	....
December	75	176	22	14	340	10	....
Total	743	3,313	3,169	1,982	5,796	3,060	463

[1] Data relative to tonnage were furnished as confidential and so are not included in this table.

TABLE 112.—DATA UPON WHICH CHART 13 IS BASED.

PART I.—NUMBER OF 300-DAY WORKERS.

Quarter.	1912	1913	1914	1915	1916
First	2,304	2,431	1,720	1,904	2,575
Second	2,295	2,441	1,698	2,019	2,639
Third	2,361	2,480	1,897	2,067	2,757
Fourth	2,370	2,344	1,798	2,123	2,789
Total	9,330	9,696	7,113	8,113	10,760

PART II.—NUMBER OF DISABLING ACCIDENTS.

Quarter.	1912	1913	1914	1915	1916
First	362	430	242	189	496
Second	443	426	261	303	573
Third	407	405	251	409	826
Fourth	362	288	121	399	521

PART III.—NUMBER OF NONDISABLING ACCIDENTS.

Quarter.	1912	1913	1914	1915	1916
First	879	957	879	1,269	1,973
Second	937	1,282	1,082	2,029	2,468
Third	1,139	1,399	1,079	2,293	2,828
Fourth	1,025	1,667	696	1,977	2,362

PART IV.—NUMBER OF NEW MEN EMPLOYED.

Quarter.	1912	1913	1914	1915	1916
First	....	....	630	64	1,377
Second	....	....	508	621	2,175
Third	....	....	967	1,117	2,449
Fourth	....	....	365	982	1,840

APPENDIX K.—RESULT OF INJURY, BY DEPARTMENTS AND YEARS.

TABLE 113.—SUMMARY OF CASES OF ACCIDENT IN THE IRON AND STEEL INDUSTRY FOR THE FIVE-YEAR PERIOD 1910 TO 1914, BY DEPARTMENTS.

Result of injury.	Department.																				
	Total, all departments.[1]	Blast furnaces.	Bessemer steel.	Open-hearth steel.	Crucible melting.	Foundries.	Heavy rolling mills.	Plate mills.	Puddle mills.	Rod mills.	Sheet mills.	Tube mills.	Unclassified rolling mills.	Fabrication.	Forges.	Wire drawing.	Electrical.	Mechanical.	Power houses.	Yards.	Coke ovens.
Death	1,524	324	56	141	2	84	71	19	9	8	87	37	84	94	8	20	33	102	6	112	27
Permanent disability:																					
Loss of—																					
Great toe	172	10	4	16		23	12	3	1	3	13	14	14	17	1	6	1	11		5	1
Other toes	244	15	8	18	3	22	20	7	1	3	15	4	16	12	2	8	6	23	1	18	3
Foot	129	7	4	18	1	12	11	4		1	6	2	12	6		4	2	6		11	3
Both feet	3	1		1				1													
Leg	106	14	3	13		5	5			2	6	1	10	7			1	6	2	17	3
Both legs	2												1								
Thumb	415	11	13	28	1	42	18	4	3	4	35	34	46	40	3	18	2	27	2	20	1
First finger	1,910	104	51	132	4	165	121	46	32	18	164	94	123	179	6	108	15	136	9	73	9
Second finger	230	19	3	17	2	11	12	7	8	5	18	16	14	15		14	3	18	3	10	
Third finger	173	10	5	10		15	8	6	3	3	11	10	13	25		5	2	14	2	9	
Fourth finger	193	19	6	12	2	19	3	5			13	9	17	33	1	10	1	11		13	
Hand	100	13		7		4	5	3	2	2	14	2	9	7		3	2	9		1	1
Both hands	1										1										
Arm	66	9		5		4	3	2	1		6	3	9	3		3	4	3		3	4
Both arms	3													2							
Eye	479	45	21	14	2	43	17	6	5	7	16	9	36	47	2	74	4	47		14	4
Both eyes	10	7																	1		
Other	844	80	27	37	5	86	26	11	1	30	21	50	43	28	4	123	5	81	1	50	10
Total	5,080	364	145	328	21	451	261	105	57	78	339	248	363	421	19	376	48	392	21	244	39
Temporary disability:																					
Terminating in—																					
First week	118,215	11,198	3,283	7,736	232	10,447	4,461	1,533	882	987	10,540	4,343	9,698	14,962	460	6,424	1,129	9,289	282	4,211	921
Second week	49,521	4,737	1,707	3,447	104	3,177	1,785	683	347	468	4,664	1,994	5,415	5,299	310	2,551	388	4,021	108	1,766	295
Third week	21,854	2,308	823	1,559	60	1,515	908	343	145	231	1,611	937	2,531	2,080	144	1,020	161	1,655	63	771	140
Fourth week	11,883	1,182	524	961	34	766	526	197	79	112	862	473	1,375	1,102	63	494	82	911	25	408	72
Fifth week	7,282	824	295	536	26	498	364	111	65	76	492	285	815	763	28	256	50	547	296	17	66

Sixth to thirteenth week	12,671	1,459	614	990	39	856	648	210	96	111	781	480	1,318	1,123	40	494	114	1,059	35	549	112
Fourteenth week and later	2,717	380	90	207	12	258	166	51	22	27	237	98	209	160	8	53	26	234	8	108	31
Unknown	2,162	488	30	131	1	249	147	9	45	20	73	13	139	16	27	35	7	78	6	44	14
Total	226,305	22,576	7,366	15,567	508	17,766	9,005	3,129	1,681	2,032	19,260	8,623	21,500	25,505	1,080	11,327	1,957	17,794	544	8,153	1,651
Grand total	232,909	23,264	7,567	16,036	531	18,301	9,337	3,253	2,747	2,118	19,686	8,908	21,947	26,020	1,107	11,723	2,038	18,288	571	8,509	1,717
Number of 300-day workers	*1,310,911*	*124,636*	*28,101*	*71,293*	*5,144*	*95,917*	*67,663*	*21,711*	*12,788*	*13,244*	*128,423*	*73,338*	*98,809*	*108,538*	*6,249*	*59,481*	*14,421*	*97,162*	*8,083*	*55,932*	*13,282*

[1] Includes some departments not shown in detail.

TABLE 114.—SUMMARY OF CASES OF ACCIDENT IN THE IRON AND STEEL INDUSTRY DURING THE YEARS 1910 TO 1914.

Result of injury.	Year.				
	1910	1911	1912	1913	1914
Death	327	204	348	426	219
Permanent disability:					
Loss of—					
Great toe	26	37	36	45	28
Other toes	21	48	57	79	39
Foot	20	16	42	25	26
Both feet	1		1		1
Leg	35	17	25	17	12
Both legs	1				1
Thumb	59	78	97	110	71
First finger	386	364	789	432	303
Second finger	34	38	67	58	33
Third finger	15	27	56	44	31
Fourth finger	21	28	57	54	33
Hand	16	24	16	27	17
Both hands		1			
Arm	12	9	22	16	7
Both arms					3
Eye	90	90	111	100	88
Both eyes	2	2	1	4	1
Other	109	152	228	189	166
Total	848	931	1,241	1,200	860
Temporary disability:					
Terminating in—					
First week	23,234	18,213	29,101	28,593	19,074
Second week	10,079	7,618	11,524	11,869	8,431
Third week	4,139	3,292	5,158	5,592	3,673
Fourth week	2,203	1,698	2,760	3,175	2,047
Fifth week	1,482	1,100	1,687	1,793	1,220
Sixth to thirteenth week	2,458	1,984	3,011	3,040	2,178
Fourteenth week and later	266	486	737	782	446
Unknown	247	285	597	712	321
Total	44,108	34,676	54,575	55,556	37,390
Grand total	45,283	35,811	56,164	57,182	38,469
Number of 300-day workers	*202,157*	*231,544*	*300,992*	*319,919*	*256,299*

APPENDIX L.—A COMPARISON OF ACCIDENT SEVERITY RATES ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENTS BOARDS AND COMMISSIONS.

One of the most interesting results of the meeting of August, 1917, of the International Association of Industrial Accident Boards and Commissions at Boston was the association's acceptance of a report of its committee on statistics, recommending the adoption by the several State commissions of a system of accident severity rating. Inasmuch as the Bureau of Labor Statistics had earlier worked out and applied the somewhat similar scheme of severity rating used in this report and in Bulletin 216, [1] a comparison of the two systems is of interest.[2]

Both systems are based on the same fundamental idea—that, because accidents differ so greatly in the seriousness of the resulting injuries, the mere frequency of accidents does not offer a true measure of accident hazard; and that such a measure

[1] Accidents and accident prevention in machine building. Bulletin 216, U. S. Bureau of Labor Statistics.

[2] The report of the committee on statistics of the I. A. I. A. B. C. was published in the October, 1917, number of the MONTHLY REVIEW, pp. 123 to 143.

can be obtained only by comparing accidents on the basis of their severity. Also, both systems adopt the same scheme for the measurement of severity, namely, the time loss resulting from the injury. In the case of temporary disability, this time loss is accurately measured by the number of days during which the worker is incapacitated for labor. In the case of death and permanent disabilities, it is necessary to use a more or less arbitrary scale.

It is in the fixing of this scale that the two systems differ. The bureau's scale values death as equivalent to the loss of 9,000 workdays, on the basis that the average age of men killed by accident is about 30 years, and their expectancy of active labor, at that time, about 30 years (300 workdays per year×30 years expectancy=9,000 workdays). Permanent total disability was given a rating of 10,500 days, on the ground that total invalidism is economically more severe than death, inasmuch as it not only deprives the victim of all his productive power, but makes him, to some extent, a burden on the time of others. In valuing permanent partial disability, the bureau's scale took the loss of the arm as the most severe of such disabilities, and rated this injury at 2,808 days (or 31 per cent of death). In so doing it was recognized that existing industrial and educational conditions probably make the loss of an arm to most workers a more serious injury, from the standpoint of earning capacity, than is represented by a 31 per cent of death rating. But, on the other hand, it appears probable that better methods of functional rehabilitation and education in the future will tend greatly to diminish the economic importance of almost all partial disabilities.

The proposed association scale rates death much lower, and permanent disabilities much higher than does the bureau's scale. Death, by the association's scale, is rated at 6,000 days (i. e., 20 years), total permanent disability being classed the same as death, and the arm is assigned a value of 4,500 days, or 75 per cent of death. The time losses assigned the lesser partial disabilities are correspondingly higher than those for similar disabilities in the bureau's scale.

The two scales, in detail, are as follows:

SCALES OF TIME LOSSES FOR WEIGHTING INDUSTRIAL ACCIDENTS SO AS TO SHOW SEVERITY OF ACCIDENTS.

Scale used by the United States Bureau of Labor Statistics in Bulletin 216 and 234.

Result of injury.	Per cent of death loss.	Time losses in days.
Death	100.0	9,000
Permanent total disability	117.0	10,500
Loss of members:		
Arm	31.0	2,808
Leg	29.0	2,592
Hand	24.0	2,196
Foot	21.0	1,845
Eye	13.0	1,152
Thumb	6.0	540
First finger	5.0	414
Second finger	3.0	270
Third finger	2.5	225
Fourth finger	1.5	135
Great toe	3.8	342

Scale proposed by the committee on statistics of the I. A. I. A. B. C.

Result of injury.	Degree of disability in per cent of permanent total disability.	Days lost.
Death	100	6,000
Permanent total disability	100	6,000
Arm above elbow, dismemberment	75	4,500
Arm at or below elbow, dismemberment	60	3,600
Hand, dismemberment	50	3,000
Thumb, any permanent disability of	10	600
Any one finger, any permanent disability of	5	300
Two fingers, any permanent disability of	12½	750
Three fingers, any permanent disability of	20	1,200
Four fingers, any permanent disability of	30	1,800
Thumb and one finger, any permanent disability of	20	1,200
Thumb and two fingers, any permanent disability of	25	1,500
Thumb and three fingers, any permanent disability of	33⅓	2,000
Thumb and four fingers, any permanent disability of	40	2,400
Leg above knee, dismemberment	75	4,500
Leg at or below knee, dismemberment	50	3,000
Foot, dismemberment	40	2,400
Great toe, or any two or more toes, any permanent disability of	5	300
One toe, other than great toe, any permanent disability of	0	....
One eye, loss of sight	30	1,800
Both eyes, loss of sight	100	6,000
One ear, loss of hearing	10	600
Both ears, loss of hearing	50	3,000

The following table shows the results obtained by applying the two scales to the same groups of accidents.

TABLE 115.—ACCIDENT SEVERITY RATES IN THE IRON AND STEEL INDUSTRY FOR THE FIVE-YEAR PERIOD, 1910 TO 1914, AND FOR MACHINE BUILDING IN 1912.

Department.	Number of 300-day workers.	Accident severity rates (days lost per 300-day worker).							
		Bureau of Labor Statistics scale.				I. A. I. A. B. C. scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
Steel industry:									
Blast furnaces	124,636	23.4	2.8	2.5	28.7	15.6	3.3	2.5	21.4
Steel works—									
Bessemer	28,101	17.9	3.1	3.8	24.8	11.9	4.0	3.8	19.3
Open hearth	71,293	17.9	3.0	2.9	23.7	11.9	4.7	2.9	19.5
Crucible	5,144	3.5	2.1	1.6	7.2	2.3	3.4	1.6	7.7
Foundries	95,917	7.9	2.6	2.2	12.7	5.3	3.4	2.2	10.9
Rolling mills—									
Heavy	67,663	9.4	2.2	1.9	13.5	6.3	2.8	1.9	11.0
Plate	21,711	7.9	3.0	2.0	12.9	5.3	4.1	2.0	11.4
Puddle	12,788	6.3	2.0	1.7	10.0	4.2	2.8	1.7	8.7
Rod	13,244	5.4	4.1	2.0	11.5	3.6	5.1	2.0	10.7
Sheet	128,423	6.1	1.4	1.7	9.2	4.1	1.9	1.7	7.7
Tube	73,338	4.5	1.7	1.5	7.7	3.0	2.1	1.5	6.6
Miscellaneous	98,809	7.6	2.4	2.8	12.8	5.1	3.3	2.8	11.2
Fabricating shops	108,538	7.8	2.2	2.4	12.4	5.2	2.8	2.4	10.4
Forge shops	6,249	11.5	1.4	2.0	14.9	7.7	1.9	2.0	11.6
Wire drawing	59,481	3.0	4.3	1.9	9.3	2.0	5.6	1.9	9.5
Electrical	14,421	20.7	2.6	1.6	24.9	13.8	3.6	1.6	19.0
Mechanical	97,162	9.5	2.5	2.3	14.2	6.3	3.2	2.3	11.8
Power houses	8,083	6.7	2.5	.9	10.1	4.5	2.5	.9	7.9
Yards	55,932	18.0	3.1	1.9	23.0	12.0	4.1	1.9	18.0
Coke ovens	13,282	18.3	3.3	1.7	23.3	12.2	4.4	1.7	18.3
Armor plate	3,000	12.0	1.1	2.0	15.1	8.0	1.8	2.0	11.8
Axle works	1,326	13.6	5.0	4.9	23.5	9.1	7.6	4.9	21.6
Car wheels	2,367	11.4	2.0	4.0	17.4	7.6	2.2	4.0	13.8
Docks	1,293	20.9	6.6	2.5	30.0	13.9	9.3	2.5	25.7
Erecting	2,157	108.5	14.7	5.4	128.6	85.7	16.5	5.4	107.6
Total[1]	1,310,911	10.5	2.5	2.1	15.1	7.0	3.2	2.1	12.3
Machine building	115,703	2.9	1.6	1.1	5.6	1.9	2.1	1.1	5.1

[1] This total includes the "unclassified" departments, not shown above.

Examination of the table shows that the severity rates obtained under the association's scale are, for the most part, considerably lower than those derived by the bureau's scale. Thus, the severity rate for the steel industry as a whole is decreased from 15.1 days to 12.3 days lost per worker and for machine building from 5.6 days to 5.1 days. In one instance, however, the reverse is true. Thus, in crucible melting the bureau's scale gives a severity rate of 7.2 days while the association's scale gives 7.3 days.

A most interesting point to be noted is that while the use of the different scales alters the rates, there is no important change in the relations between the rates for the several departments and industries. This emphasizes the fact that the precise scale used is not of primary importance. Severity rates, as absolute amounts, are not significant. Their importance lies in the fact that they offer the most satisfactory measure of accident hazards as between different industrial groups. As long as the scale used is reasonably accurate it will fulfill its function.

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS.

Iron and steel industry. (*See also Table 2.*)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	27,632	19.9	4.0	3.2	27.1	13.3	6.8	3.2	23.3
1910	79,486	11.0	3.9	2.2	17.1	7.3	4.7	2.2	14.2
1911	80,029	7.8	3.8	1.9	13.5	5.2	4.6	1.9	11.7
1912	93,666	8.2	3.4	2.2	13.8	5.4	4.3	2.2	11.9
1913	91,107	10.3	2.9	1.9	15.1	6.8	3.8	1.9	12.5
1914	77,474	6.9	2.5	1.5	10.9	4.6	3.2	1.5	9.3
1915	79,065	6.4	2.6	1.3	10.3	4.2	3.2	1.3	8.7
1916	108,994	6.3	3.1	1.3	10.7	4.2	3.8	1.3	8.3
1917	86,847	7.0	2.0	1.2	10.2	4.6	2.5	1.2	8.3

Blast furnaces. (*See also Table 3.*)

1907	961	51.7	6.9	5.5	64.1	34.1	9.1	5.5	48.7
1910	3,891	25.4	2.3	2.8	30.5	17.0	3.1	2.8	22.9
1911	3,921	16.1	8.0	2.3	26.4	10.7	6.6	2.3	19.6
1912	5,034	26.8	6.4	2.8	36.0	17.9	6.2	2.8	26.9
1913	5,641	24.0	5.1	2.3	31.4	16.0	4.8	2.3	23.1
1914	4,797	20.6	3.8	1.7	26.1	13.8	4.9	1.7	20.4
1915	4,835	22.3	2.7	1.3	26.3	14.9	3.2	1.3	19.4
1916	6,694	12.1	4.9	1.5	18.5	8.1	5.6	1.5	15.2
1917	5,194	31.4	1.9	1.1	34.4	20.7	2.5	1.1	24.3

Steel works. (*See also Table 4.*)

1907	1,176	30.6	13.7	5.5	49.8	20.4	11.5	5.5	37.4
1910	4,246	38.2	6.5	3.2	47.9	25.4	8.9	3.2	37.5
1911	4,293	14.7	4.4	2.3	21.4	9.8	5.5	2.3	17.6
1912	5,546	19.5	4.7	3.1	27.3	13.0	5.0	3.1	22.0
1913	5,207	13.8	3.7	3.1	20.6	9.2	4.4	3.1	16.7
1914	3,073	20.5	3.3	2.1	25.9	13.7	4.0	2.1	19.8
1915	4,713	11.5	4.6	1.6	17.7	7.6	5.5	1.6	14.7
1916	6,556	13.7	6.3	1.8	21.8	9.2	6.5	1.8	17.5
1917	6,347	14.2	1.9	1.4	17.5	9.4	2.6	1.4	13.4

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Sheet mills. (See also Table 5.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,211	8.1	3.8	1.2	13.1	5.3	5.2	1.2	11.7
1910	15,485	13.4	1.7	1.7	16.8	8.9	2.3	1.7	12.9
1911	14,461	3.1	2.5	1.8	7.4	2.1	2.9	1.8	6.8
1912	19,129	5.2	1.8	2.3	9.3	3.5	2.5	2.3	8.3
1913	15,780	8.0	.7	2.0	10.7	5.3	1.0	2.0	8.3
1914	12,963	1.4	1.5	1.7	4.6	.9	2.2	1.7	4.8
1915	16,266	3.9	.6	1.5	6.0	2.6	.9	1.5	5.0
1916	21,640	4.2	1.0	1.6	6.8	2.8	1.5	1.6	5.9
1917	23,916	3.4	1.0	1.5	5.9	2.3	1.4	1.5	5.2

Tube mills. (See also Table 6.)

1907	2,007	4.5	1.5	4.6	10.6	3.0	1.9	4.6	9.5
1910	6,038	1.5	.3	1.7	3.5	1.0	.4	1.7	3.1
1911	7,678	1.2	2.7	1.5	5.4	.8	3.1	1.5	5.4
1912	8,694	6.2	1.9	1.8	9.9	4.1	2.1	1.8	8.0
1913	9,619	5.6	2.0	1.2	8.8	3.7	2.3	1.2	7.2
1914	6,459	5.6	1.5	.9	8.0	3.7	1.7	.9	6.3
1915	7,109	2.5	1.5	.6	4.6	1.7	1.7	.6	4.0
1916	11,355	1.6	.8	.8	3.2	1.1	1.0	.8	2.9
1917	11,657	6.2	1.1	.5	7.8	4.1	1.5	.5	6.1

Unclassified rolling mills. (See also Table 7.)

1910	5,615	19.2	4.9	3.2	27.3	12.8	5.9	3.2	21.9
1911	8,205	13.2	4.5	2.2	19.9	8.8	5.8	2.2	16.8
1912	10,448	6.9	3.4	2.5	12.8	4.6	4.2	2.5	11.3
1913	10,673	8.4	2.8	2.1	13.3	5.6	3.5	2.1	11.2
1914	5,992	6.0	3.2	1.3	10.5	4.0	4.0	1.3	9.3
1915	9,111	10.9	3.5	.8	15.2	7.2	4.2	.8	12.2
1916	13,027	3.5	3.8	1.4	8.7	2.3	4.8	1.4	8.5
1917	11,505	7.0	2.6	.9	10.5	4.6	2.2	.9	7.5

Wire drawing. (See also Table 8.)

1910	8,374	4.3	5.9	2.2	12.4	2.9	7.9	2.2	13.0
1911	8,186	2.2	5.9	2.0	10.1	1.5	7.4	2.0	10.7
1912	8,278	2.2	6.6	2.3	11.1	1.4	8.0	2.3	11.9
1913	7,604	4.7	3.6	2.3	10.6	3.2	4.7	2.3	10.2
1914	6,306	1.4	4.3	1.8	7.5	1.0	4.8	1.8	7.6
1915	7,859	1.1	6.0	2.3	9.4	.8	7.3	2.3	10.5
1916	9,552	3.8	7.4	1.9	13.1	2.5	8.8	1.9	13.2
1917	9,528	.9	2.9	1.6	5.4	.6	3.7	1.6	5.8

Fabrication. (See also Table 9.)

1907	2,081	25.9	6.9	2.5	35.3	17.1	8.8	2.5	28.4
1910	3,935	9.2	1.7	1.8	12.7	6.0	2.3	1.8	10.1
1911	4,007	2.2	3.5	2.0	7.7	1.5	4.6	2.0	8.1
1912	5,023	9.0	3.2	2.6	14.8	6.0	4.4	2.6	13.0
1913	5,313	8.5	5.6	2.3	16.4	5.9	6.9	2.3	14.8
1914	3,811	7.1	1.9	1.5	10.5	4.7	2.8	1.5	9.0
1915	2,994	9.0	1.9	2.1	13.0	6.0	2.8	2.1	10.9
1916	4,465	14.1	1.7	2.6	18.4	9.4	2.2	2.6	14.2
1917	5,020	7.2	3.8	1.6	12.6	4.8	3.5	1.6	9.9

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Mechanical departments. (See also Table 10.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907	2,542	7.1	1.3	3.5	11.9	4.8	1.7	3.5	10.0
1910	7,871	8.0	2.9	1.4	12.3	5.3	3.7	1.4	10.4
1911	6,712	6.7	3.3	1.5	11.5	4.5	4.2	1.5	10.2
1912	7,122	6.3	4.0	1.7	12.0	4.2	5.0	1.7	10.9
1913	7,474	8.4	3.5	1.7	13.6	5.6	4.7	1.7	12.0
1914	5,125	5.3	2.6	1.2	9.1	3.5	2.9	1.2	7.6
1915	5,693	1.6	2.8	1.1	5.5	1.1	3.1	1.1	5.3
1916	9,185	8.8	4.2	1.0	14.0	5.9	5.2	1.0	12.1
1917	8,892	1.0	2.3	.8	4.1	.7	2.8	.8	4.3

Yards. (See also Table 11.)

1907	2,618	17.2	5.9	3.2	26.3	11.4	7.8	3.2	22.4
1910	5,111	17.6	2.5	1.2	21.3	11.7	3.0	1.2	15.9
1911	3,726	2.4	4.6	2.0	9.0	1.6	5.6	2.0	9.2
1912	4,102	15.4	5.3	2.3	23.0	10.2	6.8	2.3	19.3
1913	4,275	23.2	1.9	1.9	27.0	15.4	2.4	1.9	19.8
1914	2,900	6.2	4.7	1.8	12.7	4.1	6.0	1.8	11.9
1915	3,689	....	4.1	1.3	5.4	....	4.7	1.3	6.0
1916	6,302	11.4	5.4	1.5	18.3	7.6	6.6	1.5	15.7
1917	4,738	15.2	4.2	1.0	20.4	10.0	5.7	1.0	16.7

Steel manufacture and machine building. (See also Table 19.)

Iron and steel (1913)	7,562	16.6	2.2	2.4	21.2	11.1	2.8	2.1	16.0
Machine building (1912)	115,703	2.9	1.6	1.1	5.6	1.9	2.1	1.1	5.1

A large steel plant. (See also Table 20.)

1910	7,642	15.3	2.4	2.2	19.9	10.2	3.1	2.2	15.5
1911	5,774	14.1	2.1	2.4	18.6	9.4	2.7	2.4	14.5
1912	7,396	6.0	5.5	2.8	14.3	4.0	7.0	2.8	13.8
1913	7,562	16.7	2.2	2.4	21.3	11.1	2.8	2.4	16.6

Age groups in a large steel plant, 1907 to 1914. (See also Table 51.)

Under 20 years	949	9.5	3.4	7.7	20.6	6.3	4.4	7.7	18.4
20 to 29 years	16,443	6.0	1.8	3.5	11.3	4.0	2.3	3.5	9.8
30 to 39 years	14,417	6.2	.9	2.9	10.0	4.1	1.2	2.9	8.2
40 years and over	11,124	4.9	1.2	2.6	8.7	3.3	1.5	2.6	7.4
Total	42,933	5.9	1.4	3.1	10.4	3.9	1.8	3.1	8.8

Age groups in a tube mill, 1907 to 1914. (See also Table 52.)

20 to 29 years	6,351	2.8	1.7	3.1	8.2	1.9	2.1	3.1	7.1
30 to 39 years	4,977	1.8	1.0	2.4	5.2	1.2	1.2	2.4	4.8
40 years and over	2,965	9.1	.9	1.9	11.9	6.1	1.1	1.9	9.1
Total	14,293	3.8	1.3	2.6	7.7	2.5	1.6	2.6	6.7

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Inability to speak English in a large steel plant. (See also Table 53.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1906.									
American born	1,370	52.6	5.0	2.1	59.7	35.1	6.4	2.1	43.6
English-speaking foreign born	1,906	61.4	2.3	1.9	65.6	40.9	2.9	1.9	45.7
Non-English-speaking foreign born	4,218	38.4	3.2	3.5	45.1	24.6	4.1	3.5	32.2
Total	7,494	46.8	4.3	2.9	54.0	31.2	5.5	2.9	39.6
1907.									
American born	1,719	31.4	2.5	2.1	36.6	20.9	3.2	2.1	26.2
English-speaking foreign born	2,267	27.8	7.0	2.8	37.6	18.5	9.0	2.8	30.3
Non-English-speaking foreign born	3,599	30.0	5.5	4.3	39.8	20.0	7.0	4.3	31.3
Total	7,585	28.6	6.2	3.2	32.6	19.1	7.9	3.2	30.2
1908.									
American born	1,188	7.6	2.3	1.4	11.3	5.1	2.9	1.4	9.4
English-speaking foreign born	1,689	26.6	2.6	1.7	30.9	17.7	3.3	1.7	22.7
Non-English-speaking foreign born	1,698	31.8	6.4	3.7	41.9	21.2	8.2	3.7	33.1
Total	4,575	23.6	3.9	2.4	29.9	15.7	5.0	2.4	23.1
1909.									
American born	1,453	12.4	.1	1.5	14.0	8.3	1.3	1.5	11.1
English-speaking foreign born	2,027	31.1	1.9	3.0	36.0	20.7	2.4	3.0	26.1
Non-English-speaking foreign born	2,735	13.2	3.2	3.2	19.6	8.8	4.1	3.2	16.1
Total	6,215	18.8	2.1	2.7	23.6	12.5	2.7	2.7	17.9
1910.									
American born	1,843	9.8	.6	1.0	11.4	6.5	.8	1.0	8.3
English-speaking foreign born	3,283	5.5	1.5	.7	7.7	3.7	1.9	.7	6.3
Non-English-speaking foreign born	2,516	28.6	4.2	4.1	36.9	19.1	5.4	4.1	28.6
Total	7,642	14.1	3.2	1.9	19.2	9.4	4.1	1.9	15.4
1911.									
American born	1,369	26.3	1.2	1.2	28.7	17.5	1.5	1.2	20.2
English-speaking foreign born	2,446	14.7	3.5	2.4	20.6	9.8	4.5	2.4	16.7
Non-English-speaking foreign born	1,959	4.6	4.2	3.2	12.0	3.1	5.4	3.2	11.5
Total	5,774	14.0	2.5	2.0	18.5	9.3	3.2	2.0	14.5
1912.									
American born	1,863	....	1.7	1.5	3.2	....	2.3	1.5	3.8
English-speaking foreign born	2,656	3.4	5.9	1.8	11.1	2.3	7.6	1.8	11.7
Non-English-speaking foreing born	2,877	12.5	7.1	4.4	24.0	8.3	9.1	4.4	21.9
Total	7,396	6.1	5.3	2.7	14.1	4.1	6.8	2.7	13.6
1913.									
American born	1,782	15.2	.7	1.1	17.0	10.1	.9	1.1	12.1
English-speaking foreign born	2,472	18.2	1.7	1.4	21.3	12.1	2.2	1.4	15.7
Non-English-speaking foreign born	2,877	12.5	7.1	4.4	24.0	8.3	9.1	4.4	21.8
Total	7,532	16.7	2.2	2.3	21.2	11.1	2.8	2.3	16.2
Total 8 years.									
American born	12,587	18.6	1.7	1.5	21.8	12.4	2.2	1.5	16.1
English-speaking foreign born	18,746	21.1	3.3	2.0	26.4	14.1	4.2	2.0	20.3
Non-English-speaking foreign born	22,910	23.2	3.5	2.8	29.5	15.4	4.5	2.8	22.7
Total	54,243	21.4	3.2	2.6	27.2	14.3	4.1	2.6	21.0

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Night and day rates in a large steel plant. (See also Table 54.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1907:									
Night	2,079	13.0	1.4	5.4	19.8	8.7	1.8	5.4	15.9
Day	4,036	2.2	1.0	4.7	7.9	1.5	1.3	4.7	7.5
1908:									
Night	1,435	....	1.1	3.3	4.4	....	1.4	3.3	4.7
Day	2,786	6.5	1.5	3.8	11.8	4.3	1.9	3.8	10.0
1909:									
Night	1,883	14.3	2.5	4.0	20.8	9.5	3.2	4.0	16.7
Day	3,644	12.3	1.7	4.0	18.0	8.2	2.2	4.0	14.4
1910:									
Night	1,857	4.8	1.6	3.8	10.2	3.2	2.0	3.8	9.0
Day	3,604	10.0	2.0	3.8	15.8	6.7	2.6	3.8	13.1
1911:									
Night	1,703	....	.4	2.4	2.8	....	.5	2.4	2.9
Day	3,618	5.0	1.2	2.6	8.8	3.3	1.5	2.6	7.4
1912:									
Night	1,902	9.5	1.1	2.5	13.1	6.3	1.4	2.5	10.2
Day	3,863	11.6	1.0	1.9	14.5	7.7	1.3	1.9	10.9
1913:									
Night	2,012	4.5	.3	1.2	6.0	3.0	.4	1.2	4.6
Day	4,086	6.6	1.1	1.1	8.8	4.4	1.4	1.1	6.9
1914:									
Night	1,416	....	1.6	1.1	2.7	....	2.0	1.1	3.1
Day	3,009	....	2.2	1.0	3.2	....	2.8	1.0	3.8
1907 to 1914:									
Night	14,287	6.3	1.2	3.0	10.5	4.2	1.5	3.0	8.7
Day	28,646	6.9	1.5	2.9	11.3	4.6	1.9	2.9	9.4

Iron and steel industry. (See also Table 71.)

All plants:									
1910	202,157	14.6	2.9	2.5	19.9	9.7	3.7	2.5	15.9
1911	231,544	7.9	2.5	1.9	12.3	5.3	3.2	1.9	10.4
1912	300,919	10.4	2.6	2.3	15.3	6.9	3.3	2.3	12.5
1913	319,919	12.0	2.2	2.2	16.4	8.0	2.8	2.2	13.0
1914	256,299	7.7	2.2	1.8	11.8	5.1	2.8	1.8	9.7
Total	1,310,911	10.5	2.5	2.1	15.1	7.0	3.2	2.1	12.3
Special plants:									
1907	27,632	19.9	4.0	3.2	27.1	13.3	5.1	3.2	21.6
1908	19,481	8.3	2.2	2.6	13.1	5.5	2.8	2.6	10.9
1909	24,543	15.8	1.4	2.7	19.9	10.5	1.8	2.7	15.0
1910	27,144	13.9	2.1	2.6	18.6	9.3	2.7	2.6	14.6
1911	24,519	8.8	1.6	2.4	12.8	5.9	2.0	2.4	10.3
1912	28,922	5.9	2.5	2.4	10.8	3.9	3.2	2.4	9.5
1913	29,766	11.1	1.4	2.0	14.5	7.4	1.8	2.0	11.2
1914	20,241	5.8	2.1	1.7	9.6	3.9	2.7	1.7	8.3
Total	202,248	11.4	2.2	2.5	16.1	7.6	2.8	2.5	12.9

Departments of special iron and steel plants, 1907 to 1914. (See also Table 76.)

Bessemer	5,920	16.7	1.9	4.0	22.6	11.3	2.0	4.0	17.3
Fabrication	15,764	13.7	3.1	2.6	19.4	9.1	3.9	2.6	15.6
Open hearths	23,453	14.6	2.6	2.7	19.9	9.7	4.2	2.7	16.6
Foundries	7,338	7.4	1.5	2.9	11.8	4.9	2.0	2.9	9.8
Mechanical	17,098	9.5	1.5	2.4	13.4	6.3	1.9	2.4	10.6
Blast furnaces	11,626	25.5	3.2	2.9	31.6	17.0	3.8	2.9	23.7
Sheet mills	19,119	8.0	2.2	1.4	11.6	5.3	3.0	1.4	9.7
Yards	16,160	11.1	2.7	2.2	16.0	7.4	3.6	2.2	13.2
Plate mills	13,625	7.9	2.6	2.8	13.3	5.3	3.6	2.8	11.8
Heavy rolling mills	34,999	8.2	1.5	2.3	12.0	5.5	1.9	2.3	9.7
Tube mills	14,539	4.3	1.5	2.9	8.7	2.9	1.9	2.9	7.7
Total	179,642	10.9	2.1	2.5	15.5	7.3	2.7	2.5	12.5

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Blast furnaces. (See also Table 77.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
All plants:									
1910	19,389	31.1	4.4	2.9	38.4	20.7	5.2	2.9	28.8
1911	21,479	21.8	2.4	2.3	26.5	14.5	2.8	2.3	19.6
1912	27,154	24.5	2.5	2.5	29.5	16.3	2.9	2.5	21.7
1913	31,988	23.9	2.6	2.6	29.1	15.9	3.1	2.6	21.6
1914	26,572	15.6	2.5	2.0	20.1	10.4	2.9	2.0	15.3
Total	124,636	23.4	2.8	2.5	28.7	15.6	3.3	2.5	21.4
Special plants:									
1905	961	46.8	4.8	5.2	56.8	31.2	5.7	5.2	42.1
1906	1,262	135.5	2.8	5.0	143.3	90.3	3.3	5.0	98.6
1907	1,566	51.7	6.9	5.5	64.1	34.5	8.1	5.5	48.1
1908	1,274	21.2	6.5	4.8	32.5	14.1	7.7	4.8	26.6
1909	1,486	54.5	.9	3.3	58.7	36.3	1.1	3.3	40.7
1910	1,353	20.0	4.2	3.2	27.4	13.3	5.0	3.2	21.5
1911	1,380	19.6	1.4	2.2	23.2	13.1	1.7	2.2	17.0
1912	1,749	5.1	1.1	1.7	7.9	3.4	1.3	1.7	6.4
1913	1,658	16.3	2.2	1.5	20.0	10.9	2.6	1.5	15.0
1914	1,160	15.5	2.5	1.6	19.6	10.3	2.9	1.6	14.8
Total	13,849	37.0	3.2	3.3	43.5	24.7	3.8	3.3	31.8

Occupational groups in blast furnaces, 1905 to 1914. (See also Table 78.)

Cast-house men	1,357	59.7	6.5	6.3	72.5	39.8	7.7	6.3	53.8
Common labor	4,930	31.0	1.8	4.0	36.6	20.7	2.1	4.0	26.8
Mechanics	3,670	22.1	2.4	1.8	26.3	14.7	2.8	1.8	19.3
Stockers	886	30.5	3.5	2.7	36.7	20.3	4.1	2.7	27.1
Unclassified	3,006	56.9	5.0	2.4	64.9	37.9	5.9	2.4	46.2
Total	13,849	37.0	3.2	3.3	43.5	24.7	3.8	3.3	31.8

Bessemer departments. (See also Table 79.)

All plants:									
1910	5,070	35.5	2.6	4.9	43.0	23.7	2.7	4.9	31.3
1911	5,155	10.5	3.0	3.3	16.8	7.0	3.2	3.3	13.5
1912	6,521	12.4	2.9	4.4	19.7	8.3	3.1	4.4	15.8
1913	6,885	20.9	3.3	3.7	28.0	13.9	3.5	3.7	21.1
1914	4,470	10.1	3.3	2.6	15.9	6.7	3.5	2.6	12.8
Total	28,101	17.9	3.1	3.8	24.8	11.9	3.3	3.8	19.0
Special plants:									
1907	967	9.3	2.6	7.3	19.2	6.2	2.7	7.3	16.2
1908	511	52.8	.3	4.8	57.9	35.2	.3	4.8	40.3
1909	750	24.0	......	4.0	28.0	16.0	......	4.0	20.0
1910	784	34.4	.4	4.6	39.4	22.9	.4	4.6	27.9
1911	669	....	5.2	2.5	7.7	....	5.5	2.5	8.0
1912	788	....	2.4	2.7	5.1	....	2.8	2.7	5.5
1913	875	10.3	.4	2.4	13.1	6.9	.4	2.4	15.2
1914	576	15.6	4.3	2.6	22.5	10.4	4.5	2.6	17.5
Total	5,920	16.7	1.9	4.0	22.6	10.9	2.0	4.0	16.9

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Open hearths. (See also Table 80.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
All plants:									
1910	9,739	27.1	4.4	4.1	35.7	18.1	7.1	4.1	29.3
1911	10,718	15.1	2.1	2.6	19.7	10.1	3.4	2.6	16.1
1912	17,355	23.9	3.6	2.9	30.3	15.9	5.8	2.9	24.6
1913	20,604	15.3	2.5	2.9	20.8	10.2	4.1	2.9	17.2
1914	12,877	9.8	2.7	2.3	14.9	6.5	4.4	2.3	13.2
Total	71,293	17.8	3.0	2.9	23.7	11.9	4.9	2.9	19.7
Special plants:									
1907	2,987	42.2	7.4	3.2	52.8	28.1	12.0	3.2	43.3
1908	2,120	4.2	1.1	2.2	7.5	2.8	1.8	2.2	6.8
1909	2,872	9.4	2.0	3.2	14.6	6.3	3.2	3.2	12.7
1910	3,138	8.6	2.6	2.9	14.1	5.7	4.2	2.9	12.8
1911	2,725	6.6	.6	2.7	9.9	4.4	1.0	2.7	8.1
1912	3,525	7.7	2.7	2.2	12.6	5.1	4.4	2.2	11.7
1913	3,603	25.0	1.7	3.1	29.8	16.7	2.8	3.1	22.6
1914	2,483	7.2	2.6	1.8	11.6	4.8	4.2	1.8	10.8
Total	23,453	14.6	2.6	2.7	19.9	9.7	4.2	2.7	16.6

Occupational groups in open hearths, 1905 to 1914. (See also Table 81.)

Common labor	4,851	29.7	5.4	5.7	40.8	19.8	8.8	5.7	34.3
Pitmen	5,492	13.2	.6	1.9	15.7	8.8	1.0	1.9	11.7
Pouring plarform men	954	9.4	.5	2.8	12.7	6.3	.8	2.8	9.9
Stocking floor men	7,761	3.5	1.1	1.7	6.3	2.3	1.8	1.7	5.8
Unclassified	5,395	20.0	5.7	2.5	28.3	13.3	9.2	2.5	25.0
Total	24,453	14.7	2.8	2.8	20.3	9.8	4.5	2.8	17.1

Foundries. (See also Table 82.)

All plants:									
1910	16,885	3.7	2.2	1.7	7.6	2.5	2.9	1.7	7.1
1911	13,499	12.0	2.2	1.9	16.0	8.0	2.9	1.9	12.8
1912	23,294	9.3	3.4	2.5	15.1	6.2	4.4	2.5	13.1
1913	24,605	7.7	2.7	2.4	12.8	5.1	3.5	2.4	11.0
1914	17,634	7.1	2.3	2.1	11.5	4.7	3.0	2.1	9.8
Total	95,917	7.9	2.6	2.2	12.7	5.3	3.4	2.2	10.9
Special plants:									
1907	939	9.6	.8	3.1	13.5	6.4	1.0	3.1	10.5
1908	719	....	......	2.5	2.5	....	......	2.5	2.5
1909	985	....	1.7	3.8	5.5	....	2.2	3.8	6.0
1910	1,189	....	1.4	3.0	4.4	....	1.8	3.0	4.8
1911	875	20.6	1.7	2.6	24.9	13.7	2.2	2.6	18.5
1912	1,056	17.0	2.8	3.3	23.1	11.3	3.7	3.3	18.3
1913	990	9.1	1.3	2.4	12.8	6.1	1.7	2.4	10.2
1914	585	....	2.0	1.7	3.7	....	2.6	1.7	4.3
Total	7,338	7.4	1.5	2.9	11.8	4.9	2.0	2.9	9.8

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Occupational groups in foundries, 1910 to 1914. (See also Table 83.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total
Cleaners	4,196	9.3	9.0	4.7	23.0	5.7	11.8	4.7	22.2
Core makers	1,273	....	.1	1.5	1.6	....	1.3	1.5	2.8
Melters and helpers	1,261	....	4.2	1.8	6.0	....	5.4	1.8	7.2
Molders and helpers	5,266	9.3	6.8	3.3	19.4	5.7	8.9	3.3	17.9
Total	11,996	7.2	6.6	3.4	17.2	4.5	8.6	3.4	16.5

Heavy rolling mills. (See also Table 84.)

	Number of 300-day workers.	BLS Death.	BLS Permanent disability.	BLS Temporary disability.	BLS Total.	IA Death.	IA Permanent disability.	IA Temporary disability.	IA Total
All plants:									
1910	9,442	18.1	3.5	2.8	24.4	12.1	4.5	2.8	19.4
1911	12,409	6.5	2.1	2.0	10.7	4.3	2.7	2.0	9.0
1912	16,258	10.5	2.1	2.0	14.6	7.0	2.7	2.0	11.7
1913	17,569	7.7	1.4	1.7	10.8	5.1	1.8	1.7	8.6
1914	11,985	6.8	2.4	1.3	10.4	4.5	3.1	1.3	8.9
Total	67,663	9.4	2.2	1.9	13.5	6.3	2.8	1.9	11.0
Special plants:									
1907	4,556	15.8	.7	2.9	19.4	10.5	.9	2.9	14.3
1908	3,135	5.7	2.3	2.3	10.3	3.8	2.9	2.3	9.0
1909	4,210	15.0	.6	2.8	18.4	10.0	.8	2.8	13.6
1910	4,886	11.1	2.1	2.3	15.5	7.4	2.7	2.3	12.4
1911	4,195	8.6	3.2	2.6	14.4	5.7	4.1	2.6	12.4
1912	5,226	1.7	1.6	2.3	5.6	1.1	2.0	2.3	5.4
1913	5,287	5.1	.6	1.8	7.5	3.4	.8	1.8	6.0
1914	3,504	2.6	1.4	1.4	5.4	1.7	1.9	1.4	5.0
Total	34,999	8.2	1.5	2.3	12.0	5.5	1.9	2.3	9.7

Plate mills. (See also Table 85.)

	Number of 300-day workers.	BLS Death.	BLS Permanent disability.	BLS Temporary disability.	BLS Total.	IA Death.	IA Permanent disability.	IA Temporary disability.	IA Total
All plants:									
1910	3,287	19.2	3.6	2.0	24.8	12.8	4.9	2.0	19.7
1911	4,390	10.3	2.1	1.9	14.2	6.9	2.9	1.9	11.7
1912	5,128	3.5	4.3	2.3	10.2	2.3	5.9	2.3	10.5
1913	5,430	5.0	2.7	1.8	9.5	3.3	3.7	1.8	8.8
1914	3,476	5.2	2.1	1.4	8.7	3.4	2.9	1.4	7.7
Total	21,711	7.9	3.0	2.0	12.9	5.3	4.1	2.0	11.4
Special plants:									
1907	1,915	18.8	8.2	3.7	30.7	12.5	11.2	3.7	27.4
1908	1,173	7.7	.8	2.6	11.1	5.1	1.1	2.6	8.8
1909	1,634	5.5	.4	3.1	9.0	3.7	.5	3.1	7.3
1910	1,872	14.4	3.7	2.7	20.8	9.6	5.1	2.7	17.4
1911	1,645	....	1.6	2.8	4.4	....	2.2	2.8	5.0
1912	1,992	4.5	3.0	3.0	10.5	3.0	4.1	3.0	10.0
1913	2,015	8.9	.9	2.6	12.4	5.9	1.2	2.6	9.7
1914	1,379	....	.6	1.5	2.1	....	.8	1.5	2.3
Total	13,625	7.9	2.6	2.8	13.3	5.3	3.6	2.8	11.7

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Sheet mills. (See also Table 86.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
All plants:									
1910	18,501	13.1	1.7	1.7	16.5	8.7	2.3	1.7	12.7
1911	29,710	3.0	1.5	1.3	5.9	2.0	2.1	1.3	5.4
1912	32,087	5.3	1.6	2.1	9.0	3.5	2.2	2.1	7.8
1913	25,938	7.3	1.2	1.7	10.1	4.9	1.6	1.7	8.2
1914	22,187	4.1	1.2	1.7	6.9	2.7	1.6	1.7	6.0
Total	128,423	6.1	1.4	1.7	9.2	4.1	1.9	1.7	7.7
Special plants:									
1907	2,211	8.1	3.8	1.2	13.1	5.4	5.6	1.2	12.2
1908	1,951	....	1.5	1.2	2.7	....	2.0	1.2	3.2
1909	2,366	15.2	2.0	1.3	18.5	10.1	2.7	1.3	14.1
1910	2,637	13.7	2.4	1.1	17.5	9.1	3.3	1.1	13.5
1911	2,433	14.8	.8	1.5	17.1	9.9	1.1	1.5	12.5
1912	2,925	3.1	2.4	2.0	7.5	2.1	3.3	2.0	7.4
1913	2,691	3.3	2.5	1.7	8.6	2.2	4.7	1.7	8.6
1914	1,905	4.7	.3	1.4	6.4	3.1	.4	1.4	4.9
Total	19,119	8.0	2.2	1.4	11.6	5.3	3.0	1.4	9.7

Occupational groups in sheet mills, 1910 to 1914. (See also Table 87.)

Hot-mill crews	5,200	3.5	0.8	1.7	6.0	2.3	1.0	1.7	5.0
Other occupations	7,391	13.4	2.9	1.5	17.8	8.9	3.6	1.5	14.0
Total	12,591	7.9	2.0	1.5	11.4	5.3	2.5	1.5	9.3

Tube mills. (See also Table 88.)

All plants:									
1910	9,767	2.8	1.0	2.1	5.8	1.9	1.2	2.1	5.2
1911	13,676	.7	1.9	1.6	4.2	.5	2.3	1.6	4.4
1912	17,080	5.8	1.9	1.5	9.2	3.9	2.3	1.5	7.7
1913	18,909	7.1	1.7	1.2	10.0	4.7	2.1	1.2	8.8
1914	13,906	4.5	1.4	1.2	7.2	3.0	1.7	1.2	5.9
Total	73,338	4.5	1.7	1.5	7.7	3.0	2.1	1.5	6.6
Special plants:									
1907	2,007	4.5	1.5	4.6	10.6	3.0	1.9	4.6	9.5
1908	1,451	....	.8	3.7	4.5	....	1.0	3.7	4.7
1909	1,813	5.0	4.0	3.6	12.6	3.3	4.9	3.6	11.8
1910	1,792	5.0	1.1	3.7	9.8	3.3	1.4	3.7	8.4
1911	1,717	....	.8	3.1	3.9	....	1.0	3.1	4.1
1912	2,131	8.4	1.1	2.3	11.8	5.6	1.4	2.3	9.3
1913	2,101	8.6	.9	1.2	10.7	5.7	1.1	1.2	8.0
1914	1,527	....	1.9	1.1	3.0	....	2.3	1.1	3.4
Total	14,539	4.3	1.5	2.9	8.7	2.9	1.9	2.9	7.7

Occupational groups in tube mills, 1907 to 1914. (See also Table 89.)

Common labor	2,123	8.5	3.8	10.7	23.0	5.7	4.7	10.7	21.1
Furnace crews	3,066	....	.2	.9	1.1	....	.2	.9	1.1
Finishing crews	4,110	2.2	.4	1.0	3.6	1.5	.5	1.0	3.0
Unclassified	5,240	6.9	2.2	2.4	11.5	4.6	2.7	2.4	9.7
Total	14,539	4.3	1.5	2.9	8.7	2.9	1.9	2.9	7.7

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Continued.

Unclassified rolling mills. (See also Table 90.)

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
1910	14,434	9.4	3.5	4.0	16.8	6.3	4.8	4.0	15.1
1911	21,231	6.8	2.3	2.1	11.1	4.5	3.4	2.1	10.0
1912	22,909	6.7	2.1	2.7	11.5	4.5	2.9	2.7	10.1
1913	23,382	9.2	2.3	2.9	14.5	6.1	3.4	2.9	12.4
1914	22,873	4.7	1.8	2.2	8.7	3.1	2.5	2.2	7.8
Total	99,809	7.6	2.4	2.8	12.8	5.1	3.3	2.8	11.2
Bar mills, 1910 to 1014	21,555	5.4	1.7	3.6	10.7	3.6	2.3	3.6	9.5

Fabricating shops. (See also Table 91.)

All plants:									
1910	8,713	11.4	2.4	5.6	19.9	7.6	3.1	5.6	16.3
1911	19,530	3.2	2.3	1.8	7.3	2.1	2.9	1.8	6.8
1912	28,988	9.6	2.1	2.4	14.1	6.4	2.7	2.4	11.5
1913	30,470	9.8	1.9	2.3	13.9	6.5	2.4	2.3	11.2
1914	20,837	5.2	2.4	2.0	9.6	3.5	3.1	2.0	8.6
Total	108,538	7.8	2.2	2.4	12.4	5.2	2.8	2.4	10.4
Special plants:									
1907	2,081	25.9	6.9	2.5	35.3	17.3	8.8	2.5	28.6
1908	1,758	10.2	4.8	1.7	16.7	6.8	6.1	1.7	14.6
1909	1,770	25.4	.8	2.3	28.5	16.9	1.0	2.3	20.2
1910	2,074	21.7	2.2	2.6	26.5	14.5	2.8	2.6	19.9
1911	2,203	4.1	2.1	2.7	8.9	2.7	2.7	2.7	8.1
1912	2,074	13.0	4.5	3.3	20.8	8.7	5.7	3.3	17.7
1913	2,045	4.4	1.1	3.0	8.5	2.9	1.4	3.0	7.3
1914	1,759	5.1	2.3	2.2	9.6	3.4	2.9	2.2	8.5
Total	15,764	13.7	3.1	2.6	19.4	9.1	3.9	2.6	15.6

Wire drawing. (See also Table 92.)

1910	10,370	4.3	5.9	2.1	12.3	2.9	7.7	2.1	12.7
1911	11,819	2.8	4.7	1.7	9.2	1.9	6.1	1.7	9.7
1912	13,059	2.8	5.7	2.1	10.5	1.9	7.4	2.1	11.4
1913	12,769	4.2	2.6	2.1	8.9	2.8	3.4	2.1	8.3
1914	11,468	1.6	3.1	1.6	6.2	1.1	4.0	1.6	6.7
Total	59,481	3.0	4.3	1.9	9.3	2.0	5.6	1.9	9.5

Electrical departments. (See also Table 93.)

1910	1,526	11.8	2.0	2.0	15.8	7.9	2.8	2.0	12.7
1911	2,760	9.8	2.0	1.6	13.4	6.5	2.8	1.6	10.9
1912	3,796	14.2	3.6	1.6	19.4	9.4	5.0	1.6	16.0
1913	4,012	31.4	2.7	1.5	35.6	20.9	3.7	1.5	26.1
1914	2,327	30.9	2.2	1.6	34.7	20.6	3.0	1.6	25.2
Total	14,421	20.7	2.6	1.6	24.9	13.8	3.6	1.6	19.0

TABLE 116.—ACCIDENT SEVERITY RATES (DAYS LOST PER 300-DAY WORKER) ACCORDING TO THE BUREAU OF LABOR STATISTICS SCALE AND THE SCALE PROPOSED BY THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS—Concluded.

	Number of 300-day workers.	Bureau of Labor Statistics scale.				International Association scale.			
		Death.	Permanent disability.	Temporary disability.	Total.	Death.	Permanent disability.	Temporary disability.	Total.
***Mechanical departments.* (*See also Table 94.*)**									
All plants:									
1910	15,927	10.2	2.1	1.6	13.9	6.8	2.7	1.6	11.1
1911	17,863	6.6	2.6	2.2	11.4	4.4	3.3	2.2	9.9
1912	21,591	7.9	2.7	2.5	13.1	5.3	3.5	2.5	11.3
1913	24,009	13.1	2.4	2.8	18.3	8.7	3.1	2.8	14.6
1914	17,772	8.6	2.4	2.2	13.2	5.7	3.1	2.2	11.0
Total	97,161	9.5	2.5	2.3	14.2	6.3	3.2	2.3	11.8
Special plants:									
1905	1,088	57.9	8.3	4.1	70.3	38.6	10.6	4.1	53.3
1906	1,146	7.9	4.1	2.0	14.0	5.3	5.2	2.0	12.5
1907	2,542	7.1	1.3	3.5	11.9	4.7	1.7	3.5	9.9
1908	1,619	22.2	1.5	3.2	26.9	14.8	1.9	3.2	19.9
1909	1,977	13.7	2.7	2.8	19.2	9.1	3.5	2.8	15.4
1910	2,223	12.1	.6	2.6	15.3	8.1	.8	2.6	11.5
1911	2,144	8.4	.6	2.0	11.0	5.6	.8	2.0	8.4
1912	2,362	3.8	1.8	1.7	7.3	2.5	2.3	1.7	6.5
1913	2,569	10.5	1.2	1.5	13.2	7.0	1.5	1.5	10.0
1914	1,662	....	3.0	1.7	4.7	....	3.8	1.7	5.5
Total	19,332	12.1	2.0	2.4	16.5	8.1	2.6	2.4	13.1
***Yards.* (*See also Table 95.*)**									
All plants:									
1910	15,932	22.6	2.3	1.6	26.5	15.1	3.0	1.6	19.7
1911	9,085	10.9	4.2	2.0	17.1	7.3	5.6	2.0	14.9
1912	11,180	18.5	3.9	2.3	24.7	12.3	5.2	2.3	18.8
1913	11,859	21.2	2.3	2.1	25.6	14.1	3.0	2.1	19.2
1914	7,876	11.4	3.1	1.7	16.3	7.6	4.1	1.7	13.4
Total	55,932	18.0	3.1	1.9	23.0	12.0	4.1	1.9	18.0
Special plants:									
1905	1,185	30.4	3.9	2.8	37.1	20.3	5.2	2.8	28.3
1906	1,136	23.8	3.8	3.1	30.7	15.9	5.0	3.1	24.0
1907	2,618	17.2	5.9	3.2	26.3	11.5	7.8	3.2	22.5
1908	1,522	5.9	2.9	2.9	11.7	3.9	3.8	2.9	10.6
1909	1,891	28.6	.8	3.0	32.4	19.1	1.1	3.0	23.2
1910	2,134	16.9	2.4	1.9	21.2	11.3	3.2	1.9	16.4
1911	1,810	9.9	.7	2.1	12.7	6.6	.9	2.1	9.6
1912	2,078	4.3	4.9	2.1	11.3	2.9	6.5	2.1	11.5
1913	2,571	....	1.6	.9	2.5	....	2.1	.9	3.0
1914	1,356	6.6	1.5	1.4	9.5	4.4	2.0	1.4	7.8
Total	18,481	13.1	2.9	2.3	18.3	8.7	3.8	2.3	14.8
***Miscellaneous departments, 1910 to 1914.* (*See also Table 96.*)**									
Armor plate	3,000	12.0	1.1	2.0	15.1	8.0	1.4	2.0	11.4
Axle works	1,326	13.6	5.0	4.9	23.5	9.1	6.4	4.9	20.4
Car wheels	2,367	11.4	2.0	4.0	17.4	7.6	2.6	4.0	14.2
Docks	1,293	20.9	6.6	2.5	30.0	13.9	8.4	2.5	24.8
Erecting structural steel	2,157	108.5	14.7	5.4	128.6	72.3	16.5	5.4	94.2

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