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INDUSTRIAL ACCIDENTS AND HYGIENE SERIES: NO. 13

ACCIDENTS AND ACCIDENT PREVENTION IN MACHINE BUILDING

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ACCIDENTS AND ACCIDENT PREVENTION IN MACHINE BUILDING.

SUMMARY.

PURPOSE OF THE INVESTIGATION.

The purpose of this investigation was not only to ascertain the frequency and severity of accidents in the machine-building industry but also to study and analyze these accidents in such a way as to supply the information necessary for effective safety work. To this end the report seeks, as far as possible, to locate the accident hazards in particular departments and occupations, to discover the reason and causes for the occurrence of accidents, and to point out some of the more successful methods for their prevention.

SCOPE OF THE REPORT.

The machine-building industry covers the production of a very large variety of machinery and machine appliances. The number of plants engaged in the various branches of the industry is extremely large. It was, therefore, necessary to limit the investigation to certain selected plants, representing, as fairly as could be determined, the more important classes of product. In all, the investigation covered 194 plants. These plants worked 347,109,000 man hours in 1912, which is equivalent to 115,703 full-time or 300-day workers.

The 300-day worker, or 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 300 days a year, 10 hours per day—3,000 hours per annum.[1]

For each of the 194 plants full accident data were obtained for the year 1912. In addition, similar data for a series of years were obtained from such of these plants as had the necessary records in available form.

[1] For fuller discussion of this, see p. 17.

All accidents causing loss of time beyond the day on which the accident occurred are included in the statistics of this report. The frequency of accident occurrence is expressed in rates. These rates give the number of accidents per thousand workers employed 300 days of 10 hours each. This is the same method of presentation used in the report on accidents in the iron and steel industry.[1]

ACCIDENT SEVERITY RATES: A METHOD OF MEASURING THE SERIOUSNESS OF ACCIDENTS.[2]

In this report for the first time an attempt is made to show the seriousness of accidents by what has been called "severity rates."[3] 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.

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 employee killed of an average age of 30) as equivalent to the loss of 30 years' work time—9,000 days.[4] Other 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 114.5 cases per 1,000 workers. But even a casual acquaintance with the two industries would indicate that the steel plant represented 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

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

[2] See Ch. I for a full discussion of meaning and importance of "severity" rates

[3] The method used by the Bureau of Labor Statistics in computing severity rates, and the meaning and value of these rates were explained in an article appearing in the July, 1916, number of the MONTHLY REVIEW of the U. S. Bureau of Labor Statistics, pp. 6-17.

[4] For full explanation of the method followed, see p. 18.

rates were computed according to the method described, the steel plant having a severity rate of 21.2 days lost per full-time or 300-day 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.

ACCIDENT RATES FOR THE INDUSTRY AS A WHOLE.[1]

The number of accidents occurring during the year 1912 was 13,647, resulting in 37 deaths, 411 permanent injuries, and 13,199 temporary disabilities. This is equivalent to an accident frequency rate of 118 per 1,000 full-time workers and a severity rate of 5.6 days lost per worker. These rates may be contrasted with the experience of a representative steel plant during the same year, for which the frequency rate was 153.5 and the severity rate 14.3 days lost. Accidents in the steel plant were thus only about one-third more frequent than in machine building but their severity was more than twice as great.

ACCIDENT RATES, BY CHARACTER OF PRODUCT.[1]

The accident hazards of the machine-building plants vary greatly with the character of their products. Those engaged in the making of locomotives have the highest severity rate—10.6 days lost per worker—and the builders of ships have the next highest—8 days lost per worker. The severity rates for the other classified groups are as follows: Machines for the steel industry, 7.7 days; cranes and hoists, 4.2 days; electrical apparatus, 3.4 days; power-transmission machinery, 3.2 days; mining machinery, 3 days; and machine tools, 2.4 days.

ACCIDENT RATES, BY DEPARTMENTS.[2]

Classifying the combined plants by departmental divisions, boiler shops and yard labor show by far the greatest hazards. Boiler shops have a frequency rate of 224.1 per 1,000 workers and a severity rate of 26.7 days lost per worker, while yard labor has a frequency rate of 221.1 and a severity rate of no less than 29 days lost. These rates are, roughly, as high as those in the iron and steel industry, which is recognized as inherently a much more hazardous industry than machine building. The high rates of the boiler shops are, primarily, the result of insecure trestles and scaffolding. For the excessive rates in the yard department responsibility rests upon the general neglect of safety precautions in the transportation work of many plants.

Other important departments show the following severity rates: Power, 22.1 days lost; forge shops, 14.2 days; erecting shops, 9.4 days; iron foundries, 6.4 days; woodworking, 5.8 days; machine shops, 4 days; electric shops, 3.6 days.

[1] See p. 29 et seq.
[2] See p. 30 et seq.

COURSE OF ACCIDENT RATES OVER A SERIES OF YEARS.[1]

One of the fundamental inquiries in a study of this character is whether or not accidents are decreasing. A precise answer is difficult, because of the fact that very few plants had reliable accident records over a period of years. Such information was obtainable for two groups of plants. The first group covers the years 1907 to 1912. No significant change in accident occurrence is observable. The second group covers the years 1910 to 1913. The frequency rate shows no decrease, but the severity rate, after running as high as 6.4 days in 1910, 8.2 days in 1911 and 6.9 days in 1912, drops to 3.2 days in 1913. This decrease undoubtedly reflects the more thorough safety organization effected in some of these plants in 1912. The fact that the frequency rate shows no decline is certainly due to the more complete reporting of minor accidents in the later years.

A study of the course of accident rates in individual departments is offered but is not very conclusive, as in some cases the records were available for only a very limited period and in others the number of employees was too small for the drawing of conclusions.

EFFECT OF SAFETY SYSTEMS UPON ACCIDENT OCCURRENCE.[2]

A striking method of showing the effect of a good safety system in accident prevention is to compare the accident rates in plants having, with those in plants not having, well-organized systems. This is done for three important groups of plants. In every case the plants not having a good safety organization show accident frequency rates three or four times as high as those having a well-developed system.

ACCIDENT RATES FOR A LARGE MACHINE-BUILDING ESTABLISHMENT, BY OCCUPATIONS.[3]

The study of accident rates by occupations is of particular importance from the standpoint of safety work. It is by locating accident hazards in particular occupational groups that precise knowledge is gained as to the proper place for applying preventive measures. The great handicap to such a study is the difficulty of determining the number of 300-day workers in the individual occupation, and this information is necessary for the proper computation of rates. This difficulty was overcome for one large machine-building concern and a very interesting group of occupational rates was obtained.

The highest severity rate among the occupations listed in this establishment is that of cranemen—28.5 days. It is due to an exceedingly large number of fatal injuries. This fatality hazard is attributable to the faulty construction of cranes, now greatly modified by the safety features incorporated in their original design.

[1] See p. 36 et seq. [2] See p. 42 et seq. [3] See p. 44 et seq.

Common labor has the next highest severity rate—17.3 days. This group is so large that a high rate among them is very significant. There is no one particular preventive measure by which the rate can be reduced. There is demanded a general application of all possible remedial measures.

Machine hands show the high rate of 13.9 days lost per worker. As the group is small this may not be a normal rate, but, in some measure, it certainly reflects the fact that a good many automatic machines have been constructed with their moving parts needlessly exposed.

IMPORTANT CAUSES OF ACCIDENT.[1]

The analysis of accident causes, together with the determination of occupational rates, is at present the most important practical subject to be considered in accident studies. A careful study of accident causes was made in selected groups of machine-building plants and is presented in Tables 18 and 19.

For the industry as a whole "falling objects" stands out as the most frequent cause of accidents, the frequency rate for 5 machine-building plants from 1907 to 1912 being 14.44 cases per 1,000 300-day workers, and for 4 machine-building plants, 1910 to 1913, 14.35 cases per 1,000 300-day workers. As measured by severity "cranes and hoists" assumes first place, the severity rate being 2.26 days lost per 300-day worker in the group of 5 plants, 1907 to 1912, and 1.22 days lost per 300-day worker in the group of 4 plants, 1910 to 1913.[2] In foundries "hot metal" appears as the accident cause with most serious effects, the severity rate being 2.82 days lost per worker out of a total of 7.41 days lost for all foundry causes. In the more progressive foundries provision of proper shoes, leggings, and eye protectors has nearly eliminated many of the dangers of handling hot metal.

In machine shops the "operating machines" is responsible for a severity rate of 1.36 days out of 3.23 days for all causes. Also, in electrical assembly shops "operating machines" is responsible for a severity rate of 0.96 days out of a total of 2.35 days for all causes.

Comparing accident causes in machine building with those in steel making, it develops that, for the most part, the accident causes are of similar importance in both industries. Thus "falling and flying objects" is by far the most frequent cause of injury in both steel making and machine building. In both industries, also, cranes and hoists are fertile causes of accidents, with severe resulting injuries. "Using tools," on the other hand, is the cause of a considerable percentage of accidents, but the resulting severity is inconsiderable.

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[1] See p. 48 et seq. [2] See p. 50 et seq.

NATURE OF INJURY.[1]

Nature of injury is of much less importance from the standpoint of accident prevention than is cause of injury. Perhaps the most interesting point in this connection is the comparison of the character of the injuries occurring in machine building with those occurring in steel making. Injuries by bruising and lacerating the hands and fingers are much more important both as to frequency and severity in machine building than in steel making, as would be expected from the character of the processes carried on. Also, eye injuries are much more important both as to frequency and severity in machine building. On the other hand, burns stand out prominently in the steel industry. In other respects there is a remarkable similarity between the two industries.

INABILITY TO SPEAK ENGLISH AS RELATED TO ACCIDENTS.[2]

It was not possible in the plants covered to separate the employees into English and non-English speakers. For one large machine-building plant, however, separation was possible between the American born and foreign born. The foreign born showed an accident rate approximately double that for the native born. This excess rate among foreign born is clearly attributable to the same causes which lead to a constant excess among non-English speaking steel workers—partly to their failure to understand clearly the orders given them, and partly to the fact that the recent immigrant suffers from lack of experience, and thus falls largely into the group of unskilled occupations involving exposure to inherently high accident hazards.

ACCIDENT RATES HIGHER AT NIGHT.[3]

The compilation of the accident experience of a large machine-building plant which worked both day and night developed that the accident frequency rate was 50 per cent higher among nightworkers than among dayworkers. This is in keeping with the experience of the iron and steel industry.

DISTRIBUTION OF ACCIDENTS BY MONTHS.[4]

An analysis of the monthly distribution of accidents in three important plants shows the highest frequency rates in the months of August and September. This would indicate that the depressing influence of summer heat may be a factor in accident hazard and suggests the value of proper ventilating apparatus as an accident preventive measure as well as a needed contribution to the comfort of the workers.

[1] See p. 54 et seq. [2] See p. 57 et seq. [3] See p. 59 et seq. [4] See p. 63 et seq.

UNITED STATES GOVERNMENT ARSENALS AND NAVY YARDS.[1]

The navy yards and arsenals of the United States Government are machine-building plants. But the discussion of the accident rates therein is separated from that for private plants because of the fact that accident reports from the Government shops for the period covered by this study were extremely incomplete for short-time disabilities. To make fair comparisons between the rates for the two groups of plants it is therefore necessary to exclude all disabilities of less than two weeks' duration. This requires recomputation of the rates previously considered, which are based on the inclusion of all disabilities of over a day's duration.

The most obvious comparison is that between Government navy yards and private shipbuilding plants. The Government yards show the lower frequency rate, 74.8 cases per 1,000 workers, as against 99.4 cases in private plants, but, on the other hand, show the higher severity rate, 12.6 days lost per worker as against 7.4 days in private plants.

The Government arsenals, because of their varied activities, may perhaps be compared with fairness with the entire machine-building industry. When this is done, the arsenals show a higher frequency rate—51.7 cases against 32.2 cases per 1,000 workers—and also a slightly higher severity rate—6.4 against 5.2 days lost per worker.

This somewhat unsatisfactory showing of the Government shops calls for careful consideration. Certain factors in their conduct impress the outside observer as favorable to low accident rates—extreme orderliness and cleanliness, freedom from violent fluctuations in employment, the quality and stability of the working force, and the eight-hour day. Certain other factors, existing at least in 1912, would seem to have a contrary effect—imperfect mechanical safeguarding, lack of safety organization, and an honest conviction on the part of the supervising authorities that such accidents as occurred were without remedy.

Comparing the accident rates of the Government arsenals with those of the Government navy yards, it is found that the navy yards have much the higher rates. This is in accordance with the known character of the relative hazards of the work done.

METHODS OF ACCIDENT PREVENTION.

Experience has everywhere shown that the most effective work for the prevention of accidents must come from a proper safety organization within the plant itself.[2] Such an organization involves some form of a safety committee system, with representatives of both employer and employees working together to develop the best safety

[1] See p. 64 et seq. [2] For a fuller discussion of the subject of safety organization see Ch. III.

methods, not only in the field of mechanical safeguards, but also in the education of the employees in the observance of proper precautions and the maintenance of the safety spirit. It is important to note, in this connection, that the existence of compensation laws in most of the States now furnishes an economic incentive for accident reduction, which was so often absent under the old liability system.

The plant safety organization, however, does not itself do away with the need of mechanical safeguards. It is rather an assurance that the proper safeguards will be adopted and will be properly used. For practically all of the dangers attending the use of the machinery and processes in machine building, excellent safeguards have been devised and are in use in certain plants.[1]

In discussing the question of safety in the machine-building industry it is important to remember that that industry not only uses machinery which needs to be safeguarded, but that its work consists of the production of machines for use in other industries. The extent to which the machines thus manufactured will later be a source of danger to the workers in those other industries depends in considerable measure upon the character of their original construction. The subject of machine design—of building a machine in such a way as to offer the minimum of hazard to its future operators—thus becomes of very great significance. This subject is discussed in Chapter V.

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[1] For an illustrated description of these safeguards see Ch. IV.

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 determination 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 has also 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 definite 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 of 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 1,000 workers, and constituted an approach to a correct method. To say that a given industry had an accident rate of 100 per 1,000 workers does convey a definite idea, and can be compared with a rate of, say, 300 per 1,000 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 varies 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, inasmuch 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.

Thus, if a plant having 1,000 machines, each requiring one man to operate, worked 10 hours a day for 300 days, the total number of man-hours worked would be 3,000,000 per year (i. e., 1,000×10×300), and the number of full-time workers would be 1,000, although individual employees may have changed many times during the year. Another plant having exactly the same equipment, but working only 9 hours a day for only 200 days would have a total of only 1,800,000 man-hours (1,000×9×200), the equivalent of only 600 full-time workers (1,800,000÷3,000). By thus reducing the employment in the two plants to a common unit, accident hazard may be accurately compared. Thus, if each of these plants had 200 accidents during the course of the year, the rate for the first plant would be 200 per 1,000 full-time workers, while for the latter it would be 333 per 1,000 full-time workers (i. e., $200 \times \frac{1000}{600}$) and the relation 200 to 333 would correctly express the relative accident frequency in the two plants.

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.

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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."

This resolution has not been adopted by the committee on statistics and compensation insurance cost of the International Association of Industrial Accident Boards and Commissions, but the necessity of reaching an approximation to the man-hours worked in establishments which keep no accurate records has been tacitly accepted.

The establishments covered by this study kept accurate time records so the man-hours were taken from these records.

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 by the bureau 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 the 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 1.—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.

States.	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

[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] For this State the periods named are to be reduced by any time for which payments on account of temporary total disability have been made.

TABLE 1.—COMPARATIVE TIME ALLOWANCES FOR SPECIFIED DISABILITIES UNDER THE LAWS OF VARIOUS STATES—OTHER DISABILITIES COMPARED WITH LOSS OF ARM—Concluded.

Relative time allowances (loss of arm=100).

States.	Loss of—											
	Arm.	Hand.	Leg.	Foot.	Eye.	Thumb.	One joint of thumb.	First finger.	Second finger.	Third finger.	Fourth finger.	Great toe.
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

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 as 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 is 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.

In Table 2 is brought 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 2.—TIME LOSSES FIXED FOR DEATH AND PERMANENT DISABILITIES.

Items.	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 member:			
Arm	2,808	100.0	26.7
Leg	2,592	92.3	24.7
Hand	2,196	78.2	20.9
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

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 3.—TIME LOSSES IN ONE PLANT.

Items.	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 explain 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 4.—ACCIDENT RATES IN STEEL MANUFACTURE AND IN MACHINE BUILDING.

Industries.	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	16.7	2.2	2.4	21.3
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 industry 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 A presents the same material in graphic form.

TABLE 5.—ACCIDENT EXPERIENCE OF A LARGE STEEL PLANT, 1910 TO 1913.

Years.	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 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.

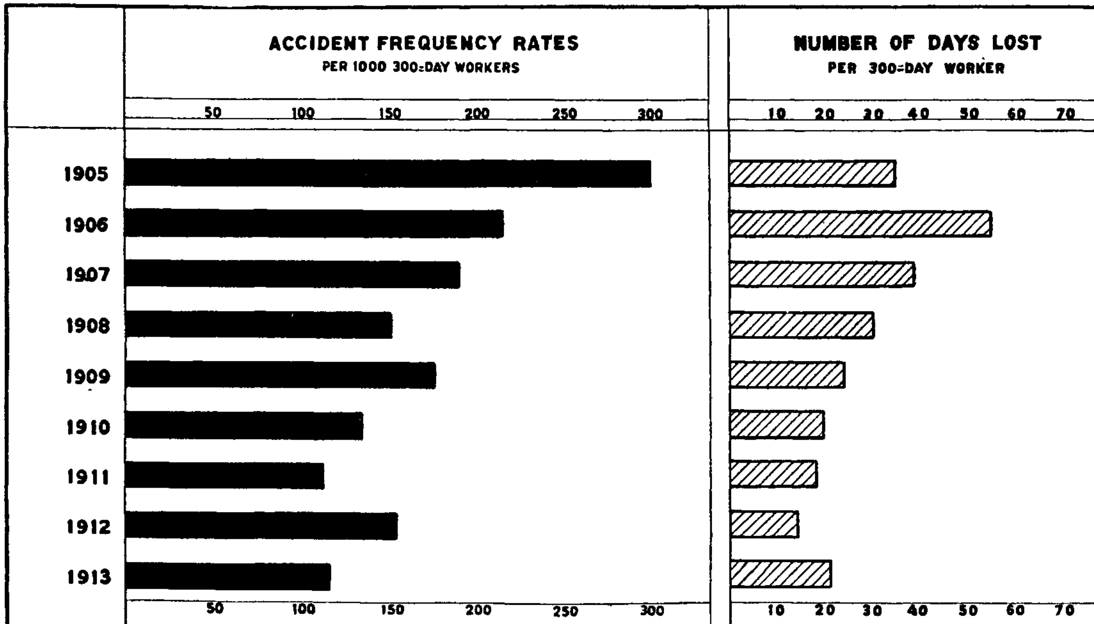
This leads to a second point which can not be too much emphasized: The fact that inasmuch as the real significance of severity rates is in the measurement of relative hazards, the character of the weighting scale used becomes comparatively unimportant. Thus by changing

FREQUENCY AND SEVERITY OF ACCIDENTS

IN THE IRON AND STEEL INDUSTRY.

EXPERIENCE OF A LARGE PLANT 1905-1913.

SHOWING THE VARIATION IN ACCIDENT RATES OVER A PERIOD OF YEARS, AND CONTRASTING ACCIDENT FREQUENCY AND ACCIDENT SEVERITY (SEVERITY BEING MEASURED IN TERMS OF DAYS LOST. SEE TEXT.)



	ACCIDENT FREQUENCY RATES	DAYS LOST PER 300-DAY WORKER	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

CHART A.

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 errors in accident reporting are 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, 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.

CHAPTER II.—ACCIDENT EXPERIENCE.

As a basis for this report, accident data for a single year, 1912, were obtained from 194 machine-building plants, employing for that year a total of 115,703 300-day workers, which is equivalent to 347,109,000 man hours.[1] It is believed that the plants thus covered are sufficient in number and are well enough distributed to be fairly representative of the industry in its important branches. Also, in addition to the data for the year 1912, information regarding accidents over a series of years was secured from such of these plants as had records of sufficient completeness for this purpose.

An analysis of the information obtained is presented in this chapter. All accident rates are given in two forms—accident frequency rates (i. e., the number of accidents per 1,000 300-day workers) and accident severity rates (i. e., the average number of days lost per 300-day worker). The significance of severity rates and their method of computation were explained in the preceding chapter. Also, the reasons were there pointed out for believing that severity rates are a much more accurate measure of true hazard than are frequency rates, especially for purposes of comparison between industries.

ACCIDENT RATES FOR 1912, BY CHARACTER OF PRODUCT.

The machine-building industry covers the manufacture of a large variety of machines and machine tools as finished products, and the accident hazard of a plant varies greatly with the character of the product. This is shown in the following table, which classifies the machine-building plants according to their products and shows for each class, for the year 1912, the number of 300-day workers, the number of cases of accidents, and the resulting accident rates:

TABLE 6.—FREQUENCY AND SEVERITY OF ACCIDENTS IN 194 MACHINE-BUILDING PLANTS IN 1912, BY CLASSIFIED PRODUCTS.

Products.	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.
Ships	6,615	3	15	1,422	1,440	0.5	2.3	215.0	217.8	4.1	1.6	2.3	8.0
Mining machinery	3,994	......	12	755	767	......	3.0	189.0	192.0	......	1.1	1.9	3.0
Cranes and hoists	4,362	1	15	813	829	.2	3.4	186.4	190.0	2.1	.5	1.6	4.2
Charging cars, etc.	2,692	1	16	438	455	.4	5.9	162.7	169.0	3.3	2.9	1.5	7.7
Locomotives and engines	31,229	22	160	4,348	4,530	.7	5.1	139.2	145.0	6.3	2.9	1.4	10.6
Electrical apparatus	35,674	5	100	3,455	3,560	.1	2.8	96.8	99.8	1.3	1.1	1.0	3.4
Power transmission machinery	2,226	......	9	186	195	......	4.0	85.6	89.6	......	2.1	1.1	3.2
Machine tools	24,359	3	68	1,486	1,557	.1	2.8	61.0	63.9	1.1	.8	.5	2.4
Unclassified	4,552	2	16	296	314	.4	3.5	65.0	68.9	4.0	1.1	.7	5.8
Total	115,703	37	411	13,199	13,647	.3	3.6	114.1	118.0	2.9	1.6	1.1	5.6

[1] This does not include the navy yards and arsenals of the Federal Government. Such information as was available regarding these Government shops is presented on p. 64 et seq.

Considering, first, the last line of the table, it will be seen that among the 115,703 300-day workers, there occurred during the course of the year a total of 13,647 injuries, consisting of 37 deaths, 411 permanent disabilities, and 13,199 temporary disabilities. This is equivalent, as shown, to an accident frequency rate of 118 per 1,000 workers and a severity rate (i. e., time lost) of 5.6 days per worker. These rates may be contrasted with the experience of a large steel plant during the same year, for which the frequency rate was 153.5 cases and the severity rate 14.3 days lost.[1] Accidents in the steel plant were thus only about one-third more frequent than in the machine-building plants, but their severity was more than twice as great.

It is also to be noted that the accident rates for the different groups are very dissimilar. The highest frequency rate (217.8 cases) and the next to the highest severity rate (8 days) appear in shipbuilding. This is the result largely of the building construction involved in the putting together of ship hulls, this work having the high hazard incident to the operation of reaming, riveting, and other construction machines. Also, the scaffolding used is more temporary in character than is customary in general building construction.

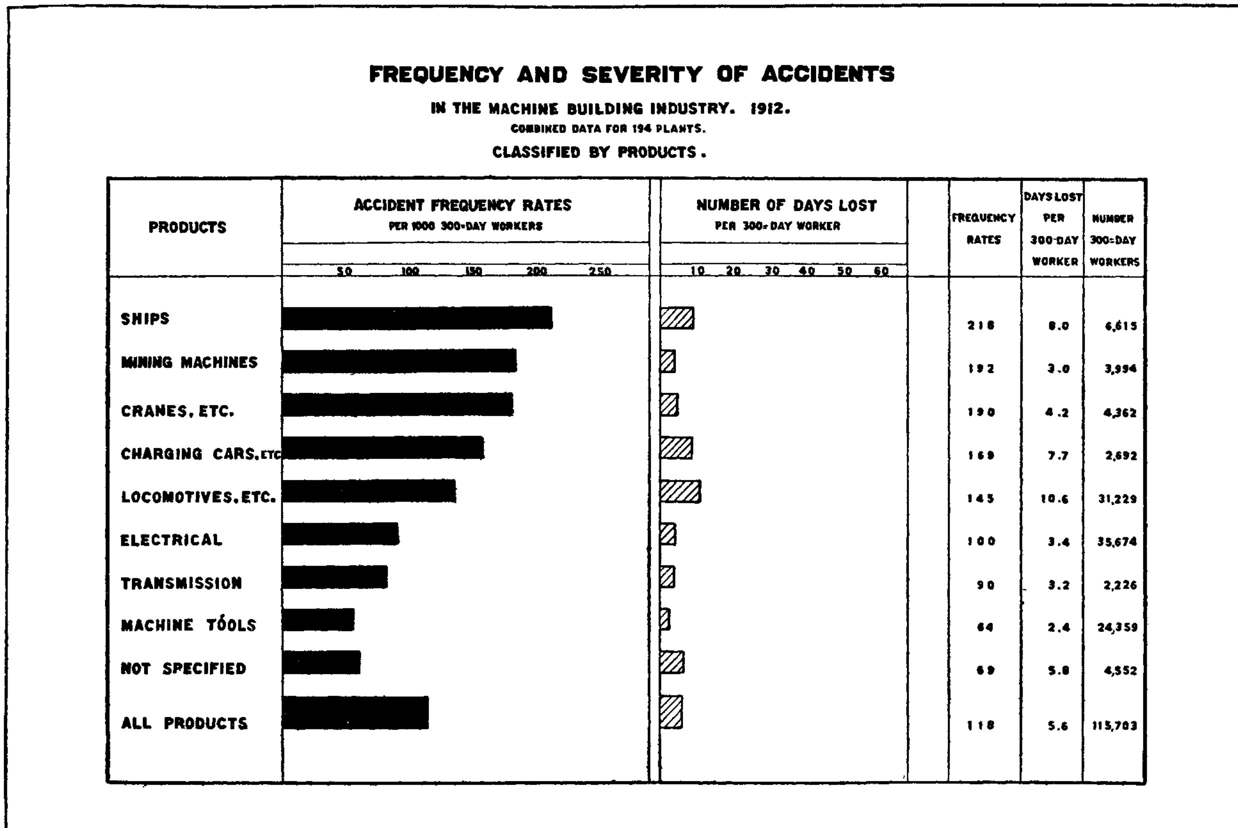
Of the three groups having the largest number of 300-day workers—i. e., locomotives and engines, electrical apparatus, and machine tools—"locomotives and engines" shows the highest frequency rate (145 cases) and also the highest severity rate (10.6 days), whereas for "electrical apparatus" the corresponding rates are at a much lower level (99.8 cases and 3.4 days), and for "machine tools" are at a still lower level (63.9 cases and 2.4 days). In the case of these three groups, therefore, frequency rates and severity rates vary uniformly.

But this is not the case with all of the groups listed. Thus, "cranes and hoists" has a higher frequency rate than "locomotives and engines" (190 against 145 cases) but a very much lower severity rate (4.2 against 10.6 days lost). Other striking contrasts of this character are shown in Chart B, which is a graphic presentation of the data in the table. The existence of these contrasts reinforces the earlier statement that no fair comparison of hazard in diverse industries or industrial groups can be made on the basis of accident frequency alone. The frequency may be great when the severity is relatively low.

ACCIDENT RATES FOR 1912, BY DEPARTMENTS.

The preceding section has shown how the accident hazards of machine-building plants vary with the character of the product. From the standpoint of accident prevention, however, it is of much more importance to study the accident experience of the various

[1] Second report on Accidents in the Iron and Steel Industry (now in preparation).



PRODUCTS	FREQUENCY RATES	DAYS LOST PER 300-DAY WORKER	NUMBER 300-DAY WORKERS
SHIPS	218	8.0	6,615
MINING MACHINES	192	3.0	3,994
CRANES, ETC.	190	4.2	4,362
CHARGING CARS, ETC	169	7.7	2,692
LOCOMOTIVES, ETC.	145	10.6	31,229
ELECTRICAL	100	3.4	35,674
TRANSMISSION	90	3.2	2,226
MACHINE TOOLS	64	2.4	24,359
NOT SPECIFIED	69	5.8	4,552
ALL PRODUCTS	118	5.6	115,703

CHART B.

departments. A knowledge of the accident rates in particular departments, and better still in particular occupations, of a plant or industry, indicates the fields in which safety work is most called for, or, at least, in which investigation is most needed for the proper devising of safeguarding methods.

The following table shows the combined departmental accident experience for the year 1912, of the 194 plants covered. Chart C presents the same information in graphic form. In using these data it is to be borne in mind that while, as a rule, the number of 300-day workers in each department is sufficiently large to make deductions fairly conclusive, this is probably not true in the case of the brass foundries and the power departments. In each of these instances there are less than 1,000 300-day workers concerned, and it is the general rule of this report to require at least 1,000 workers in order to justify the computation of rates. Nevertheless, rates based on a lesser number of workers may be sometimes, as at present, of sufficient interest to justify presentation, provided the results are interpreted with caution.

TABLE 7.—FREQUENCY AND SEVERITY OF ACCIDENTS IN 194 MACHINE-BUILDING PLANTS IN 1912, BY DEPARTMENTS.

[For number of cases on which these rates are founded, see p. 112.]

Departments.	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.
Boiler shops	2,994	2.0	9.7	212.4	224.1	18.0	6.3	2.4	26.7
Yards	1,221	2.5	5.7	212.9	221.1	22.1	4.3	2.6	29.0
Erecting shops	11,373	.5	4.9	175.2	180.6	4.7	2.8	1.9	9.4
Forge shops	2,776	1.1	4.7	158.1	163.9	9.7	2.8	1.7	14.2
Foundries (iron)	12,307	.3	4.0	135.7	140.0	2.9	2.1	1.4	6.4
Machine shops	37,595	.2	3.5	104.4	108.1	1.7	1.4	.9	4.0
Power houses	877	2.3	2.3	99.2	103.8	20.5	.3	1.3	22.1
Maintenance	1,468	....	.7	93.3	94.0	....	.8	1.1	1.9
Woodworking	3,571	.3	7.6	73.9	81.8	2.5	2.4	.9	5.8
Electric shops	20,144	.2	3.2	78.4	81.8	1.8	1.0	.8	3.6
Foundries (brass)	717	....	....	72.5	72.5	....	....	.8	.8
Unclassified	20,660	.1	1.5	104.6	106.2	.4	.5	1.1	2.0
Total	115,703	.3	3.6	114.1	118.0	2.9	1.6	1.1	5.6

The departments are arranged in the table, as also in the chart, in the descending order of frequency rates.

Boiler shops have by far the highest accident rates of any of the strictly machine-building departments. Its frequency rate (224.1 cases per 1,000 workers) is the highest of any department. Its severity rate of 26.7 days lost per worker is exceeded only by the yard department which has a rate of 29 days; and its death rate of 18 days is exceeded only by yards with 22.1 days and by the power department with 20.5 days. The frequency rate of boiler shops, 224.1 cases, is

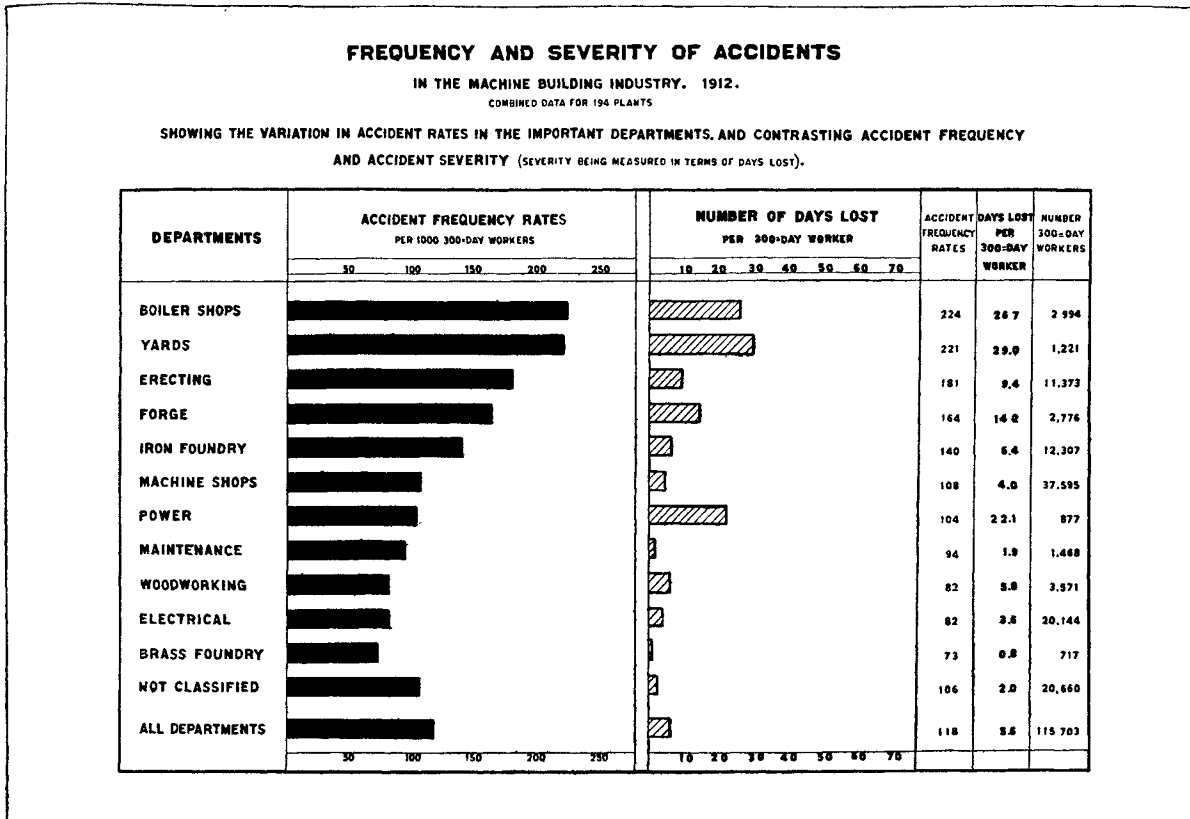

FREQUENCY AND SEVERITY OF ACCIDENTS
IN THE MACHINE BUILDING INDUSTRY. 1912.
COMBINED DATA FOR 194 PLANTS
SHOWING THE VARIATION IN ACCIDENT RATES IN THE IMPORTANT DEPARTMENTS, AND CONTRASTING ACCIDENT FREQUENCY AND ACCIDENT SEVERITY (SEVERITY BEING MEASURED IN TERMS OF DAYS LOST).
DEPARTMENTS
ACCIDENT FREQUENCY RATES
PER 1000 300-DAY WORKERS
50 100 150 200 250
NUMBER OF DAYS LOST
PER 300-DAY WORKER
10 20 30 40 50 60 70
ACCIDENT FREQUENCY RATES
DAYS LOST PER 300-DAY WORKER
NUMBER 300-DAY WORKERS
BOILER SHOPS 224 26.7 2,994
YARDS 221 29.0 1,221
ERECTING 181 9.4 11,373
FORGE 164 14.2 2,776
IRON FOUNDRY 140 6.4 12,307
MACHINE SHOPS 108 4.0 37,595
POWER 104 22.1 877
MAINTENANCE 94 1.9 1,468
WOODWORKING 82 5.8 3,571
ELECTRICAL 82 3.6 20,144
BRASS FOUNDRY 73 0.8 717
NOT CLASSIFIED 106 2.0 20,660
ALL DEPARTMENTS 118 5.6 115,703

CHART C.

indeed almost as high as the rate of 245.2 cases per 1,000 workers in the iron and steel industry in 1910.[1]

As the boiler shops show such high accident rates, it is appropriate to inquire more particularly regarding accident causes in that department. In general, it may be stated that the work of constructing boilers is similar in character to the erection of structural iron, which is generally agreed to be extrahazardous. This extra hazard arises, in part at least, from the necessary use of temporary staging and trestles which afford an insecure footing, and also from the fact that many of the air riveters, reamers, and other pneumatic tools can not be given fixed location, but must be moved and handled with constant danger of loss of control and of consequent loss of footing. The substitution of fixed apparatus in many fabricating shops has tended somewhat to reduce the frequency of accident, but probably the most effective point of attack would be the temporary structures used in the building processes. A very great improvement in scaffolding used in building construction has been made in recent years, and there is no reason why inventive genius could not improve the conditions of the boiler shop. In another direction also improvement is possible. Boiler making is rough and not particularly precise work, and it is often relegated to very dark and ill-ventilated buildings, and improvement in the character of the lighting would, in many cases, tend to lessen the number of accidents.

Next to the boiler shops in frequency of accident, and exceeding them in severity, is the relatively small yard department. The exact limits of the employment in this department and the assignment to it of its proper quota of accidents are matters of consider-

[1] Conditions of Employment in the Iron and Steel Industry (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, p. 43.

Summary of accidents in iron and steel industry, by departments, year ending June 30, 1910.

Departments.	300-day workers.	Number of injuries.				Accident frequency rates (per 1,000 300-day workers).			
		Fatal.	Permanent disability.	Temporary disability, 1 day and over.	Total.	Fatal.	Permanent injury.	Temporary disability, 1 day and over.	Total.
Blast furnaces	19,604	60	50	4,937	5,047	3.06	2.55	251.8	257.4
Bessemer steel works	3,668	16	11	1,525	1,552	4.36	3.00	415.8	423.1
Open-hearth steel works	9,017	30	38	2,999	3,067	3.33	4.21	332.6	340.1
Puddling	1,239			62	62			50.0	50.0
Rolling mills (mechanical)	13,566	28	40	4,131	4,199	2.06	2.95	304.5	309.5
Rolling mills (hand)	10,675	11	28	3,872	3,911	1.03	2.62	362.7	366.4
Mechanical	17,421	23	31	4,093	4,147	1.32	1.78	234.9	238.0
Yards	16,441	47	23	2,413	2,483	2.86	1.40	146.8	151.0
Steel foundries	16,480	8	37	2,153	2,198	.49	2.25	130.6	133.4
Departments not specified	38,868	51	112	9,179	9,372	1.32	3.67	237.1	242.0
Total	146,979	274	400	35,364	36,038	1.86	2.72	240.6	245.2

able difficulty. If the high rates shown in the table were not confirmed by the previous more extensive study of similar occupations in iron and steel, some doubt might be entertained regarding their validity. The death frequency for yard employees in iron and steel is 2.86 cases per 1,000 300-day workers in an exposure of 16,441 persons. In machine building the death frequency for yard employees is 2.5 cases per 1,000 300-day workers in an exposure of 1,221 persons. The liability to fatal injury in strictly yard operations is indicated by the fact that switchmen in the iron and steel industry in 1910 had a death frequency rate of no less than 27.3 cases per 1,000 300-day workers.[1]

It is of interest to note some of the reasons which have tended, and evidently still tend, to keep yard conditions from responding to safety efforts as promptly and as fully as have other departments. In the first place, there is the fact of divided authority. In large plants the tracks of adjacent railways are directly connected with those of the plant, and it may easily happen that the railway does not observe the same safety precautions as does the plant. The railway may even relax the rules of its own yards when it passes into territory under another jurisdiction.

In the second place, it may be that in matters of its transportation equipment the plant is deficient in those elements of safety required by law for public carriers. And in the third place, transportation, though so vital an element in plant operation, is detached in a measure from the other operations and has not been as carefully considered from the safety standpoint as have other plant activities. That the frequency of death should be nearly as great in the yard operations of these machine-building plants as in the iron and steel industry indicates the need for rigorous revision of yard methods.

The third department in order of accident frequency is erecting. The work in this department partakes of the nature of fabricating, such as goes on in boiler shops, and of assembling, which is a conspicuous element in the work of electrical shops. Its frequency rate is 180.6 cases per 1,000 300-day workers, while the severity rate is 9.4 days lost per worker. This severity rate may be compared with the one of 26.7 days for boiler shops and 29.0 days for yards.

From the standpoint of size, machine shops constitute much the most important department. Both in frequency of accident (108.1 cases per 1,000 300-day workers) and in severity (4 days lost per worker) this department stands somewhat below the average for all departments. The reasons for the existing rates are brought out more clearly in the section on causes of injury in machine building.[2]

[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. 99.

[2] See p. 49.

ACCIDENT RATES OVER A SERIES OF YEARS.

The data of the preceding sections exhibit the accident hazards of the machine-building industry as a whole and by departments. The next step is to study the course of accidents by plants and by departments over a series of years.

Such a study involves several difficulties. In the first place, there is the very practical difficulty that accident data for a series of years could be obtained from only a limited number of the plants from which information was obtained for the single year 1912. Most of the plants either had no records for earlier years or, if they had, the records were too incomplete for use.

In the second place, many of the most desired analyses deal with groups of such small size that the influence of unusual causes may become unduly prominent. All small groups, therefore, must be interpreted with great caution. Finally, it is to be emphasized that with improvement in accident prevention work the reporting of accident cases tends to be more complete. In the analyses presented below, every possible precaution was exercised in selecting plants whose records have been kept with care and uniformity, but in spite of this effort improvements which have undoubtedly been made are masked in a measure by more exact reporting.

The following table shows the accident rates in a group of five important machine-building plants over a period of six years, 1907 to 1912. This is the largest group of plants for which accident data could be obtained for a period of any considerable length. These five plants, while included in the total of 194 plants for which detailed information was presented for the year 1912 (see Table 7), are engaged in work causing injuries of less frequency but of greater severity than the average for the larger group. This fact, however, in no way interferes with the value of the following comparisons of the same group of plants over a series of years.

TABLE 8.—FREQUENCY AND SEVERITY OF ACCIDENTS IN FIVE MACHINE-BUILDING PLANTS, BY YEARS, 1907 TO 1912.

[For number of cases on which these rates are founded, see p. 113.]

Years.	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	22,023	0.8	5.6	75.7	82.1	6.9	3.0	0.8	10.7
1908	8,261	....	3.3	36.0	39.2	....	1.2	.3	1.5
1909	11,303	.4	3.6	59.1	63.1	3.2	2.5	.5	6.2
1910	18,729	.5	4.3	82.9	87.7	4.3	2.5	.7	7.5
1911	16,481	1.2	3.2	76.2	80.6	10.9	1.6	.7	13.2
1912	17,233	.7	4.7	95.8	101.2	6.3	2.3	.9	9.5
Total	94,030	.7	4.3	75.4	80.4	5.9	2.3	.7	8.9

In the tabulation of accident data the year 1908 appears as abnormal, due to the depressed industrial conditions of the time. The data for that year should, therefore, be omitted from any deductions drawn from this table. With this exclusion it appears that the accident rates, for both frequency and severity of injury, show considerable variation from 1907 to 1912, but do not show any tendency to decline.

It is possible, of course, that a better reporting of accidents in the later years masks an actual reduction in accident hazards, and personal knowledge of conditions in the plants leads to the belief that improvement in equipment and other safety activities had actually resulted in a reduction of general hazard. But it is evident that the improvement could not have been very great. Better accident reporting may account for the stationary, or indeed rising, frequency rate. But, as was noted in Chapter I, the severity rate is not markedly influenced by a fuller reporting of accidents.

In any case the showing made by these machine-building plants is in marked contrast to the showing during the same years of the iron and steel industry, in which there occurred some very remarkable instances of progressive accident reduction.[1] Undoubtedly, one important reason for this difference in the experience of the two industries is that there never were such seriously hazardous conditions in machine building as those prevailing in the iron and steel industry. In iron and steel plants as late as 1910 general frequency rates of 500 cases and over per 1,000 300-day workers were common and fatality frequency rates of nearly 5 cases per 1,000 300-day workers were not unknown. When it is noted that the fatality rate in coal mining,[2] admittedly the most hazardous industry so far as fatalities are concerned, has varied from 4.23 to 6.33 cases per 1,000 300-day workers during the period 1896 to 1913, it is evident that the conditions in iron and steel manufacture, even in 1910, were such as to call for the most serious attention. On the other hand, in machine building, with a fatality rate of 0.7 case and a general frequency rate of less than 100, the need of immediate preventive measures would not be forced so strongly upon the attention of employers.

As a result of this lesser degree of accident hazard, machine builders did not begin thorough organization for accident prevention as early as such efforts were undertaken by steel works, mines, and railways. Up to the year 1912 their efforts had been largely directed to mechanical safeguards without the thorough organization elsewhere found essential. This was not true in all machine-building plants, as is evident from the comparisons of plants having and plants not having good safety systems (see p. 43), but it was sufficiently general to influence the accident rates for machine building as a whole.

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

[2] U. S. Bulletin No. 157, Bureau of Labor Statistics, p. 104.

The next table is of the same character and of similar effect as the preceding one, although it is for a more limited period of time. It shows the accident experience of another group of four machine-building plants, over a period of four years, 1910 to 1913. This group contains plants of low intrinsic hazard on the whole and so presents rather lower accident rates than the group considered above.

TABLE 9.—FREQUENCY AND SEVERITY OF ACCIDENTS IN FOUR MACHINE-BUILDING PLANTS, 1910 TO 1913.

[For number of cases on which these rates are founded, see p. 113.]

Years.	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	28,584	0.4	4.3	72.5	77.1	3.5	2.2	0.7	6.4
1911	25,997	.7	3.5	68.4	72.5	5.9	1.7	.6	8.2
1912	28,042	.5	3.9	86.1	90.5	4.2	1.9	.8	6.9
1913	32,101	.2	3.0	83.2	86.4	1.4	1.0	.8	3.2
Total	114,724	.4	3.7	77.9	81.9	3.5	1.8	.7	6.0

Increased exactness in the reporting of accidents undoubtedly affects, to some extent, the course of the frequency rates. The severity rates, it will be noted, show no considerable change until 1913, when there was a marked decrease from a rate of 6.9 days lost to 3.2 days. The decrease took place among the deaths and permanent injuries, and is almost certainly accounted for by the more thorough safety organization effected in some of these plants in 1912.

FATAL ACCIDENTS IN ENGINE BUILDING.

For the engine-building division of the machine-building trades records of fatal accidents, together with the amount of exposure, are available for a long series of years, from 1902 to 1913. This permits the computation of fatal accident rates. The course of these rates is too irregular to permit of any important deductions, but are perhaps of sufficient interest to warrant presentation in tabular form.

TABLE 10.—FATAL ACCIDENT RATES IN ENGINE BUILDING, BY YEARS, 1902 TO 1913.

Years.	Number of 300-day workers.	Fatalities.	Fatal accident rates per 1,000 300-day workers.	Years.	Number of 300-day workers.	Fatalities.	Fatal accident rates per 1,000 300-day workers.
1902	10,156	13	1.28	1909	5,967	4	0.67
1903	12,220	10	.82	1910	11,936	7	.59
1904	8,595	5	.58	1911	10,832	14	1.29
1905	12,269	12	.98	1912	11,146	12	1.08
1906	14,215	8	.56	1913	12,984	2	.15
1907	15,433	16	1.04				
1908	4,238			Total	129,991	103	.79

COURSE OF ACCIDENT RATES, BY DEPARTMENTS.

Whenever a department has a sufficient number of 300-day workers, it is highly desirable to ascertain its accident experience over a period of time. It is entirely possible that one department may show a considerable reduction of accident hazard when no such change is observable in the accident rates for the plant as a whole or for a group of plants. And, on the other hand, conditions in one department may be growing worse but the fact be concealed in the general accident rate for the plant as a whole by the improvement in other departments. The experience of individual departments through successive years is thus essential for the purpose of effective safety work.

In the following series of tables there is presented information of this character for such departments and for such periods of time as the existing records make possible. Some of the data are necessarily somewhat fragmentary.

ELECTRICAL ASSEMBLY SHOPS.

Accident rates for two groups of electrical assembly shops, covering different periods of time, are shown in the table below. Group A presents data for two plants for the three-year period, 1910 to 1912; group B for the three plants for the two-year period, 1912 and 1913.

TABLE 11.—FREQUENCY AND SEVERITY OF ACCIDENTS IN ELECTRICAL ASSEMBLY SHOPS, BY YEARS.

[For number of cases on which these rates are founded, see p. 114.]

Years.	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.
Group A (2 shops):									
1910	7,109	0.1	3.9	50.4	54.4	1.3	1.6	0.6	3.5
1911	6,636	....	3.5	45.1	48.5	....	1.9	.4	2.3
1912	7,688	.1	3.6	60.1	63.8	1.2	1.1	.5	2.8
Total	21,433	.1	3.7	52.2	56.0	.8	1.5	.5	2.8
Group B (3 shops):									
1912	18,219	.2	3.1	74.7	78.0	1.5	.7	.7	2.9
1913	19,033	.1	3.6	80.3	84.1	.9	.9	.8	2.6
Total	37,252	.1	3.4	77.6	81.1	1.2	.8	.8	2.8

Both frequency rates and severity rates are low in all of these shops, and no material change is observable from year to year in either of the groups.

FORGE SHOPS.

Accident rates for six forge shops during the years 1912 and 1913 are shown in the following table:

TABLE 12.—FREQUENCY AND SEVERITY OF ACCIDENTS IN SIX FORGE SHOPS, 1912 AND 1913.

[For number of cases on which these rates are founded, see p. 114.]

Years.	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.
1912	1,255	1.6	4.8	115.5	121.9	14.3	2.5	1.5	18.3
1913	1,359	.7	5.2	94.2	100.1	6.6	1.2	.9	8.7
Total	2,614	1.2	5.0	104.4	110.5	10.3	1.9	1.2	13.4

Inasmuch as the data cover a period of only two years, and as the amount of exposure is small, the rather marked reduction in rates can not be accepted as very conclusive. Especially is this so as no information is available regarding the working conditions, which would be likely to affect the rates.

FOUNDRIES.

For a group of four foundries it was possible to secure data for a period of six years—1907 to 1912—and for a second group of five foundries information was obtainable for a two-year period—1912 and 1913.

TABLE 13.—FREQUENCY AND SEVERITY OF ACCIDENTS IN FOUNDRIES, BY YEARS.

[For number of cases on which these rates are founded, see p. 114.]

Years.	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.
Group A (4 plants):									
1907	2,222	0.5	5.9	53.1	59.5	4.1	4.3	0.5	8.9
1908	993			31.2	31.2			.2	.2
1909	1,363		3.7	38.2	41.8		5.0	.3	5.3
1910	2,010		2.5	58.7	61.2		3.2	.4	3.6
1911	1,709	2.9	1.2	56.8	60.9	26.3	.2	.5	27.0
1912	1,826		2.2	73.4	75.6		.2	.3	.5
Total	10,123	.6	2.9	54.3	57.8	5.3	2.3	.5	8.1
Group B (5 plants):									
1912	3,542	.3	1.4	63.5	65.2	2.5	1.4	1.0	4.9
1913	3,427	.6	3.5	110.3	114.4	5.3	.6	1.3	7.2
Total	6,966	.4	2.5	87.0	89.9	3.9	1.0	1.2	6.1

The normal accident hazard of group A in the above table is best understood by the omission of fatalities, as it is known that the high rate of 1911 was due to a single mass accident of very unusual character. With this omission, the severity rates are distinctly lower in the later years. This may be attributed to a decrease in the number of foot burns, resulting from the adoption of improved shoes and leggings for the workers. An increase in the frequency rates of this group during the same years, 1910 to 1912, in which there were marked decreases in severity rates (except fatalities) is partly due to the better reporting of minor injuries.

Group B shows an increase in both frequency and severity rates for 1913 over 1912, but the period is too short to make these results very significant.

MACHINE SHOPS.

Accident rates for a group of five machine shops over a six-year period and for a group of eight shops over a two-year period are given below.

TABLE 14.—FREQUENCY AND SEVERITY OF ACCIDENTS IN MACHINE SHOPS, BY YEARS.

[For number of cases on which these rates are founded, see p. 114.]

Years.	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.
Group A (5 shops):									
1907	7,817	0.1	6.1	84.4	90.7	1.2	2.7	0.5	4.4
1908	3,520	....	2.6	27.3	29.8	....	.8	.2	1.0
1909	4,747	....	3.2	53.9	57.1	....	1.6	.5	2.1
1910	6,688	.2	4.2	93.3	97.6	1.3	2.0	.7	4.0
1911	6,303	.2	3.3	71.2	74.7	1.4	1.7	.6	3.7
1912	6,647	.2	3.0	81.7	84.9	1.4	1.6	.7	3.7
Total	35,722	.1	4.0	73.6	77.7	1.0	1.9	.6	3.5
Group B (8 shops):									
1912	9,676	.2	3.9	108.3	112.4	1.9	1.9	1.0	4.8
1913	10,472	.3	2.6	117.5	120.3	2.6	1.0	1.1	4.7
Total	20,148	.3	3.2	113.1	116.6	2.2	1.4	1.0	4.6

These machine-shop groups contain the largest number of 300-day workers of any of the departmental groups which it has been possible to assemble. Their accident experience, therefore, should carry considerable weight, especially so as mechanical safeguarding has been undertaken by all machine shops and here, if anywhere, the effect of mechanical safeguarding should show itself. As a matter of fact the frequency rates for group A show little change, their smallness in 1908 and 1909 corresponding with the usual experience of accident rates for those years. The severity rates are scarcely more conclusive, although some argument could be offered for a very slight improvement. On the whole, it would seem fairly justifiable to say that this machine-shop experience indicates that mechanical safeguarding in the absence of other preventive methods does not accomplish much.

Group B, covering only two years, also shows a condition of substantially uniform accident rates.

Both of these groups contain individual machine shops in which very possibly the accident hazard had been definitely reduced, but the exposures of such shops were too small to justify separate computation.

WOODWORKING SHOPS.

The next table shows the accident rates for eight woodworking shops for the years 1912 and 1913. The period is too short to permit of any valuable deductions, but the table affords some additional rates for comparison with those shown for the woodworking department in Table 7.

TABLE 15.—FREQUENCY AND SEVERITY OF ACCIDENTS IN EIGHT WOODWORKING SHOPS, 1912 AND 1913.

[For number of cases on which these rates are founded, see p. 114.]

Years.	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.
1912	1,442	....	9.7	62.4	72.1	....	2.9	0.8	3.7
1913	1,561	....	5.8	71.1	76.9	....	1.1	1.0	2.1
Total	3,003	....	7.7	66.9	74.6	....	2.0	.9	2.9

EFFECT OF SAFETY SYSTEMS UPON ACCIDENT OCCURRENCE.

A primary purpose of this report is to emphasize the possibilities of constructive effort for the reduction of accidents. A pointed method of doing this is to contrast the accident experience of plants having well-developed safety systems with that of those in which safety systems are in process of development. A contrast of this kind is here attempted for the machine-building industry. The comparison is limited to three groups of plants employing the largest number of workers—electrical apparatus, locomotives and engines, and machine tools—inasmuch as the relatively small size of the other groups would render the results of questionable value.

As a basis for this comparison, careful study was made of the various plants, their methods of mechanical safeguarding, their committee organizations, and their safety-education work. With the knowledge thus obtained the plants were divided into two classes.

In class A were placed those having in considerable measure the requisites of a good safety organization, namely:

1. Safeguarding by signs, warnings, and mechanical contrivances.
2. Adequate safety inspection.
3. Safety committees of superintendents, foremen, and workmen.
4. Emergency and hospital care of the injured.
5. A compensation or relief system.

In class B were placed the plants in which some important element of this combination was lacking.

After thus classifying the plants the accident data for each class were compiled, with the results shown in the following table.

TABLE 16.—FREQUENCY AND SEVERITY OF ACCIDENTS IN 3 GROUPS OF MACHINE-BUILDING PLANTS, CLASSIFIED ACCORDING TO CHARACTER OF SAFETY SYSTEM.

Safety organization.	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.
Electrical apparatus:									
Class A	23,012	0.1	2.4	62.6	65.1	0.8	0.4	0.7	1.9
Class B	9,538	.2	3.4	181.9	185.5	1.9	2.6	1.8	6.3
Unclassified	3,124	.3	4.2	89.3	93.8	2.9	1.1	.9	4.9
Total	35,674	.1	2.8	96.9	99.8	1.3	1.1	1.0	3.4
Locomotives and engines:									
Class A	4,971	....	3.4	116.1	119.5	....	1.8	1.0	2.8
Class B	19,355	1.0	5.8	134.9	141.7	8.8	2.5	1.4	12.7
Unclassified	6,903	.4	4.5	168.2	173.1	3.9	5.2	1.8	10.9
Total	31,229	.7	5.1	139.2	145.0	6.3	2.9	1.4	10.6
Machine tools:									
Class A	6,769	....	1.2	40.9	42.1	....	.2	.3	.5
Class B	1,955	....	3.1	120.3	123.4	....	1.2	.9	2.1
Unclassified	15,635	.2	3.5	62.3	66.0	1.7	1.0	.5	3.2
Total	24,359	.1	2.8	61.0	63.9	1.1	.8	.5	2.4

Inspection of this table shows that in each of the three groups class A has a very much lower accident rate than has class B, as measured both by frequency and severity. Thus in the case of the electrical apparatus group the plants of class A show a frequency rate of only 65.1 as against 185.5 for the plants of class B, and a severity rate of only 1.9 as against 6.3 days lost per worker. It is evident, therefore, that the development of safety methods and safety organization does have a marked effect in reducing the accident rate.[1] Details as to the character and possibilities of accident preventive work in machine-building plants are discussed in Chapter IV.

OCCUPATIONAL ACCIDENT RATES.

It was one of the chief efforts in this study to accumulate sufficient data for the presentation of satisfactory occupational accident rates. The importance of accident rates by individual occupations as an aid to effective preventive methods can not well be overemphasized. But the difficulties in the way of obtaining the material for such a presentation are very serious. One great difficulty is that occupational names are used with a variety of meanings. Thus some concerns distinguish between a machine hand who tends a screw machine and a machinist who operates a lathe, but others make no such distinction, using machinist as an extremely inclusive term. This uncertainty as to the meaning of occupational names interferes seriously with the attempt to consolidate the records of different plants, and such consolidation is necessary in order to obtain a sufficient volume of data for rate computation. A second and still greater difficulty in the way of getting occupational rates is that of determining the exposure of each occupation; that is to say, the number or proportion of 300-day workers engaged in each occupation. This is especially difficult when the men in different occupations have workdays of different lengths.

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[1] The method of comparison employed above was also used in the first iron and steel report (1913), the plants being divided into three classes according as the safety system was (A) well developed, (B) in process of development, or (C) not developed at all. In the classification of machine-building plants in the above text classes A and B correspond to those in the iron and steel report. There is no class C, inasmuch as all of the machine-building plants had made more than a beginning in safety work and safety organization.

For an account of the use of this method of comparison in the iron and steel industry, see Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, pp. 43-49. The results of the comparison there made are shown in the following table, reproduced from the report referred to:

Comparison of accident rates in iron and steel plants classified according to degree of development of safety systems, year ending June 30, 1910.

Plants having safety systems of specified class.	300-day workers.	Number of accidents.				Accident-frequency rates (per 1,000 300-day workers).			
		Fatal.	Permanent disability.	Temporary disability, 1 day and over.	Total.	Fatal.	Permanent disability.	Temporary disability, 1 day and over.	Total.
Class A. System well developed	24,411	42	44	3,993	4,079	1.73	1.79	163.6	167.1
Class B. System in process of development	28,830	73	105	7,674	7,852	2.53	3.64	266.2	272.4
Class C. System not developed	14,916	37	34	7,505	7,576	2.48	2.28	503.2	507.9

Because of these handicaps the study of occupational rates in machine building, as presented below, is necessarily somewhat limited. Only those cases have been included in which all the facts were ascertainable with accuracy.

In considering the rates presented it is to be clearly understood that they are strictly valid only for the particular group for the particular period covered. But, in addition, they may be accepted as fairly representative of relative occupational hazards throughout the industry.[1]

TABLE 17.—FREQUENCY AND SEVERITY OF ACCIDENTS IN A MACHINE-BUILDING PLANT DURING 7 YEARS, 1907 TO 1913, BY OCCUPATIONS.

Occupations.	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.
Bench and vise hands	2,937	....	1.4	59.2	60.6	....	0.9	0.5	1.4
Blacksmiths and helpers	4,350	0.5	4.4	73.1	78.0	4.1	2.5	.7	7.3
Boiler makers and helpers	2,413	.4	5.0	251.6	256.9	3.7	2.5	2.3	8.5
Calkers and chippers	1,769	.6	5.1	176.4	182.1	5.1	6.0	1.3	12.4
Carpenters	1,074	....	15.8	90.3	106.1	....	5.7	1.0	6.7
Core makers	920	....	....	13.0	13.0	....	....	.1	.1
Cranemen	1,011	3.0	3.0	54.4	60.3	26.7	1.2	.6	28.5
Drillers and helpers	3,269	.3	6.4	131.2	137.9	2.8	2.7	1.1	6.6
Erectors and helpers	2,360	.9	11.0	172.9	184.8	7.6	7.2	1.6	16.4
Laborers	10,035	1.4	7.3	127.4	136.0	12.5	3.6	1.2	17.3
Machinists and helpers	18,534	.3	3.5	70.2	74.0	2.6	1.8	.6	5.0
Machine hands	1,290	.8	6.2	174.4	181.4	7.0	5.5	1.4	13.9
Pattern makers	1,246	.8	15.3	22.5	38.6	7.2	8.4	.2	15.8
Reamers, riveters, etc	2,734	1.1	6.6	179.2	186.9	9.9	3.9	1.5	15.3
Sheet-iron workers	1,946	....	1.0	23.6	24.6	....	1.3	.2	1.5
Other occupations	16,648	1.3	2.6	55.1	59.0	11.9	1.6	.7	14.2
Total	72,536	.8	4.7	92.3	97.8	6.9	2.5	.8	10.2

The close correspondence of the rates to the known hazards of the occupations will appear as comment is made upon the individual occupations. Since the severity rates are the more exact measure of relative hazard they will be mainly used in this discussion.

The highest severity rate (28.5 days) is among cranemen. It is entirely due to the number of deaths. In permanent and temporary disability cranemen rank low. This fatality hazard is attributable to the faulty construction of cranes, now fortunately greatly modified by the safety features incorporated by all makers. Formerly it was frequently necessary for a craneman to climb out on the girders of his crane. There being no protective railings and no secure footway a fall to the floor many feet below could easily occur, with fatal results. With the improved patterns of cranes in use this high rate should be much reduced and the occupation become of relatively small hazard.

[1] Appendix B, p. 110, gives details regarding the results of the individual injuries upon which this table is based.

Common labor ranks next in severity (17.3 days). This group is so large (10,035 300-day workers) that a high rate among them is of the greatest significance. There is no one particular preventive measure by which the rate can be reduced. The only recourse is the vigorous and persistent application of all the preventive methods which experience has shown to be successful.

Erectors have a severity rate of 16.4 days. Permanent injuries of a severe character are a large factor, two cases of loss of foot, one case of loss of hand, and five cases of loss of eye being included. The erector is constantly engaged in operations involving the moving and adjusting of heavy parts and the use of more or less temporary and insecure trestles and scaffolds. Improvement in his rate will depend largely on improvement in crane methods, in better design and construction of scaffolds, and in other means of reaching the structures which are being erected.

The high rate (12.4 days) of calkers and chippers is due, in this particular group, to two cases of the loss of an arm, an injury which in a group of small size has considerable influence. This injury might not be as serious in other groupings of this occupation, but the loss of eyes from flying chips is sufficiently frequent to give these workers, where due precautions are not used, a uniformly high severity rate. Improved crane methods affecting the moving of the parts on which they work and the use of proper protective goggles will bring down this rate.

In the case of machine hands the small size of the group introduces the possibility that the high rate of 13.9 days lost per worker may be due to some unusual occurrence. In some measure, however, it certainly reflects the fact that a good many automatic machines to which the operator need only feed the material have been constructed with their moving parts unduly and needlessly exposed. The continuance of such a rate with modern and well protected machines must be regarded as impossible. Manufacturers who have machines of this type which are not well protected should be warned by this rate that under compensation they are likely to suffer heavily if the defects are not remedied.

Reamers and riveters with a severity rate of 15.3 days and boiler makers with 8.5 days may be regarded as belonging essentially in the same class as erectors. They suffer from similar dangers with the additional dangers incident to certain machines which they operate. These are frequently actuated by compressed air and since they must often be held in place by the workman there is a chance that the pressure will swing the machine and throw the man from the trestle or scaffold. A very frequent cause of injury appearing in the records is "lost control of air machine." Machines electrically actuated are now being used for reaming and riveting and it is clear that they considerably lessen the danger. In general the precautions suggested for erectors should be here applied.

Drillers were separated from the main body of machinists under the impression that the drill presented greater hazards than the lathe, miller, and other machine-shop apparatus. This impression seems to have been justified by the resulting severity rate of 6.6 days for drillers and 5 days for the larger group of machinists. The special hazard of the drill is that of the clothing being caught and twisted upon it. Numberless illustrations could be given. One will suffice. An apprentice boy reached around the drill to get a tool. His sleeve was caught and before the machine could be stopped all his clothing was torn off except his shoes. The possible remedies for this hazard are two, both of which should be applied if possible: (1) Clothing for drill operators which has no loose ends or slack places. Since this is a matter of personal adjustment it has some difficulties, but these have been overcome wherever effort has been made. (2) Inventive genius has been trying to devise a chuck for drills which will allow the tool to revolve freely when the drill is not pressing upon the work. Such safety chucks have not been wholly successful but have gone far enough to indicate usefulness in some circumstances.

The modern construction of machine-shop apparatus should practically eliminate accidents, formerly very common, arising in the adjustment of gears, belts, and other parts of the machine. This leaves the danger of being caught between the moving work and the tool or parts of the machine. Practically, the reduction of this danger must rest entirely upon the devising of safer methods and upon greater care and skill on the part of the worker.

In the discussion of causes of injury, page 48, it will appear that objects flying from the machine are a considerable source of danger. It will probably be hard to convince machinists that this menace of loss of sight is frequent enough to justify the use of protective goggles, but if they could realize that loss of eyes is the most serious single result of accidents causing permanent injury, protection might seem worth while. In a group of plants having an exposure of 94,030 during a series of years eye losses had a severity rate of 0.44 day while all permanent injuries to hands and fingers, including loss, had a rate of 1.05 days.[1]

Among the other occupations the low rates of bench and vise hands, and sheet-iron workers, both in frequency and severity, are noteworthy.

Both carpenters and pattern makers have high severity rates in permanent disability. This is due to the operation of three machines—

[1] See Table 23, p. 56.

the rip saw, the band saw, and the wood planer or jointer. Fatalities among these workmen are nearly always due to what is known as the "kick back" from the rip saw. The board is caught by the saw teeth and thrown violently backward, striking the man in the abdomen. One concern employing between 3,000 and 4,000 men has had but two fatalities in the course of its history. These were due to accidents of this kind. The efficient guarding of saws is a matter of no small difficulty, but there are a number of reliable devices for this purpose, among which any manufacturer should be able to find something suited to his needs and which his workpeople will use. The inclosure of the band saw to the point of almost perfect safety is now so nearly universal that the finding of one not so inclosed causes a distinct shock of surprise. There are still in use on a good many planers the square cutter heads which allow the hand to drop as far as the knuckles between the blades, although none was observed in 1912 in the plants included in this study. With the substitution of the cylinder head and the application of convenient covers for the portion of the knives not in use the high permanent injury rate should drop materially. An absolutely perfect safety device for the jointer, an automatic feed, was observed in use in one of the Government arsenals. The initial expense of this device was considerable, but the man in charge was of the opinion that the increased efficiency made it a good investment.

ACCIDENT CAUSES.[1]

The analysis of the causes of accident and the determination of occupational rates seem at present to be the most important practical subjects to be considered in accident studies. Occupational rates in machine building have been considered in the preceding section. The subject of accident causes will now be considered in as much detail as the available material makes possible.

ACCIDENT CAUSES, BY PLANT GROUPS AND BY DEPARTMENTS.

The relative importance of the various accident causes in machine building is indicated in Table 18. This table distributes frequency and severity rates by causes for three important machine-building departments—electrical assembly shops, foundries, and machine shops—and also for two groups of entire plants. Only three departments were chosen for presentation because for none of the others was there a sufficient volume of exposure to permit of fair comparison.

[1] For a classification of causes adopted by the International Association of Industrial Accident Boards and Commissions in May, 1916, see Bulletin No. 201, U. S. Bureau of Labor Statistics. This classification will be used in future by the bureau in common with other organizations concerned in its preparation. The tabulation of the present report had progressed too far to permit the application to it of this later classification.

TABLE 18.—CAUSES OF INJURY IN SPECIFIED MACHINE-BUILDING DEPARTMENTS AND PLANTS.

Causes of injury.	Frequency rates (cases per 1,000 300-day workers).				
	Electrical assembly shops, 6 plants, 1907 to 1913.	Foundries, 5 plants, 1907 to 1913.	Machine shops, 6 plants, 1907 to 1913.	Machine building.	
				5 plants, 1907 to 1912.	4 plants, 1910 to 1913.
Number of 300-day workers	**30,906**	**15,189**	**47,412**	**94,030**	**114,724**
Cranes and hoists	2.10	8.16	5.97	7.15	5.74
Falling objects	8.35	14.88	12.17	14.44	14.35
Falls of worker	4.50	4.01	4.39	8.11	7.80
Hot metal	1.55	13.56	.34	1.99	2.43
Handling material	8.09	7.83	9.24	8.10	8.88
Operating machines	16.53	1.84	22.29	13.04	14.12
Objects flying from machines	2.36	.72	7.87	4.02	4.65
Objects falling from machines	.42	....	2.53	1.07	1.09
Using tools	4.27	1.38	5.86	5.38	5.20
Objects flying from tools	.32	.26	.93	.99	1.03
Other flying objects	.54	2.17	1.56	3.19	2.60
Reaming, riveting, and chipping	.06	.59	.30	1.29	1.11
Objects flying during reaming, riveting, etc.	.32	4.15	.57	2.34	1.79
Other causes	11.10	7.97	4.91	8.89	10.70
Causes not reported	.23	.26	.38	.40	.45
Total	60.76	67.81	79.30	80.41	81.94
	Severity rates (days lost per 300-day worker).				
Cranes and hoists	0.04	1.06	0.25	2.26	1.22
Falling objects	.10	1.32	.74	1.11	.89
Falls of worker	.07	.64	.07	.98	.46
Hot metal	.01	2.82	[1]	.45	.02
Handling material	.11	.18	.12	.14	.14
Operating machines	.96	.27	1.36	1.13	1.04
Objects flying from machines	.17	[1]	.29	.47	.34
Objects falling from machines	[1]	....	.03	.02	.01
Using tools	.04	.01	.07	.06	.05
Objects flying from tools	.06	[1]	.15	.11	.11
Other flying objects	.06	.12	.03	.34	.26
Reaming, riveting, and chipping	[1]	[1]	[1]	.05	.04
Objects flying during reaming, riveting, etc.	[1]	.20	[1]	.36	.19
Other causes	.71	.77	.12	1.23	1.23
Causes not reported	[1]	[1]	.01	.21	.09
Total	2.35	7.41	3.23	8.93	6.00

[1] Less than 0.005.

From the upper half of this table it appears that, for the industry as a whole, as represented by the two groups of plants, the most important single cause of accident as regards frequency is that of "falling objects." This is also the most frequent cause in foundry work. But in the electrical assembly and machine shops primacy shifts to the "operation of machines" as the most fertile cause of accident.

As regards the severity of resulting injuries, as shown in the lower half of the table, "cranes and hoists" stands out for the industry as a whole as the most serious single cause. In foundries "hot metal" appears as the accident cause of most serious after effects, the severity rate for hot metal being 2.82 days lost per worker out of 7.41 days lost per worker for all causes. This preeminence of hot metal as a hazard of foundry work emphasizes the point at which preventive measures can be applied effectively. In the more progressive foundries provision of proper shoes, leggings, and eye protectors has nearly eliminated certain kinds of burns.

ACCIDENT CAUSES OVER A SERIES OF YEARS.

In the study of accident causes it is of particular interest to trace the importance of the several causes over a period of years. It has been possible to obtain the necessary material for this purpose for two groups of machine-building plants of sufficient size to make yearly comparison reasonably safe. The first group consists of five plants with accident experience over a period of six years, 1907 to 1912. This information is presented in Table 19. Table 20 shows, for the purpose of comparison, the experience of a large iron and steel plant.

TABLE 19.—ACCIDENT CAUSES IN 5 MACHINE-BUILDING PLANTS, BY YEARS, 1907 TO 1912.

[Covering 7,561 cases of accident.]

Accident causes.	Frequency rates (cases per 1,000 300-day workers).						
	1907	1908	1909	1910	1911	1912	Total.
Number of 200-day workers	**22,023**	**8,261**	**11,303**	**18,729**	**16,481**	**17,233**	**94,030**
Cranes and hoists	6.67	3.63	6.72	9.56	7.83	6.44	7.15
Falling objects	16.07	5.33	10.71	14.42	15.53	18.16	14.44
Falls of worker	7.58	5.08	6.72	7.74	8.43	11.26	8.11
Hot metal	1.91	.73	1.33	2.08	2.00	3.02	1.99
Handling material	8.72	4.12	6.37	11.91	6.49	7.78	8.10
Operating machines	14.76	5.81	11.77	13.67	12.01	15.44	13.04
Objects flying from machines	2.59	1.69	2.39	4.54	4.13	7.37	4.02
Objects falling from machines	1.14	.36	.62	1.76	1.09	.87	1.07
Using tools	6.04	4.24	3.89	5.71	5.58	5.51	5.38
Objects flying from tools	.95	.61	.88	1.17	.91	1.16	.99
Other flying objects	3.54	.73	1.68	2.99	3.16	5.16	3.19
Reaming, riveting, etc	.54	1.33	1.33	1.23	1.94	1.62	1.29
Objects flying during reaming, riveting, etc	2.63	1.21	1.24	1.71	2.61	3.66	2.34
Other causes	8.63	4.24	7.08	8.97	8.56	12.88	8.89
Causes not reported	.36	.12	.35	.21	.36	.87	.40
Total	82.14	39.22	63.08	87.67	80.64	101.20	80.41
	Severity rates (days lost per 300-day worker).						
Cranes and hoists	3.34	0.19	1.36	0.85	3.99	2.33	2.26
Falling objects	1.29	.05	.36	1.12	.92	2.06	1.11
Falls of worker	1.37	.15	1.76	.56	1.19	.65	.98
Hot metal	.22	.01	.01	.01	2.21	.04	.45
Handling material	.18	.05	.09	.23	.07	.15	.11
Operating machines	1.28	.48	1.39	.95	.97	1.44	1.13
Objects flying from machines	.43	.03	.42	.77	.77	.14	.47
Objects falling from machines	.03	.02	(1)	.01	.02	.02	.02
Using tools	.07	.05	.03	.09	.03	.04	.06
Objects flying from tools	.08	(1)	.01	.18	(1)	.29	.11
Other flying objects	.18	.21	.28	.72	.31	.27	.34
Reaming, riveting, etc	(1)	.03	.01	.02	.20	.01	.05
Objects flying during reaming, riveting, etc	.37	(1)	.41	.01	.02	1.22	.36
Other causes	1.40	.20	.09	1.98	2.44	.30	1.23
Causes not reported	.49	(1)	(1)	.01	(1)	.53	.21
Total	10.73	1.47	6.23	7.51	13.15	9.49	8.93

[1] Less than 0.005.

TABLE 20.—ACCIDENT CAUSES IN A STEEL PLANT, BY YEARS, 1905 TO 1913.

[Covering 10,390 cases of accident.]

Accident causes.	Frequency rates (cases per 1,000 300-day workers).									
	1905	1906	1907	1908	1909	1910	1911	1912	1913	Total.
Falling and flying objects	92.7	55.4	55.1	46.3	52.1	38.3	20.4	39.7	25.3	46.9
Falls of worker	31.2	22.7	19.6	20.3	16.9	12.3	12.0	14.7	9.0	17.4
Hot metal	26.6	22.6	24.5	11.1	15.1	9.8	7.3	12.3	11.9	16.0
Cranes and hoists	19.0	14.9	14.1	14.2	20.0	12.2	16.1	18.9	12.2	15.6
Handling material and work	26.2	17.2	10.6	10.9	17.7	16.2	10.9	14.8	10.2	15.0
Using tools	17.2	9.3	11.2	4.6	10.0	7.6	9.5	10.5	10.8	10.2
Operating machines	15.9	12.0	10.9	10.1	7.4	7.6	5.4	4.3	3.6	8.5
Locomotives, cars, etc	12.5	11.1	7.3	4.6	8.0	5.0	3.3	6.9	5.0	7.2
Electricity	4.2	3.6	3.3	1.3	2.1	2.6	1.0	2.4	.7	2.4
Belts, shafts, and gears	1.6	1.1	1.6	1.1	.2	.7	.5	.1	.8	.8
Unclassified	52.9	44.4	30.9	25.2	24.7	21.3	25.5	29.3	25.0	31.3
Total	300.0	214.3	189.1	149.7	174.2	133.6	111.9	153.9	114.5	171.3
	Severity rates. (days lost per 300-day worker).									
Falling and flying objects	9.3	9.3	7.9	2.0	6.2	6.0	1.4	4.0	4.7	5.9
Falls of worker	1.9	4.2	4.0	4.6	6.2	2.6	3.7	1.7	3.7	3.6
Hot metal	1.8	9.3	1.1	.3	3.5	2.6	1.8	2.9	5.2	3.3
Cranes and hoists	3.8	5.6	6.7	2.4	.5	1.9	6.6	1.2	4.4	3.7
Handling material and work	.3	.3	.3	.4	.5	.3	.2	.7	.2	.4
Using tools	.3	.1	.3	(1)	.3	.1	.2	.3	.2	.2
Operating machines	.7	1.7	1.7	2.8	.2	1.4	1.7	.4	.2	1.1
Locomotives, cars, etc	3.8	7.6	1.8	2.3	1.7	.4	1.6	.9	.3	2.3
Electricity	.1	2.4	2.4	(1)	(1)	(1)	(1)	(1)	(1)	.6
Belts, shafts, and gears	1.9	1.2	1.2	4.3	(1)	.6	(1)	(1)	(1)	.9
Unclassified	10.7	12.6	10.7	10.8	4.6	4.0	1.4	2.2	2.1	6.5
Total	34.5	54.3	38.1	29.9	23.7	19.9	18.6	14.3	21.2	28.5

1 Less than 0.005.

Again it may be repeated that the year 1908, and to some extent the year 1909, were abnormal years in machine building, and the accident rates for those years are of little present significance. With this in mind, an examination of Table 19 shows that in machine building accident rates, for both frequency and severity and both in total and by separate causes, show considerable variations from year to year but do not show any downward tendency. To some extent, an actual reduction in hazard may be concealed, particularly in the case of frequency rates, by a better system of reporting. But, in any case, it is clear that during the years covered no such marked reduction in accident rate took place in machine building as is shown to have taken place in the steel plant whose experience is presented in Table 20. This particular steel plant is one in which safety work was vigorously pushed during the years covered, but which is in no way exceptional and is fairly illustrative of the steel industry as a whole.

In making the above comparisons it is to be repeated that the opportunity for accident reduction in machine building was much less than that in the steel industry. The sources of danger in machine building are both less serious and less easily brought under control than many of those in iron and steel plants. Accident hazards in machine building were never at the high point reached in some of the steel plants in the years before active safety work. Thus, in the tables above, the frequency rate for the group of machine-building plants, during the six years covered, only once rose above 100 cases per 1,000 300-day workers, this being in 1912, when the rate was 101.2. In contrast to this, the steel plant shown in the table (one of the earliest to undertake safety work) had a frequency rate of 300 cases per 1,000 300-day workers in 1905 and of 189.1 cases in 1907.

But, even when all due allowance is made for these fundamental differences, it remains true that up to the year 1912 the machine-building industry had not fully awakened to the possibilities of accident prevention. By that time, however, many individual plants had inaugurated important safety activities and these were being rapidly taken up by the entire industry. That these efforts were productive of success is indicated by the experience of a group of plants for which data were obtainable for the year 1913 in comparison with preceding years. This group consists of four plants with experience extending over a period of four years, 1910 to 1913.

TABLE 21.—ACCIDENT CAUSES IN 4 MACHINE-BUILDING PLANTS, BY YEARS, 1910 TO 1913.

[Covering 9,401 cases of accident.]

Accident causes.	Frequency rates (cases per 1,000 300-day workers).				
	1910	1911	1912	1913	Total.
Number of 300-day workers	**28,584**	**25,997**	**28,042**	**32,101**	**114,724**
Cranes and hoists	7.56	5.85	5.03	4.67	5.74
Falling objects	12.77	13.23	15.55	15.61	14.35
Falls of worker	6.79	6.89	9.84	7.66	7.80
Hot metal	1.99	1.62	2.71	3.24	2.43
Handling material	10.04	6.46	8.42	10.22	8.88
Operating machines	13.58	13.12	16.33	13.49	14.12
Objects flying from machines	3.36	3.77	5.49	5.79	4.65
Objects falling	1.22	.92	.75	1.40	1.09
Using tools	4.97	4.77	5.42	5.54	5.20
Objects flying from tools	.98	.96	1.00	1.15	1.03
Other flying objects	2.20	2.08	3.50	2.59	2.60
Reaming, riveting, and chipping	.84	1.19	1.03	1.34	1.11
Objects flying during reaming, riveting, etc	1.22	1.69	2.46	1.78	1.79
Other causes	9.45	9.81	12.45	11.03	10.70
Causes not reported	.17	.15	.53	.87	.45
Total	77.14	72.51	90.51	86.38	81.94
	Severity rates (days lost per 300-day worker).				
Cranes and hoists	0.57	2.59	1.51	0.43	1.22
Falling objects	1.11	.64	1.30	.54	.89
Falls of worker	.41	.77	.43	.12	.42
Hot metal	.02	.01	.03	.03	.02
Handling material	.20	.07	.15	.12	.14
Operating machines	1.10	.93	1.16	.98	1.04
Objects flying from machines	.23	.77	.22	.19	.34
Objects falling from machines	.01	.01	.01	.01	.01
Using tools	.08	.04	.04	.05	.05
Objects flying from tools	.06	.13	.18	.06	.11
Other flying objects	.56	.13	.23	.12	.26
Reaming, riveting, and chipping	.01	.13	.01	.03	.04
Objects flying during reaming, riveting, etc	.01	.01	.75	.01	.19
Other causes	2.02	2.00	.57	.46	1.23
Causes not reported	.01	(1)	.33	.02	.09
Total	6.41	8.23	6.92	3.17	6.05

1 Less than 0.005.

The frequency rates of this group of plants show an irregular but rather upward tendency from 1910 to 1913, but the increase is no greater than could be accounted for by the better reporting which has certainly occurred in some of these concerns and probably in all of them. The striking change is in the severity rates, which drop from over 6 days lost per worker in 1910 to 1912 to 3.17 days lost in 1913.

This brings up again the important fact that an increase in frequency rates may be entirely compatible with a decrease in severity. The increase in frequency may be due simply to better reporting, and, as better reporting is nearly always correlated with special efforts at accident reduction, there may well be a corresponding reduction in accident severity as measured by severity rates. It is possible indeed that a very great improvement in reporting might give rising figures for both frequency and severity rates when the real accident hazards were actually diminishing. This fact suggests the danger of concluding from slightly rising accident rates that no improvement in accident reduction has occurred. Hasty conclusions have led in several plants to undue discouragement in their efforts toward accident prevention.

On the other hand such a fall in severity rates as occurs between 1912 and 1913 in the plant group shown in the table (from 6.92 to 3.17 days lost) may be accepted as fairly conclusive, inasmuch as the reduction was distributed among practically all causes. A drop at only one point might very well be due to a fortuitous circumstance, but when nearly all causes show the same tendency, it is safe to infer that some general and pervasive influence is at work. Personal knowledge of conditions in these plants substantiates the indication of the rates. Machine-building concerns generally had begun active preventive work by 1912. Those whose activities were well under way before that year were not sufficiently numerous to influence materially the accident rates for the industry, but these rates began to respond on a fairly general scale in 1913.

It would be instructive to know the causes of accident, by departments, over a series of years in supplement to the data for groups of plants as above given. But until a much larger amount of material is available such a study would not be sufficiently conclusive to be worth the labor of preparation.

NECESSITY OF RATES FOR THE MEASUREMENT OF ACCIDENT CAUSES.

Before leaving this discussion of accident causes it is desirable to point out by means of a simple illustration a mathematical defect which renders inconclusive a method which has frequently been used as a means of determining the importance of accident causes from year to year. The groups of accidents in the years which it is desired to compare have been thrown into the form of percentages and the conclusion drawn, for example, that the handling of cranes and hoists had improved if they caused 10 per cent of all recorded accidents in one year and only 8 per cent in the year following. An illustration will serve to bring out the dangers which lurk in this procedure.

Let it be supposed that a concern employs 10,000 300-day workers in 1910 and 9,000 in 1911. Ten causes of accident are recognized, designated by letters A, B, C, D, and so on. In 1910 assign 100 accidents to each cause and in 1911 the same number except the last cause, J, to which 150 are assigned. The following table presents the resulting distribution by percentages and by frequency rates:

Causes.	Cases.		Per cent due to each cause.		Frequency rates.	
	1910	1911	1910	1911	1910	1911
A	100	100	10.0	9.5	10.0	11.1
B	100	100	10.0	9.5	10.0	11.1
C	100	100	10.0	9.5	10.0	11.1
D	100	100	10.0	9.5	10.0	11.1
E	100	100	10.0	9.5	10.0	11.1
F	100	100	10.0	9.5	10.0	11.1
G	100	100	10.0	9.5	10.0	11.1
H	100	100	10.0	9.5	10.0	11.1
I	100	100	10.0	9.5	10.0	11.1
J	100	150	10.0	14.3	10.0	16.7
Total	1,000	1,050	100.0	100.0	100.0	116.7

It might be concluded from the percentage column of this table that there has been a decrease in the importance of each cause except cause J. When, however, the frequency rates are considered, it is clear that each of the causes has become more serious.

The inherent weakness of all such percentages as those of the table is that they can not vary independently. If cause J changes it modifies the percentage for each of the other causes as well, and thus completely conceals what has actually taken place. This same difficulty has frequently been emphasized in the study of mortality, as, for example, when an epidemic of typhoid fever produces a lowered percentage of tuberculosis, at the same time that the incidence of tuberculosis, as shown by the rates, was increasing.

Thus, in the measurement of the changing importance of accident causes, percentage distribution may be of misleading significance. The only reliable guide is that offered by accident rates, either frequency or severity.

NATURE OF INJURY.

From the standpoint of accident prevention, 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 is of much significance in the study of accident compensation.

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 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)

A simple classification of the type outlined is used in the following table, which gives an analysis of the nature of the injuries which occurred in seven machine-building plants during a period of several years. The table represents a total of 14,204 injuries, occurring among a total of 179,956 300-day workers.

TABLE 22.—NATURE OF INJURY IN SEVEN MACHINE-BUILDING PLANTS, 1907 TO 1913.

Injuries.	Number of injuries.	Days lost.	Accident frequency rates (per 1,000 300-day workers).	Accident severity rates (days lost per 300-day worker).
Bruises, cuts, and lacerations to—				
Hand and fingers	4,007	77,245	22.3	0.43
Foot and toes	1,744	17,638	9.7	.10
Other parts	3,062	98,393	17.0	.55
Burns	755	129,505	4.2	.72
Crushing injuries to—				
Hand and fingers	425	105,222	2.4	.58
Foot and toes	37	14,466	.2	.08
Other parts	29	254,592	.2	1.41
Dislocations and sprains	869	9,929	4.8	.06
Eye injuries	1,498	78,449	8.3	.44
Fractures	1,112	258,947	6.2	1.44
Punctured wounds	439	3,094	2.4	.02
Unclassified injuries	227	160,786	1.3	.89
Total	14,204	1,208,266	78.9	6.71

This table classifies the injuries according to their nature, in a few large groups, and shows the accident rates, according to both frequency and severity, for each group. The accident rates, standing by themselves, are not so significant as they will become when similar compilations are made for other industries or for other periods of time.

PERMANENT RESULTS OF INJURY.

The table following shows the frequency and severity of permanent injuries in three important departments of machine building and also in two groups of entire plants.

[1] For a classification of injuries by their nature and anatomical location proposed by the International Association of Accident Boards and Commissions, see Bulletin No. 201, U. S. Bureau of Labor Statistics, p. 81.

TABLE 23.—FREQUENCY AND SEVERITY OF PERMANENT INJURIES IN SPECIFIED GROUPS OF PLANTS.

Injuries.	Electrical assembly shops, 6 plants, 1907 to 1913.	Found-ries, 6 plants, 1907 to 1913.	Machine shops, 6 plants, 1907 to 1913.	Machine building. 5 plants, 1907 to 1912 (Group A).	Machine building. 194 plants, 1912 (Group B).
	Frequency rates (cases per 1,000 300-day workers).				
Number of 300-day workers	**30,906**	**15,925**	**47,412**	**94,030**	**115,703**
Loss of great toe	0.06	0.13	0.04	0.13	0.05
Loss of 1 joint of great toe	....	....	....	.02	....
Loss of other toe or toes	.03	.06	.02	.06	.07
Loss of 1 joint of other toe or toes	....	....	.06	.03	.01
Loss of foot	....	.06	.15	.10	.03
Loss of leg	....	.06	.02	.06	.01
Loss of thumb	.10	....	.13	.19	.10
Loss of 1 joint of thumb	.42	.13	.38	.39	.16
Loss of 1 joint of finger or fingers	1.62	.88	1.41	1.37	1.61
Loss of first finger	.49	.19	.55	.48	.54
Loss of second finger	.19	.19	.17	.29	.10
Loss of third finger	....	.06	.19	.13	.04
Loss of fourth finger	....	.06	.04	.20	.05
Loss of hand	.06	....	.04	.13	.04
Loss of arm	....	.19	.02	.06	.02
Loss of eye	.16	.25	.21	.38	.31
Other permanent injuries	.32	.38	.30	.29	.41
Total	3.46	2.64	3.73	4.32	3.55
	Severity rates (days lost per 300-day worker).				
Loss of great toe	0.02	0.04	0.01	0.04	0.02
Loss of 1 joint of great toe	....	....	....	[1]	....
Loss of other toe or toes	[1]	.01	[1]	.01	.01
Loss of 1 joint of other toe or toes	....	....	[1]	[1]	[1]
Loss of foot	....	.12	.27	.18	.05
Loss of leg	....	.16	.05	.17	.02
Loss of thumb	.05	....	.07	.10	.07
Loss of 1 joint of thumb	.11	.03	.10	.11	.04
Loss of 1 joint of finger or fingers	.26	.14	.22	.22	.25
Loss of first finger	.20	.08	.23	.20	.22
Loss of second finger	.05	.05	.05	.08	.03
Loss of third finger	....	.01	.04	.03	.01
Loss of fourth finger	....	.01	.01	.03	.01
Loss of hand	.14	....	.09	.28	.09
Loss of arm	....	.41	.06	.18	.05
Loss of eye	.19	.29	.24	.44	.36
Other permanent injuries	.29	.34	.27	.26	.37
Total	1.32	1.70	1.72	2.33	1.59

[1] Less than 0.005.

The first part of this table makes it possible to compare the frequency of the specified forms of permanent injury in three important departments and in two groups of plants which may be taken as fairly representing the general industry. Injuries to the hand are by far the most numerous. Adding together the injuries to the various parts of the hand, the total numbers of cases of hand injury per 1,000 workers are: In electrical assembly shops, 2.88; in foundries, 1.51; in machine shops, 2.91; in group A of machine-building plants, 3.18; and in group B, 2.64.

Also it may be noted that loss of eye occurs sufficiently often to attract attention; but its real importance appears more clearly when comparison is made of the frequency of several injuries, as shown in the upper part of the table, with the severity, as shown in the lower part. Such a comparison may be made between hand injuries and eye injuries. Thus, in machine shops, hand injuries have a frequency of 2.91 cases per 1,000 workers, while eye injuries have a frequency of only 0.21. But, as regards severity, hand injuries show a time loss of 0.81 day per worker, while the time loss from eye injuries is as much as 0.24 per worker. That is to say, injuries to the hand while 14 times as numerous as injuries to the eye are less than four times as important from the standpoint of economic severity.

This comparison does more than illustrate the value of the severity rates as a means of more exact analysis of accident hazard. It points very directly to one of the most serious of preventable accidents. With proper precautions eye losses can be reduced almost to the vanishing point. This has been accomplished by a number of plants which, at the outset, had much more serious conditions to face than those confronting any of the plants here included. Indeed, as has been elsewhere noted, the mere fact that conditions are not very severe may have a direct tendency to obscure the real importance of preventive effort.

INABILITY TO SPEAK ENGLISH AS RELATED TO ACCIDENTS.

In the first report of the bureau on accidents in the iron and steel industry [1] a careful study was presented of the comparative accident rates of English speaking and non-English speaking workers, the basis of the comparison being the experience of a large steel plant over a period of years. The results of that study are shown in Chart D. From the chart it appears that while the accident rates were reduced for non-English speaking steel workers as well as those speaking English, the improvement in the case of the non-English speaking workers was much less definite and much less steady.

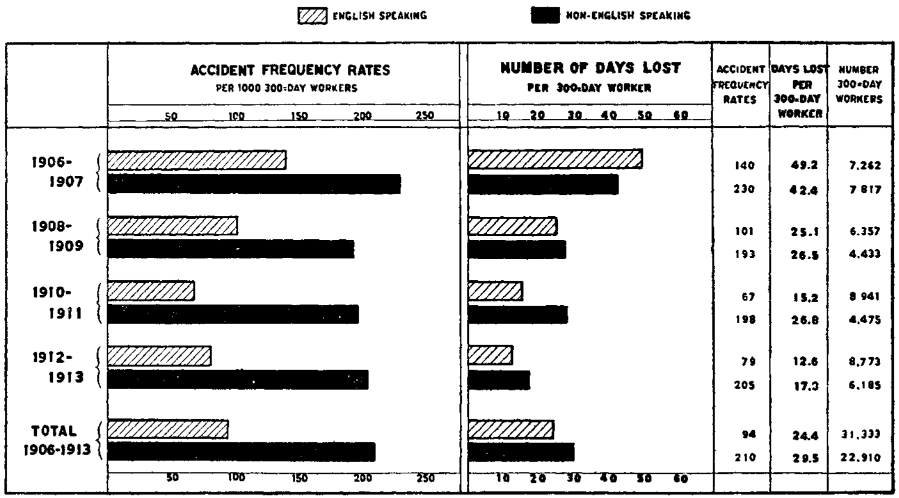
It is not to be concluded from this fact that the evident handicap upon the non-English speaking employees is entirely due to their inability to understand directions and orders. This is unquestionably a factor in their less favorable accident rate. But another factor also enters, namely, that the non-English speaking workers, as a rule, suffer from lack of experience and thus are found largely in the group of unskilled occupations involving inherently high accident hazards.

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

INABILITY TO SPEAK ENGLISH AS RELATED TO ACCIDENTS

EXPERIENCE OF A LARGE STEEL PLANT, 1906 TO 1913.

SHOWING THAT ACCIDENTS WERE MORE FREQUENT AND ALSO MORE SEVERE AMONG NON-ENGLISH SPEAKING WORKERS, THAN AMONG THOSE SPEAKING ENGLISH.



	ACCIDENT FREQUENCY RATES	DAYS LOST PER 300-DAY WORKER	NUMBER 300-DAY WORKERS
1906-1907	140	49.2	7,262
	230	42.4	7 817
1908-1909	101	25.1	6,357
	193	26.5	4,433
1910-1911	67	15.2	8 941
	198	26.8	4,475
1912-1913	79	12.6	8,773
	205	17.3	6,185
TOTAL 1906-1913	94	24.4	31,333
	210	29.5	22,910

CHART D.

For the machine-building industry it was not possible to obtain such full information as to the effects of inability to speak English upon accident rates as was obtainable for the steel industry. Of much interest, however, as bearing upon the same subject is the following table, which compares the accident rates of the American-born worker and the foreign-born worker in a large machine-building plant:

TABLE 24.—FREQUENCY AND SEVERITY OF ACCIDENTS AMONG AMERICAN AND FOREIGN-BORN WORKMEN IN A MACHINE-BUILDING PLANT DURING THE PERIOD 1910 TO 1913.

Groups.	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.
American born	22,556	0.5	1.6	58.5	60.6	4.4	0.7	0.5	5.6
Foreign born	18,039	.9	4.6	96.3	101.7	8.0	2.6	.9	11.5
Total	40,595	.7	2.9	75.3	78.9	6.0	1.6	.7	8.3

The foreign born are not entirely non-English speaking, but the constant excess of the accident rates of the foreign born, as shown in the table, may clearly be attributed to causes similar to those affecting the accident rates of the non-English speaking workers in the steel industry, referred to above. This conclusion is strengthened by the accident experience of a group of Polish workers which it was possible to isolate from the other foreign born. In this Polish group, consisting of 4,798 300-day workers, is found the greatest proportion of non-English speakers and also the greatest proportion of those engaged in common labor. The accident frequency rate of this group was 115 cases per 1,000 workers and the severity rate 15.7 days lost per worker. These are distinctly higher than the rates for the foreign born as a whole (101.7 and 11.5 days).

DAY AND NIGHT ACCIDENT RATES.

The question of accident distribution through the hours of the day has been illustrated elsewhere by so many and such extensive compilations that no special study of it need be made here. Attention will be chiefly confined to the allied question of day and night accident distribution, as illustrated by such limited data as could be obtained from the machine-building plants covered.[1]

The following table shows, by hours of the day and night, the distribution of 6,075 accidents in a large machine-building plant in 1913. This number is chiefly composed of nondisabling accidents,

[1] A considerable body of additional data regarding day and night accidents has recently been accumulated by the United States Bureau of Labor Statistics and will be embodied in a later report.

for which class of accidents full reports were available in this plant. For the purpose of studying distribution of accidents those of a nondisabling character are just as useful as those causing disability.

TABLE 25.—DISTRIBUTION THROUGH THE DAY AND NIGHT OF DISABLING AND NONDISABLING INJURIES IN A MACHINE-BUILDING PLANT, 1913.

Hour ending at—	Nondisabling injuries.		Disabling injuries.	
	Day.	Night.	Day.	Night.
7	31	43	8	19
8	362	**53**	87	**20**
9	499	44	102	19
10	**628**	52	**159**	16
11	574	42	119	10
12	396	25	98	8
1	263	14	41	1
2	463	**46**	84	4
3	**510**	36	**107**	**6**
4	429	32	93	3
5	290	22	72	5
6	80	27	29	3
Total	4,525	436	1,000	114

As regards the hourly distribution of accidents shown in the table, it is sufficient to note that it conforms entirely to the general type of the compilations hitherto made.

There are two peaks of accident occurrence, one in each half of the working period, with the peak tending to come earlier in the second half.

For the purpose of accurate comparison of day and night accidents, the data given in the preceding table are presented in the next table in the form of day and night frequency rates.

TABLE 26.—COMPARISON OF DAY AND NIGHT ACCIDENT RATES IN A MACHINE-BUILDING PLANT, 1913.

Classes of accidents.	Number of 300-day workers.		Cases of injury.		Frequency rates (cases per 1,000 300-day workers).	
	Day.	Night.	Day.	Night.	Day.	Night.
Nondisabling			4,525	436	338.73	494.89
Disabling			1,000	114	74.86	129.40
Total	13,359	881	5,525	550	413.58	624.29

The excess in night frequency rates is very marked for both nondisabling and disabling accidents. Combining both classes of accidents, the frequency rate appears as 413.58 cases for dayworkers as against 624.29 cases for nightworkers. The night rate is thus almost exactly 50 per cent higher than the day rate.

That the excess of night accident rates over day rates is true of the individual departments as it is of the plants as a whole is indicated on the following table, which presents such information as could be secured on this point. The table gives data and accident frequency rates for three important departments of a large plant for the years 1907 and 1910 combined.

TABLE 27.—COMPARISON OF DAY AND NIGHT ACCIDENT RATES IN A MACHINE-BUILDING PLANT FOR THE YEARS 1907 AND 1910 COMBINED, BY DEPARTMENTS.

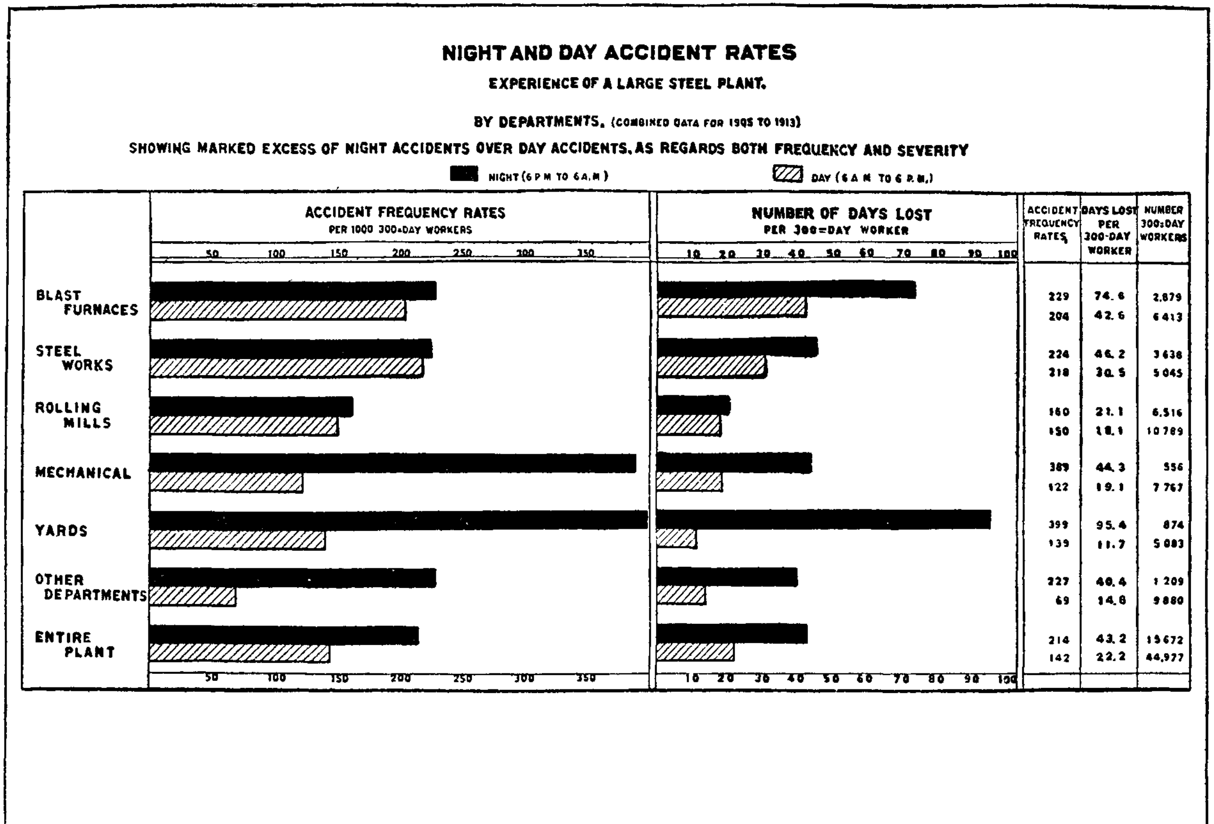
Departments.	Number of 300-day workers.		Cases of injury.		Frequency rates (cases per 1,000 300-day workers).	
	Day.	Night.	Day.	Night.	Day.	Night.
Boiler	2,090	937	347	173	166.03	184.63
Erecting	6,596	2,955	266	213	40.32	72.08
Machine shops	4,947	2,120	460	512	92.98	243.40
Other	6,073	1,651	422	228	69.49	138.10
Total	19,706	7,663	1,495	1,126	75.87	146.94

It is of interest to compare the experience of the machine industry, in this matter of night and day accident rates, with the experience of the iron and steel industry as shown in Chart E. In the latter industry the excess in night rates over day rates is shown to be constant.

It is also of interest to compare the rates for machine shops in machine building, as shown in the preceding table, with the mechanical department of the iron and steel industry as shown in the chart, the two departments resembling each other in character of work. The mechanical department of the steel industry shows a night accident rate of 389 cases per 1,000 300-day workers as against a day rate of 122 cases. The corresponding figures for the machine shops of the machine-building industry are: Night, 243.4; day, 92.98. In both departments, therefore, the night accident rate is very much higher than the day accident rate.

The constant excess of night accident rates over day accident rates, in all of the examples available, indicate that such result is due to the operation of definite causes. Two such causes suggest themselves as of importance: (1) That the artificial light of the night is not equal to natural daylight, and (2) that the physical condition of the nightworker is not so good as that of the man on daywork. This comes, in part at least, from the fact that it is quite impossible that conditions of restful sleep can be furnished in the day comparable with those of the night.

In any case, whatever may be the causes of higher night accident rates, the subject demands serious attention. A good deal of excellent work has been done on the lighting problem. Much remains to be done in making known and usable the information available.



	Accident frequency rates	Days lost per 300-day worker	Number 300-day workers
Blast furnaces	229	74.6	2,879
	204	42.6	6413
Steel works	224	46.2	3638
	218	30.5	5045
Rolling mills	160	21.1	6,516
	150	18.1	10789
Mechanical	389	44.3	556
	122	19.1	7767
Yards	399	95.4	874
	139	11.7	5083
Other departments	227	40.4	1209
	69	14.8	9880
Entire plant	214	43.2	15672
	142	22.2	44,977

CHART E.

DISTRIBUTION OF ACCIDENTS BY MONTHS.

There exists some disposition to regard an inquiry into the monthly distribution of accidents rather as one of curious interest than of practical utility. Nothing could be further from the fact. If it be found that there is a constant monthly or seasonal peak of accidents, it will be an indication of definite climatic or operating conditions whose effects can be determined and against which provision can in a measure be made. Data upon this subject were obtainable from three machine-building plants engaged in different classes of manufacture. Plant A produces engines, plant B produces electrical apparatus, and plant C produces machine tools. The monthly accident experience of these three plants is shown in the following table. The experience of a large steel plant is added for purposes of comparison.

TABLE 28.—DISTRIBUTION OF ACCIDENTS IN THE MONTHS OF THE YEAR, FOR 3 MACHINE-BUILDING PLANTS AND 1 STEEL PLANT.

Months.	Number of 300-day workers.				Number of injuries.				Frequency rates (cases per 1,000 300-day workers).			
	Plant A.	Plant B.	Plant C.	Steel plant.	Plant A.	Plant B.	Plant C.	Steel plant.	Plant A.	Plant B.	Plant C.	Steel plant.
January	6,291	3,123	2,183	3,199	492	212	88	663	78.21	67.88	40.31	207.25
February	5,646	3,062	2,207	3,304	358	199	84	668	63.41	64.99	38.06	202.18
March	5,524	3,089	2,224	3,366	447	196	99	641	80.92	63.45	44.51	190.43
April	5,680	3,094	2,223	3,310	485	213	104	620	85.39	68.84	46.78	187.31
May	5,846	3,088	2,226	3,420	580	237	105	618	99.21	76.75	47.17	180.70
June	5,846	3,122	2,237	3,409	616	233	116	634	105.37	74.63	51.86	185.98
July	5,990	3,151	2,229	3,313	705	206	95	644	117.70	65.38	42.62	194.39
August	6,361	3,185	986	3,336	745	265	54	743	117.12	83.20	**54.77**	**222.72**
September	6,500	3,268	2,178	3,362	792	247	90	640	**121.85**	75.58	41.32	190.36
October	6,436	3,300	2,203	3,339	675	292	97	695	104.88	**88.48**	44.03	208.15
November	6,359	3,388	2,202	3,349	633	180	66	577	99.54	53.13	29.97	172.29
December	6,057	3,388	2,197	3,210	567	197	67	607	93.61	58.15	30.50	189.10
Total	72,536	38,258	25,295	39,917	7,095	2,677	1,065	7,750	97.81	69.97	42.10	194.15

Inspection of the table brings out the fact that the high points in these four groups occur as follows: Two in August, one in September, and one in October. This concentration of the high points of accident frequency becomes more definite if the data are combined in groups of three months each—January to March, February to April, etc. If this is done, it is found that in the three machine-building plants the group of three months having the least frequency is always a group including January, while the highest frequency is always in a three-month group including the month of August. The highest point for the steel plant is also in the three-month group including August.

These facts, taken with the occurrence of the actual peak in two plants in August and in one in September, seem to indicate that the depressing influence of summer heat and humidity may be a factor in the accident hazard. The use of ventilating fans may, therefore, be considered not only a needed contribution to the comfort of hard-pressed workmen, but also as a distinct safety device. At the same time it should be kept in mind that there may be factors other than heat concealed in these high rates which may appear, upon further study, to be of decisive importance.

One further point in connection with this subject may be commented upon. In the preceding table the steel plant shows a peak for January as well as for August. An important compilation of fatal cases shows, for three years, a peak in December and January, with a smaller rise in the warm months.[1] An explanation of this December-January peak has been the deficiency of natural light due to the shortness of the day and to cloudiness. The possible importance of this factor is obvious. There is another which must be influential. This is low temperature. The steel industry has many occupations exposed to the outdoor cold. This has a twofold effect upon accident hazard. First and directly, the cold benumbs the muscles, and thus renders the worker less expert; second, the use of gloves and mittens, made necessary by the cold, must at times increase the liability to accident. A better design of glove might have an importance similar to that of the foundry man's shoe, which has so much reduced foundry burns.

GOVERNMENT ARSENALS AND NAVY YARDS.

The navy yards and arsenals operated by the United States Government are machine-building plants, and thus within the scope of this study. But important differences in the character of the accident records obtainable render difficult a comparison of the accident experience of the two classes of plants.

Under the Federal compensation act of 1908 accident reports from Government shops were made to the Bureau of Labor Statistics, which was charged with the administration of that law. But until 1912 there was no available record of exposure—i. e., of the number of persons employed—and, in consequence, no accident rates could be computed for the earlier years. For the years 1912, 1913, and 1914 exact information regarding employment is available. But even with this information at hand it has not been possible to compute accident rates exactly comparable with those presented above for private plants, owing to the fact that the accident reports from the Government shops appear, on analysis, to be extremely incomplete for disabilities of less than two weeks' duration. The evidence for this statement is presented in the next section. But there seems no doubt as to the fact itself, and because of it, it is necessary, in contrasting the acci-

[1] John Calder, in Journal of American Society Mechanical Engineers.

dent rates in Government shops with those in private plants, to exclude all accidents causing disabilities of less than two weeks.

Such computations have been made for a few important groupings, and are presented in the next table. This table shows accident frequency and accident severity rates in Government arsenals and navy yards for the three years 1912 to 1914, and brings into comparison therewith the corresponding rates for the private machine-building plants as a whole and also for the shipbuilding departments of those plants, for the year 1912. These rates, it must be remembered, are based on the exclusion of disabilities of under two weeks' duration, and thus differ from the rates earlier given, which are based on all disabilities of a duration of one day and over.

TABLE 29.—FREQUENCY AND SEVERITY OF ACCIDENTS IN ARSENALS AND NAVY YARDS, 1912 TO 1914, AND IN MACHINE AND SHIP BUILDING, 1912.

Years.	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, over 2 weeks.	Total.	Death.	Permanent disability.	Temporary disability, over 2 weeks.	Total.
Arsenals:									
1912	3,992	0.3	2.5	48.1	50.9	2.3	0.9	2.0	5.2
1913	3,950	.8	3.3	48.1	52.2	6.8	1.7	1.2	9.7
1914	4,612	.2	3.2	49.0	52.4	2.0	1.2	1.6	4.8
Total	12,554	.4	2.9	48.4	51.7	3.6	1.2	1.6	6.4
Navy yards:									
1912	15,608	1.2	1.6	68.1	70.9	9.7	.9	2.5	13.1
1913	15,226	.9	2.1	77.6	80.6	8.3	2.1	2.6	13.0
1914	15,094	.8	2.1	70.1	73.0	7.2	.9	2.5	10.6
Total	45,928	1.0	1.9	71.9	74.8	8.8	1.3	2.5	12.6
Machine building:									
1912	115,703	.3	3.6	28.3	32.2	2.9	1.6	.7	5.2
Ship building:									
1912	6,615	.5	2.3	96.6	99.4	4.1	1.6	1.7	7.4

The first comparison suggested is between the two classes of Government shops. The rates for the arsenals show a much smaller degree of hazard than those for the navy yards—the frequency rates, for the three-year period, being for the arsenals 51.7 cases per 1,000 300-day workers as against 74.8 cases for the navy yards; and the severity rates being for the arsenals 6.4 days lost per worker as against 12.6 days for the navy yards. This is in accordance with the known character of the relative hazards of the work done.

In attempting to contrast the accident rates of Government shops with those of private plants, the most obvious comparison is that between Government navy yards and private shipbuilding plants. The Government yards have the lower frequency rate—74.8 cases per 1,000 workers for the three-year period, as against 99.4 cases in private yards in 1912. But this condition is reversed when comparison is made by severity, the severity rate for the Government shops for the three-year period being 12.6 days as against only 7.4 days for the private yards. This high severity rate in Government yards is due, in large part, to a very high fatality rate. On the other hand, the group of employees for private yards is small and the fatality rate, based on a small number of deaths, may be abnormal, although a careful study of the plants is convincing that they fairly represent the actual conditions in private yards.

There is no particular group of the private plants studied with which the Government arsenals may fairly be compared. The variety of their activities places them more on a par with the entire machine-building industry. Comparing these two groups, it will be noted that the arsenals have a higher frequency rate—51.7 cases as against 32.2 cases per 1,000 workers, and also a higher severity rate—6.4 days lost against 5.2 days lost per worker in machine-building plants.

This somewhat unsatisfactory showing of the Government plants calls for careful consideration. The following comments upon this point, it should be clearly understood, apply to the years 1912 and 1913, during which the working conditions of the Government plants were reviewed. Changes are known to have occurred since that time which may well account for the steady reduction in severity shown by later navy-yard reports. The reduction of the originally lower accident rates of the arsenals would necessarily be a more difficult matter.

The following points impress the outside observer as highly favorable to a low accident rate in Government plants:

First, extreme orderliness and cleanliness. Only the very best private plants approach the Government shops in this particular.

Second, freedom from violent fluctuations in the amount of employment. This is illustrated by the very constant number of 300-day workers shown in the three years under consideration. Under normal conditions the demands for output are fairly constant, but if war were threatened and the work were speeded up accordingly the rising accident curve which always accompanies the beginning of increased activity would no doubt occur.

Third, the quality and stability of the working force. The certainty of regular employment attracts men of skill and serious purpose. Perhaps no private employer can hope to maintain a force of such high quality.

Fourth, the reasonable working hours. The eight-hour day prevails. It may be that individual workmen abuse the leisure that the shorter day affords and are more liable to accident on that account, but anyone who contends that this condition is general has given the matter very superficial consideration and is basing conclusions upon striking cases instead of upon a solid body of facts.

The conditions tending to counteract the favorable effect of the items named above are the following:

First, imperfect mechanical safeguarding. Improvements in this respect began before 1912, but there were still at that time in many of the Government shops conditions that the expert safety man in private employ would view with the greatest surprise.

Second, lack of safety organization. In 1912 it was not possible to find in the plants visited anything remotely resembling the method of inspection, committee work, and safety education which had then become nearly universal in the iron and steel industry, railways, and mines and which was taking root in other branches of industry.

Third, and strongly influencing the other two, an honest conviction on the part of the supervising authorities that such accidents as occurred were without remedy. The old view of such accidents led to constant search for some reckless behavior on the part of the man employed. Of course, such instances could be found and steady attention to them developed a conviction that the fundamental cause of accidents was a hopelessly ingrained carelessness. Nothing has become clearer during the progress of the safety movement than the effective response of the men who do the work. The results attained are largely due to this response and the supervising man who does not recognize this fact and act upon it must himself be recognized as hopeless.

INCOMPLETE REPORTING BY GOVERNMENT SHOPS.

The accident reports from the Government shops, under the Federal compensation act of 1908, show uniformly what appears to be an exceedingly large proportion of injuries terminating in the third week. In most instances the number reported as terminating in the third week is greater than the number for the second week. This has frequently been interpreted as indicating a practice on the part of injured workers of stretching short-time disabilities into the third week in order to benefit from the compensation act, which allowed no compensation for the first two weeks of disability but gave full wages for all of the time lost if the disability extended over 15 days.

A careful analysis of the accident reports indicate that the excessive proportion of injuries reported as terminating in the third week, as well as other peculiarities in their distribution, can be much more logically explained on the ground that there was a gross deficiency in the accident reports for short-time disabilities. This analysis is briefly as follows:

The distribution of disabilities in the Government shops, according to week of termination, is shown by numbers in part 1 of Table 30, and by percentages in part 2 of that table.[1] There are also shown the corresponding data for the iron and steel industry and the machine-building industry.

TABLE 30.—ACCIDENT REPORTS IN GOVERNMENT SHOPS AND IN THE IRON AND STEEL AND THE MACHINE-BUILDING INDUSTRIES.

Part 1.—Number of disabilities terminating in specified week.

Week in which disability terminated.	Government shops.						Iron and steel (1910).	Machine building (1912).
	Arsenals.			Navy yards.				
	1912	1913	1914	1912	1913	1914		
Number of 300-day workers	3,992	3,950	4,612	15,608	15,226	15,094	65,147	1 5,703
First week	89	138	197	535	534	501	9,889	7,680
Second week	27	26	46	153	136	140	4,433	2,048
Third week	57	69	89	339	432	362	1,915	869
Fourth week	57	52	61	257	271	240	1,014	512
Fifth week	15	24	19	129	125	132	807	272
Sixth week and later	55	36	57	320	304	321	1,251	621
Total	300	345	469	1,733	1,802	1,696	19,309	12,002

Part 2.—Percentages.

Week in which disability terminated.	Arsenals 1912	Arsenals 1913	Arsenals 1914	Navy yards 1912	Navy yards 1913	Navy yards 1914	Iron and steel (1910).	Machine building (1912).
First week	30	40	42	31	30	30	51	64
Second week	9	8	10	9	8	8	23	17
Third week	19	20	19	20	24	21	10	7
Fourth week	19	15	13	15	15	14	5	4
Fifth week	5	7	4	7	7	8	4	2
Sixth week and later	18	10	12	18	17	19	6	5
Total	100	100	100	100	100	100	100	100

Part 3.—Percentages (excluding all under the third week).

Week in which disability terminated.	Arsenals 1912	Arsenals 1913	Arsenals 1914	Navy yards 1912	Navy yards 1913	Navy yards 1914	Iron and steel (1910).	Machine building (1912).
Third week	31	38	39	32	38	34	39	38
Fourth week	31	29	27	25	24	23	20	23
Fifth week	8	13	8	12	11	13	16	12
Sixth week and later	30	20	25	31	27	30	25	27
Total	100	100	100	100	100	100	100	100

Part 4.—Accident frequency rates (per 1,000 300-day workers).

Week in which disability terminated.	Arsenals 1912	Arsenals 1913	Arsenals 1914	Navy yards 1912	Navy yards 1913	Navy yards 1914	Iron and steel (1910).	Machine building (1912).
First week	22	35	43	34	35	33	152	66
Second week	7	7	10	10	9	9	68	18
Third week	14	18	19	22	28	24	29	8
Fourth week	14	13	13	17	18	16	16	4
Fifth week	4	6	4	8	8	9	12	2
Sixth week and later	14	9	12	21	20	21	19	5
Total	75	88	101	112	118	112	296	103

A study of the data of these tables shows some striking facts. First, it will be noted that the percentage of injuries terminating in both the first and second weeks is very much smaller for the Gov-

[1] The Government shop data used as a basis for this discussion are given in Bulletin No. 155, U. S. Bureau of Labor Statistics (report on operation of the Federal compensation act).

ernment shops than for the steel or machine-building industry. Thus, taking the experience of the navy yards for 1914, it appears that only 38 per cent of all cases are reported as terminated in the first two weeks, whereas in the steel and machine-building industries the percentages were, respectively, 74 per cent and 81 per cent. Nor is this the only striking peculiarity. For injuries terminating in the sixth week and later the navy yards show a percenatge of 19 as against 6 and 5, respectively, in the steel and machine-building industries.

These comparisons themselves would indicate probable error in the reports for the Government shops. The probability becomes even stronger when the comparisons are based upon the accident reports for the third week and over, all of those for the first and second weeks being excluded. This is done in part 3 of the table. It is there seen that when the first two weeks are excluded the experience of the Government shops is substantially the same as that of the steel and machine-building industries. It may be particularly noted that the excessive percentage of Government shop disabilities terminating in the sixth week and over disappears, becoming 30 as against 25 and 27, respectively, for the steel and machine-building industries.

This substantial harmony in the distribution of disability periods for three distinct industrial groups is a strong argument for the basic accuracy of such distribution. If so, there is nothing abnormal in the percentages for the Government shops for injuries terminating in the third and later weeks. For the short-time disabilities, however, the distribution for the Government shops is so abnormal that it seems impossible to explain it except on the ground of extremely faulty reporting.

The comparisons so far made have been in the form of percentages. If, in place of percentages, accident frequency rates are used, the conclusion as to the incompleteness of reporting becomes even more evident. Part 4 of the table shows the accident rates distributed by week of the termination of disability. Thus, the total accident rate for navy yards, 1914, was 112 per 1,000 300-day workers. Of these 112 accidents per 1,000 workers, 33 caused disability of less than a week, 9 caused disability of between one and two weeks, and so on. Rates of the same character are shown for the steel and machine-building industries.

Comparing the data in the last three columns of part 4 of the table, the most striking fact is, that for disabilities terminating in the third and later weeks, the accident rates in the navy yards are practically the same as those for the steel industry, the respective rates being: For the third week, 24 against 29; for the fourth week, 16 against 16; for the fifth week, 9 against 12; and for the sixth and later weeks, 21 against 19. This close harmony of experience for the third and later weeks would suggest, with a reasonable degree of conclusiveness, that the true accident frequency in Government shops is about the same as that in the iron and steel industry. If this is so, then there should be a similar harmony in accident rates for the first and second weeks, inasmuch as there is nothing in the character of the work in the Government shops to warrant radical departure from the experience of other industries. Examination of the accident rates for the first and second weeks, however, shows extraordinary lack of harmony. For the first week the accident rate in navy yards for 1914 was only 33, according to the reports, as against 152 in the steel industry, and for the second week only 9 as against 68.

Inasmuch as it is known that the accident rates of the steel industry err, if at all, in the direction of being too low for the early weeks, the conclusion seems clear that the rates as shown for the navy yards (as also for the arsenals) are entirely too low, an error that could only be explained by failure to report short-time disabilities in full. Estimating the true situation from the data of the table it would appear that perhaps as many as three-fifths of the accidents having two weeks and less of disability in Government shops were not reported.

CHAPTER III.—SAFETY ORGANIZATION.

To be effective in producing the best results the safety movement must rest upon forces steadily operative within the industrial organism. As long as the standards are fixed and enforced entirely by outside agencies, such as governmental bureaus or insurance companies, the utmost desire to obey the law or follow the suggestions of the inspector seldom suffices to bring about the hoped-for results. When there is a disposition to evade the law and to refuse constructive advice the results, of course, are very much worse.

A motive must be supplied for thorough internal organization of the plant. This is now furnished in an important degree by the pressure of compensation acts. When an injury means a certain cost instead of a possible one there is an insistent reminder of the importance of accident prevention which can be furnished in no other way. The marked success of some great corporations in accident prevention has been due in great part to the establishment of compensation plans before any State had enacted a workable measure.

The safety organization, called by various names, is fast becoming, where it is not so already, as much a department of the business as is accounting or production. The elements of such an organization are briefly presented below.

THE INSPECTOR.

Safety activities in machine building have been somewhat different from those in the iron and steel industry. In the latter industry an entire system had very often grown up around some efficient inspector. He had been obliged to devise for himself means and methods. The results were characterized by a good deal of crudity but nearly always presented original features of much interest. The inspectors of the machine-building concerns have had the advantages and the disadvantages resulting from the fact that they have frequently been called in to administer a plan already determined by the managers' offices. Having a definite plan saves many mistakes. It may also be a serious handicap to a man of original ideas.

There appears a greater tendency in machine-building concerns to employ as inspectors men of technical training or practical shop experience. Many safety men in iron and steel came from the legal department. This was probably due to the manner in which safety effort originated in that industry.

On the whole the choice of engineers, draftsmen, and shop men by the machine-building concerns is undoubtedly wise. Many problems of a mechanical character remain to be solved and if this industry uses largely men with that kind of skill it should hasten the solution of these problems and contribute to the development of safety organization.

The hostility, often quite plainly marked, on the part of operating men against the safety man has in a measure disappeared. The operating man now recognizes his colleague as a cost saver and welcomes his attention to matters which an active superintendent of production has little time to work out.

THE SAFETY COMMITTEE.

The safety committee in its various forms is the mobile army in the attack upon bad working conditions. It can not be too often or too emphatically stated that the safety committee system has an influence upon the conduct of business much beyond its immediate purpose. In most lines of industrial endeavor there is frequent conflict between the man employing and the man who works. There is almost no subject which can be discussed between the two interests which may not at some point develop antagonisms. The safety movement in this respect occupies a rather unique position inasmuch as there is essential accord of interest.

Committee organization has not yet made great progress among machine builders, but where it was observed in operation it showed the same adaptation to conditions which has appeared conspicuously in other industries.

The following outline of a committee system is applicable to a large concern. All that is necessary to adapt it to smaller plants is to consolidate the elements to meet the less complicated situation.

1. Central committee: Chairman, the general superintendent or his immediate assistant; secretary, the director of safety; members, superintendents of departments, changing at intervals so that each department head serves at some time during the year.

2. Departmental committees: Chairmen may be either the superintendents or important foremen; members, either foremen or foremen and workmen. The mixed committee seems, on the whole, most satisfactory.

3. Areal committees: These are the members of the departmental committees charged with responsibility for a certain area. A wholesome rivalry can be introduced regarding the maintenance of good conditions in these restricted areas. The determination of this condition should be by the inspection of the director of safety.

4. Special committees: These will be organized from time to time to study some technical problem or special condition. These special

committees are the readiest means by which the director of safety can keep interest alive. His ingenuity will be tested and his usefulness measured by his employment of them.

MAINTENANCE OF INTEREST.

In the report upon accidents in the iron and steel industry the topic of "Educational work of safety committees" was discussed.[1] Further study of the situation leads to the conclusion that the more fundamental problem is maintenance of interest. If that is done, the matter of education will almost take care of itself. That is to say, keeping interest alive will result in education.

This must be accomplished, first of all, among the superintendents. Under compensation, a constant reminder is furnished by the fact that cost of accidents, like other manufacturing costs, regularly appears on the departmental cost sheets. It has been the custom of some companies to treat the cost of safeguarding in the same way. This is not a reasonable procedure. A superintendent ought not to be penalized for the imperfections of machines and conditions furnished him. The cost of remedy for these imperfections should rest on the business as a whole rather than upon an individual department.

Departmental committees may be held up to their responsibilities by close supervision from the office of the director of safety, particularly by what the railway men call "surprise tests."

The maintenance of interest among the men is a rather difficult matter. In the outset of the safety movement it had the aspects of a crusade and appealed strongly to the crusading spirit. Ultimately it must settle down to a regular element of ordinary business life.

The illuminated sign at plant entrances has been a very useful device. An extension of this method is the safety bulletin board, for which the National Safety Council has been furnishing its members a weekly supply of material. These bulletin boars appeal to the eye and are quickly and easily apprehended. Safety maxims on pay envelopes have been used with good effect.

It has, however, become obvious that all these measures gradually lose their force as their novelty declines. As a result, foresighted managers have been looking for something which could be relied upon as a more permanent influence.

One important steel company has been experimenting with a bonus system to foremen. Neither the strength nor the weakness of this plan has had time to develop.

One very ingenious plan of this nature was found in operation in one of the plants covered. The account of this method is given practically as formulated by the company, with some abbreviation and a few minor changes.

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[1] Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.), Vol. IV, pp. 183-185.

The accident-prevention score board stands just inside the main gate of the factory. It is 24 feet long, and on it are shown the departments, foremen, percentages for the month, and rank of the various competing divisions.

The starting point is 1,000 both for year and for month. Each division is penalized according to its accidents—minor accidents of less than one day's absence not as yet being considered. Each day's absence bears a percentage charge in proportion to the total number of "men-days" per month per division.

There are 26 divisions in the competition of various degrees of natural hazard and of wide variation in numbers of men. The degree of hazard is disregarded in our business, which covers the same general subject throughout the plant, the differentiation being considered as equalized in the choice or selection of men with reference to their ability and fitness for their respective class of work. As to the variation in the sizes and groups of workers, we meet this by establishing a differential charge per man per day for time off, which is computed by reducing each division to men-days for each month and using a multiplier of 10 to raise the figures to a more workable and understandable basis.

A division working 50 men for 25 days per month amounts to 1,250, and multiply the result by 10 equals 8 points for each man off one day on account of accident in that division. Wide variations noticed in a year's competition in the different divisions should be the basis of an adjustment of this penalty charge, which adjustment should not have to be made during a month.

In this manner large and small divisions are equal as to their penalties. In the fourth column of the score board will be noticed the figures which represent the deductions for absence in that division.

We disregard small accidents that do not entail appreciable loss of time, and we do not penalize for the remainder of the day on which the accident occurs. It is possible by this provision to insure the prompt report of all accidents, however small, so that we may be sure of proper attendance and avoid, as far as possible, such suffering as may be otherwise charged to secrecy on the part of either men or division superintendents.

At the end of 12 months the employees of the divisions scoring 1,000 receive two days' extra pay, or such part of that amount as their time and employment bears to the full year. If none score 1,000, then the highest ranking department receives two days' extra pay and the second highest one day's extra pay. General foremen of any division under them earning these premiums also participate on the same basis, but may earn but one prize if other divisions under them score perfect.

The original plan was to distribute $25 in cash each month to all foremen of divisions earning perfect scores; but, due to the relative importance and efforts of the foremen, with a widely varying number of men to deal with, we were obliged, in fairness, to change this arrangement so that one-half of each prize is paid on a flat basis and one-half distributed according to the number of men overseen. Thus, a foreman in charge of 50 men will get a proportionately larger premium than one in charge of 10 men. It may be noticed that the cash prize is rather small, and to some might be even considered trivial; but to such there has not come the meaning of the spirit back of the accident-preventing board as it prevails in our factory. It is the difference between success and loss that counts, and men who work at the lathe, the forge, or the cupola have the same aspirations to participate in the winning spirit that inspires any team or organization, however or whenever formed. Several efforts have been made by psychologists visiting our plant to analyze the mental attitude which these men must carry, and it has been the unanimous opinion that departmental loyalty is the first stone, the great foundation, upon which stands the success and cooperation of this idea. It is the aim of each division to head the list, and they must feel that they have a chance of winning throughout the year. This interest is fostered by making up the yearly basis out of the monthly average. The great thought is then concentrated on the yearly contest, and the discouragement of any unfavorable monthly showing is avoided, because any other division may have a sufficient penalty in some months throughout the year to equalize these unfavorable periodical conditions.

We have found that this system is a matter of personal interest to both foremen and employees, and so intense has the competition become at times that an unforeseen condition arises which must be met by extreme diplomacy, and that is the ill-feeling that may be occasioned against a worker who has been responsible for causes which might have been controlled. Careful investigation and study has shown that the personal interest manifests itself, and the feeling that the loss must be minimized is responsible to a great extent toward urging them to get back to work as quickly as possible. The foremen of the various divisions of the factory are members of a safety committee which meets at regular intervals under the direction of the general superintendent. A board of governors of five looks after the details of inspections, reports, investigates complaints, and approves the monthly penalty charges. This has served as an admirable promotion toward the further education of foremen in matters pertaining to accident prevention, as well as sanitation, cleanliness, and fire prevention, etc.

For the year closing September, 1913, 10 divisions out of 26 showed perfect scores. The division ranking 16, the lowest, has a penalty of but 51 points. Included in the perfect scores is the south foundry, the division in which our heaviest work is produced, making single castings up to 50 tons in weight and generally classed as a hazardous occupation. An analysis of the year ending September, 1913, shows 161 accidents—17 applying on foot, 77 on eye, 45 on hands or fingers, 45 on scalps or face 6 on burns or scalds, 5 miscellaneous. The total expense of first aid was $308.50; hospital service, $31.50; claims, $50; a total of $390. Time lost was figured at 218 hours; thus the average cost per accident was $2.42.

For the 12 months ending September, 1914, 11 departments of the 26 showed an improvement over their record for year ending 1913. Nine departments of the 26 showed a decline. Six departments maintain their averages of the previous year, and five of these six have now presented perfect scores of 1,000 for two years. With one exception, all hazardous departments show a gain.

The following table shows the results of the methods described, over a series of years:

TABLE 31.—COST OF ACCIDENTS COMPARED WITH PAY ROLL, AND TIME LOST COMPARED WITH TIME WORKED.

[From a bulletin issued by the National Safety Council.]

	1910	1911	1912 [1]	1913 [1]	1914 [1]
Total cost of accidents for each $100 of annual pay roll [2]	$0.503	$0.228	$0.112	$0.079	$0.070
Time lost due to accidents beyond the fraction of the first day (per cent)	(3)	(3)	0.394	0.192	0.116

[1] In this year the score board and wage bonus were in use.
[2] Including first aid, hospital bills, and claims, if any.
[3] No record kept.

SURGICAL CARE.

Since many of the machine-building companies have no need for extensive premises they are frequently located in the heart of business districts in cities. This location, with its proximity to hospitals and dispensaries, has brought it about that there are comparatively few emergency hospitals and emergency rooms in the plants themselves. The large companies have, as a rule, such conveniences, and an extension of this plan is practically certain when the possibilities of the service become more fully realized.

An emphatic word of caution is needed regarding the use of "first-aid equipments." They are useful if confined to first aid under close supervision. If their use is relied upon as final and not subjected to rather prompt scrutiny, preferably of a physician, or at least of some one with the training of a nurse, it is dangerous.

CHAPTER IV.—DIRECT SAFEGUARDING METHODS IN MACHINE BUILDING.

Since factory conditions have much to do with safe production, it is desirable at the outset to describe briefly some instances of the best recent construction. No attempt will be made in this or in other descriptive matter to give the technical details. It is the aim to present broadly the features which appeal to the nontechnical observer as bearing on the matter under consideration.

The important departmental units concerned in machine building are the foundry, the machine shop, and the erecting or assembling shop. In very many cases erecting is so intimately associated with machine-shop operations that no line can be drawn between them. This being the case, it must be understood that throughout this report many processes strictly belonging under erecting are discussed, for convenience, in the machine-shop section.

SHOP CONDITIONS IN FOUNDRIES.

The steady tendency in foundry architecture in recent years has been toward an increased height of walls with larger window area and better disposition of the artificial lighting.

Two general types of building may be noted. One, which may be called the standard type, consists of a central bay with louvered roof. In this bay the floor molds for large castings are built. On each side of the central space is a side aisle where smaller molds may be prepared and poured, the core making done, and other accessory operations carried out. An excellent example of this standard type is the new foundry at the Washington Naval Gun Factory. A brief description of this foundry follows:

The main axis extends north and south. On the west is an area for the reception and distribution of raw materials. Along the high brick wall which forms the boundary of the yard are a series of bins in which are stored pig iron, coke, limestone, etc. Parallel to this line of bins are the railway tracks over which the materials are brought. Between the bins and the track is an elevated structure carrying the outer end of the bridge of a traveling crane, whose inner end is carried on the wall of the foundry. Between the tracks and this wall are two sand houses with hatches in the roofs, by which sand taken from the cars may be received directly from the crane buckets. Outside the foundry wall at the height of the charging floors and communicating with them by large doors are two platforms upon which materials may be delivered directly from the crane. These arrangements permit the most prompt and satisfactory handling of all raw materials.

Entering the foundry at the north end there is at once the impression of ample space, good wall height, and satisfactory lighting. In the side walls there are two tiers of windows occupying nearly all the wall area. In the end walls there are three tiers in the central section, above which extends the louvered roof. These windows are glazed with a ribbed glass which produces a very uniform distribution of the light.

The central section of the foundry is served by two 25-ton traveling cranes and one 50-ton crane. These run upon tracks located at the point where the walls of the central roof spring from the roofs of the lateral sections. As is usual, this central section is utilized for the placing of large molds used in making heavy castings.

Down the western side on the right of the entrance the lateral section is occupied by the apparatus for producing molten metal. This consists of a 5-ton, open-hearth furnace, two small converters for making Bessemer steel, and four cupolas in which iron is melted. The eastern lateral portion is utilized for the making of small molds and for core making. It is served by two small overhead cranes. At about the middle of its length are the ovens in which molds and cores are dried.

Such a foundry may be regarded as the direct evolution of the low-walled, dismal, and dirty buildings which were earlier considered good enough for a foundry. Three causes have been operative in producing this evolution: First, the introduction of the overhead crane as a means of transportation; second, the demand for better lighting; and, third, willingness to improve the general working conditions.

The other type of foundry is illustrated by one recently put in use by the National Brake & Electric Co. of Milwaukee. (Plate 1.) Here the main floor is surmounted by a saw-tooth roof. This method of securing uniform and well-distributed light has been long in use for the weaving rooms of textile establishments but is a rather recent innovation for foundries; in fact, but one other was noticed in the course of this study, which extended to all the important machine-building centers.

Since the methods of handling raw material and molten metal in this foundry, while having many interesting features, are not essentially different from those in use elsewhere, space will not be taken for their description.[1] Some features of internal arrangement will be presented farther on in connection with foundry safeguarding.

[1] For a full description of this plant see "Foundry" for February, 1914.

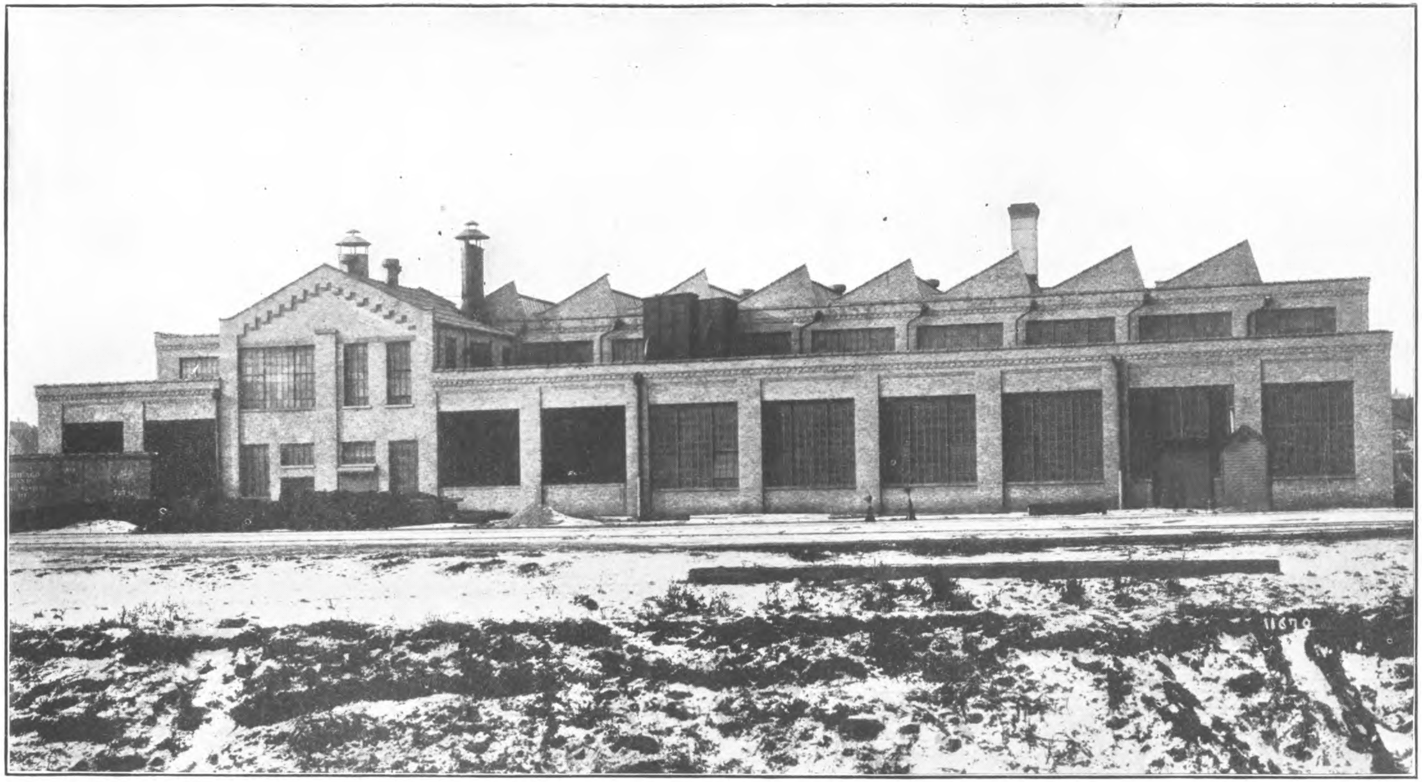

PLATE 1.—EXTERIOR OF FOUNDRY.

It was formerly assumed that being necessarily a dirty trade the provision of facilities for cleanliness was unnecessary. It might seem at first glance that the installation of toilet facilities has no significance to those interested primarily in safety. Nothing has been more impressive during the course of this study than the cumulative force of the evidence that nothing which bears upon the health and comfort of the workers is without its relation to the safety problem. This is the reason for the expanding field of the safety director. If he follows the natural leadings of his office he will become a sanitarian and ultimately will be obliged to go outside the bounds of his plant into the problems of community life. A study of the needs of men in industry can not stop with the industrial field. It must of necessity reach all their relations as men.

SAFEGUARDING IN FOUNDRIES.

Two sources of hazard at once suggest themselves when attention is directed to the foundry. There is considerable transportation of objects and there is the problem of handling molten metal. The machines used in molding present the usual features of belts and gears and other moving parts requiring covering and fencing. They do not, however, constitute a very large factor in the accident occurrence.

A primary necessity is for the safe movement of material. The character of the work done in a foundry renders it very easy for it to fall into a disorderly condition. The passageways become choked with débris and with apparatus awaiting its turn for use. With large castings particularly there is a considerable amount of material partly usable and partly useless derived from each operation. Without rather rigid rules and close supervision a very chaotic condition soon prevails.

Not a few foremen insist that this condition is inevitable where work is being turned out rapidly, and it is undoubtedly true that in many cases disorderly conditions and large output go together. The fact remains, however, that while no exact figures have been obtainable, the investigation has failed to produce a single instance in which the development of more orderly methods has not been accompanied by greater output. So uniform has been this experience as to cast grave doubt upon the insistence of disorderly foundries that they could not afford better order because it would decrease production.

The maintenance of clear aisles and the orderly disposition of apparatus have a direct bearing upon safety. In foundries where it is not the rule the men are endangered every time they attempt to pass from one part of the foundry to another, and since on every portion of the floor work is carried on, crane loads can not be carried without at some point passing above the workers.

The preparation of the metal for casting usually involves the use of the cupola, though some recent installation provides for the melting in a furnace much like that used for puddling, while for steel castings open-hearth furnaces, both stationary and tilting, are utilized, and in a few cases steel is made and cast from a form of Bessemer converter. The cupola is a cylindrical shell of steel lined with refractory material. The pig iron, coke, and flux are introduced from a charging floor at a level about half the height of the cupola. The details of hoists, charging cars, and barrows all require the same care called for in all machinery as to covering gears, the use of safety gates, and other precautions for safety.

Plate 2 shows a foundry interior with cupolas in the foreground on the right. The ladle is in place upon the car ready to receive the hot metal from the runner. As the metal comes down the runner sparking is apt to occur, and as the metal falls into the ladle these sparks are particularly likely to be projected forward in the direction of the workman. To avoid this one foundry has adopted runners with a turn near the end at nearly right angles. As a result, the metal when falling into the ladle is not moving toward the tapper, who must stand opposite the tapping hole when opening it.

In addition to the ladle on the car, other ladles appear in the picture which have bails for carrying by the crane. Since all these are suspended at a point but slightly above the center of gravity appropriate means of locking must be utilized to prevent oversetting and due care exercised not to overfill.

The crane service in the picture deserves a moment's notice. It consists of an ordinary crane on an upper track. Its bridge is seen above in the background. In the center of the picture is a wall crane. It serves the area next the wall to which it is attached for objects whose weight does not demand the service of the larger crane.

The safeguards possible in these operations are mainly those of good construction and careful operation. When it comes to the actual transfer of the metal to the molds two precautions become important. The sparking of the metal above mentioned suggests some protection for the eyes. Since the time during which this protection is required is quite brief it may be afforded by inexpensive glasses which would not be usable for the prolonged wearing necessary in the cleaning room. Eye injuries from flying sparks are sufficiently numerous and serious to demand this attention.

Among the most frequent and serious injuries in foundry operations are burns of the feet occurring during the pouring of castings. At times serious explosions and breakouts may occur. Foundry fatalities are sometimes due to such causes, but they are fortunately rare and the losses are much less than those arising from the frequent recurrence of minor burns.

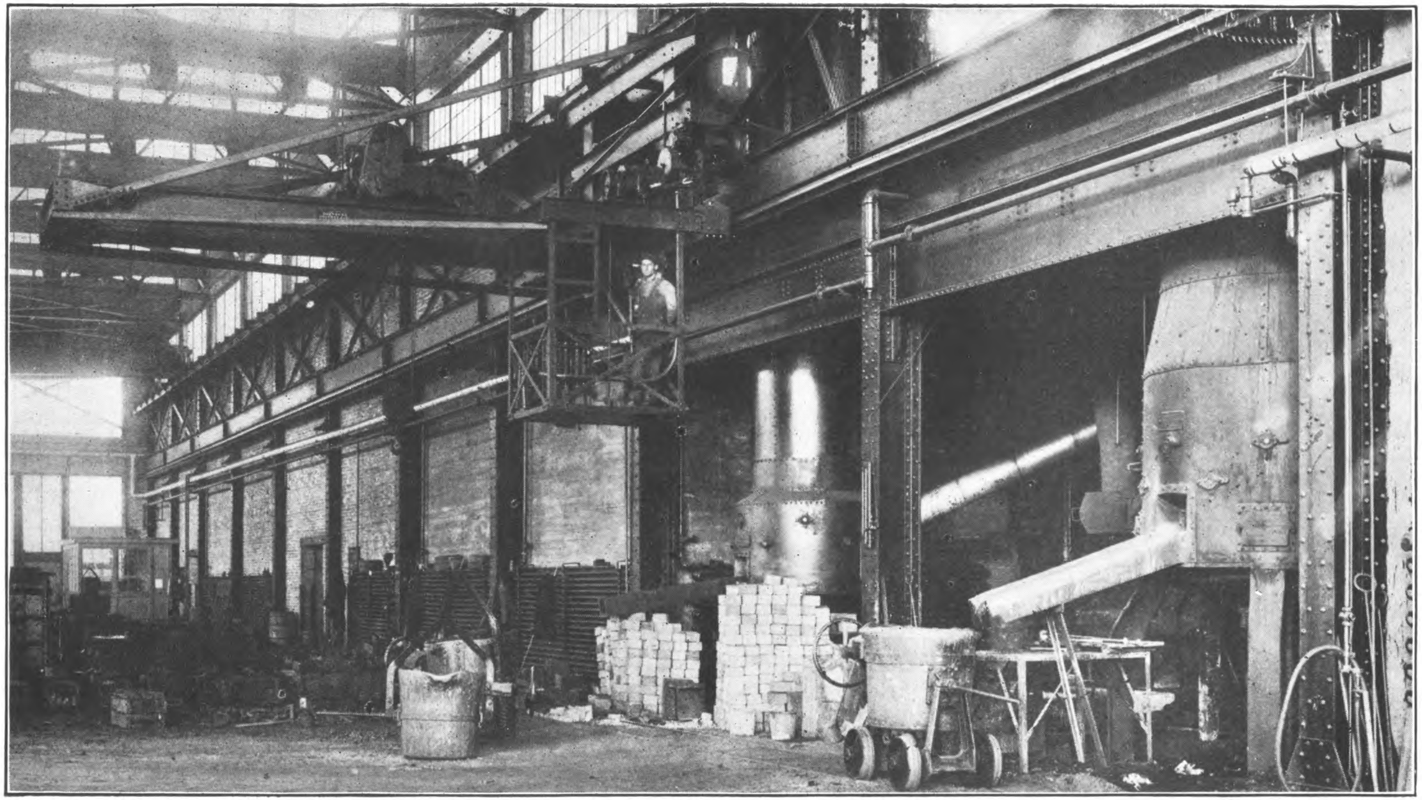

PLATE 2.—INTERIOR OF FOUNDRY.

For the majority of foot burns there is no excuse. If the employer provides proper means of protection and insists upon their use these injuries can be practically eliminated. It is altogether a question of proper shoes and the use of leggins during the operation. What is coming to be known as the foundry man's shoe is of specially prepared leather not easily affected by heat and having rubber cloth gores at the sides so that they can be readily removed. Many foundry owners are now securing and keeping on hand a supply of the proper type of shoe for the benefit of their employees since such shoes can not be easily obtained in the general market. If with this shoe a suitable canvas leggin is worn when pouring the foot burn becomes exceedingly rare.

The cleaning room has two dangers, dust and flying metal. The removal of the sand and the cores by the usual methods is exceedingly dusty. In many cases this is so serious a menace to health that either respirators should be worn or a dustless method of cleaning adopted. One foundry observed has introduced such a method. It consists of a high pressure stream of water. One man using this method cleans a greater number of castings than several by the old method. The quantity of water used makes necessary special means for its disposal and this together with the difficulties incidental to cold weather is an obstacle to the use of this method, but its speed and thoroughness, and the absence of dust, render it worth consideration.

Few, if any, castings come from the mold in condition to be immediately machined. The gates by which the metal enters must be removed and at each junction of parts there is a fin of metal to be taken off. This work is done by the chipper, using chisel and hammer or a pneumatic chipping tool. It is obvious that the process must be accompanied by flying fragments liable to cause injury, especially to the eyes, both to the chipper himself and his associates.

The remedy for eye injuries is the use of proper goggles. Emphasis is placed upon "proper," since in the early attempts to meet the situation there was much complaint of the refusal of the workmen to use the protection when furnished. They were fully justified in their antipathy. Ordinary glass has uneven surfaces and when used in glasses gives the effect of a number of irregular prisms before the eyes. A few minutes' wear of such a glass produces discomfort and prolonged wear causes serious pain. If persistently used such glasses result in grave injury to the eyes.

Proper goggles must have three qualifications: First, clearness and accurate surfaces; second, a mounting which can be adjusted, either by selection or changed shape, to the individual wearing the goggles; third, sufficient strength to withstand the blows of flying particles or if the glass yields it must do so without itself giving rise to flying pieces. An employer should not be satisfied with the assurance of the dealer regarding this last point. He should insist upon tests. Several large buyers have devised testing apparatus to which they subject each lot purchased, rejecting the lot if it fails to come up to the required standard.

The apparatus of the American Car & Foundry Co. and their requirements of the goggles they purchase are here described.

The sliding carrier shown in plate 3 holds a steel ball of five-eighths of an inch in diameter, weighing not less than 16 grams. The goggles are supported as shown and the ball drops upon pressing the button in the base.

The specifications which determine what the goggles must withstand are given below.

It may be said that not very long ago there was not in the market a goggle which would come even approximately near to meeting these standards. Now they may be obtained without difficulty.

SPECIFICATIONS FOR TESTING GOGGLES.

1. *Drop-test machine.*—The drop-test machine to consist of a support for the goggles made of white pine; the support being designed to accomodate the goggles under test in such a manner that the frame of the goggle is given proper bearing on the rubber and cotton composition strips without permitting the lens itself to rest on the support or to receive any "backing," other than that naturally given by its own frame. A representative form of support is shown in plate 3.

2. *Height of drop.*—Twenty-one inches from bottom of ball to the surface of the goggle lens.

3. *Size and weight of ball.*—The ball to be made of steel and hardened. The diameter will be five-eighths of an inch and the weight not less than 16 grams. When released the ball must fall freely without any initial momentum.

4. *Extreme variations allowed in the thickness of a single lens.*—Five millimeters. The measurement of the thickness to be taken with a standard gauge used by opticians at five points.

5. *Extreme variation in thickness allowed between two lenses of the same pair of goggles.*—Ten millimeters. The measurement of the thickness of each lens to be taken as described in paragraph 4.

6. *Number of blows.*—The maximum number of blows to be given is 15; the blows to be given consecutively on the center of the lenses and on the surface of the lens which is exposed to flying matter.

7. *Number of tests.*—On each shipment of one gross of goggles, one dozen of the gross must be tested as described in paragraphs 4, 5, and 6, and of this dozen 25 per cent, or three pairs of goggles, must stand 15 blows without breaking or cracking. This means that both lenses of at least three pairs of goggles in the test dozen must be intact after 15 blows. If less than 25 per cent stand the test the entire gross will be rejected.

8. *Flying chips of glass.*—If in the test dozen of goggles any goggles break under the drop in such a way that glass will fly from the inside surface of the lens—meaning the surface which is next to the eyes of the men wearing the goggles—then the entire gross will be rejected, even if three pairs of goggles have stood the number of blows required in paragraph 7.

With the growth of oxyacetylene and arc welding and other industrial operations of similar character another method of eye protection

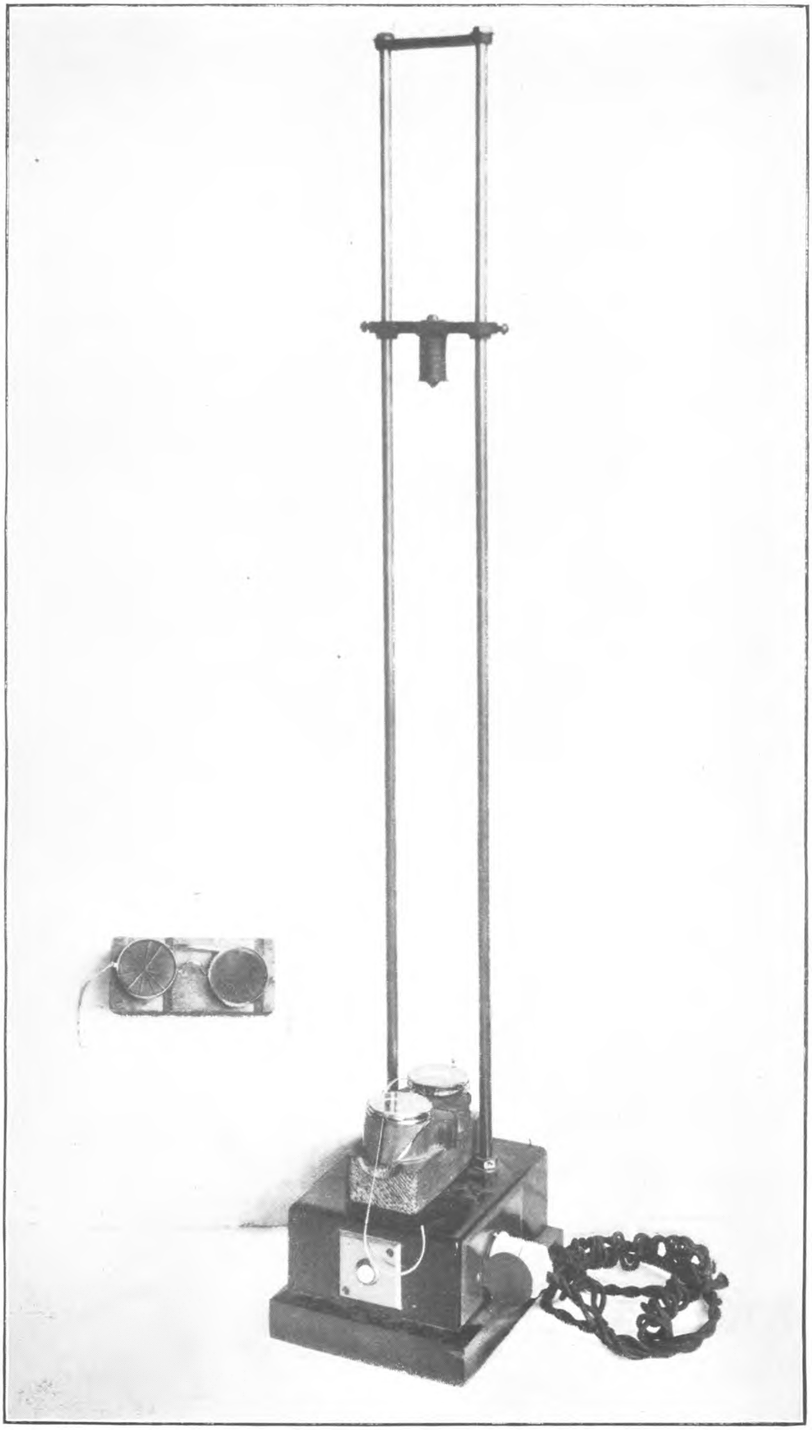

PLATE 3.—MACHINE FOR TESTING GOGGLES.

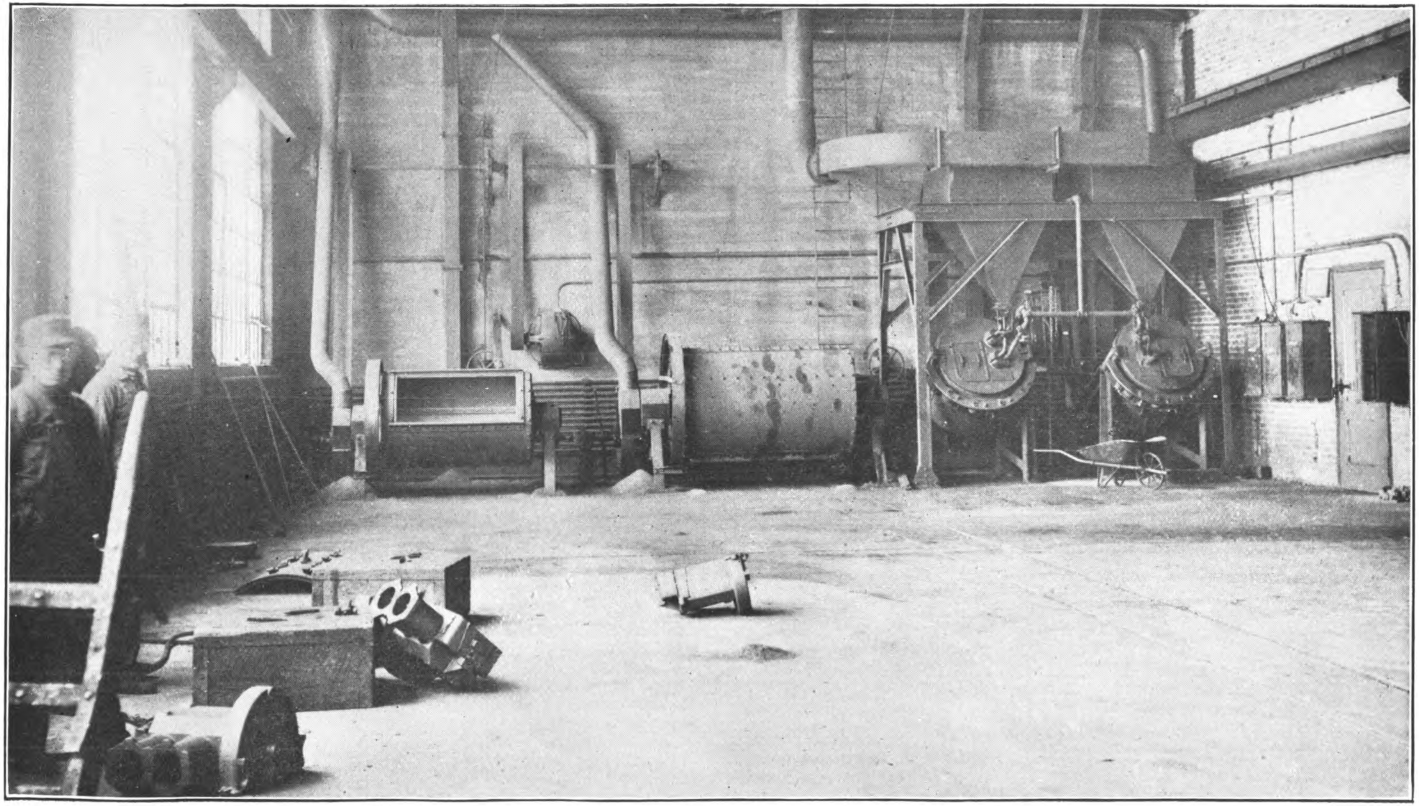

PLATE 4.—TUMBLER AND SAND-BLASTING MACHINES, WITH EXHAUSTS.

becomes of extreme importance—the use of suitably colored glasses. This has received small attention until recently, it being assumed that any coloring of the glass which reduced intensity served the purpose. With the advent of the intense heat and light of the arc this impression is being rapidly destroyed.

A study of the conditions shows that the harmful effect is not due to the intensity of the luminous rays of these operations but is due to the accompanying increase in the invisible rays known as the ultra-violet and the infra-red. An illustration of the power of the ultra-violet rays is seen in their capacity to destroy germs, which power is utilized in the water sterilizers lately put upon the market. The forms of colored glass hitherto utilized for eye protection afforded practically no defense against these harmful rays.

Since the fragments thrown off by chipping often fly with force enough to make a serious flesh wound, screens of burlap placed in the line of usual flight are a useful protection to those who work or must pass in the vicinity.

Further cleaning of the castings is accomplished by tumblers or sand blasts, both of which are shown on plate 4. In the tumbler or tumbling barrel in the rear at the left of the picture the small castings are placed in a horizontal cylinder, which is then revolved, the pieces being cleaned and even polished by attrition against one another or introduced substances. Formerly this process was very dusty but now in many cases, as shown in the picture, exhausts are applied and the dust effectively removed. In sand blasting a stream of air projects sand with much force against the surface, smoothing it and removing scale and rust. In the plate two completely inclosed machines for this purpose, which are provided with exhaust arrangements, are shown in the rear at the right of the picture. Sometimes it is impossible to use such a machine, as, for example, with very large castings. Two safeguarding methods are possible: (1) The object to be cleaned may be inclosed in a chamber and the sand applied through guarded slits in the walls, or (2) the workers obliged to be in the room with the casting may be provided with suitable helmets.

CONDITIONS IN MACHINE SHOPS.

Typical machine shops for the handling of large work are those of the Allis-Chalmers Co., at West Allis, Wis. Each shop consists of a central portion, under the louvered roof, in which are located the large machine tools served by traveling cranes, with side aisles where smaller machines are located. These side aisles have small traveling cranes, a monorail hoist, or other means of transportation. Above the side aisles are a varying number of gallery floors occupied by automatic machines, small lathes, and benches in front of the windows.

The general arrangement of the Allis-Chalmers shops deserves some notice, since the entire group was built as a unit, with the purpose of maintaining a steady progression of the material through all the processes. Many, perhaps most, shops have developed by a process of accretion which involves more or less difficulty in the transportation problem. The movement of material from place to place is a very serious factor in the causation of accidents. Evidently then arrangements which reduce the need of moving material are important safety measures.

The arrangement of the Allis-Chalmers shops is as follows: Fronting upon the street is a building several stories in height devoted to the general offices and to pattern storage. At the back of the building is a one-story extension devoted to the pattern shop. Between the pattern shop and the foundry is a yard space where flasks and other foundry apparatus which can be kept out of doors are stored. The foundry extends parallel with this pattern shop and pattern warehouse. Beyond the foundry are the machine shops, six in number, their axes at right angles to that of the buildings already mentioned. The space between the foundry and the shops and between the individual shops is utilized for outdoor storage and is served by traveling cranes and railway tracks which make every part readily accessible. The shops open directly at their extreme end into an erecting shop extending across the entire group of six shops. In this the products of the several shops are brought together and assembled into the completed machines. Railway tracks enter this building, so that the completed product may often be sent directly to its destination.

It requires no more than this statement to show that if the processes are organized to fit the plans of the buildings, it should be possible to conduct them with a minimum of transportation, and so greatly reduce that element of hazard.

Of shops intended for smaller work such as turret lathes and similar products two recent types of construction are particularly noticeable. The first of these is illustrated by the shop of Bardons & Oliver in Cleveland, makers of turret machinery. This shop exemplifies the sort of plan likely to be adopted in a city location where the ground values are high and it is therefore necessary to secure floor space by vertical instead of lateral extension.

The present building has a ground plan like a reversed letter "L." The stem of the "L" contains the shops, while the foot is devoted to stairways, elevators, and locker rooms for the workmen. The arrangements of these locker rooms, one on each floor, present features deserving attention. The entrance for workmen is at the extreme of the foot of the "L." The stairway is immediately accessible. The workman, on reaching his floor, finds an entrance to the locker room adjoining the stairway. Down the middle of the room are the washing facilities, while along the wall opposite the entrance are the individual steel lockers. These stand upon a low concrete base with no space beneath for dust to accumulate. The base is given a curve down to the floor so that it may be easily washed without danger of splashing on or into the lockers. After putting on his work clothes the workman passes to the shop by a door next the shop section, saving any retracing of his steps or interference with his fellows who may be coming from the stairs. Entering the shop the worker finds on his right the rack for the clock cards and on his left a bubbling fountain.

Two features of the shops attract particular attention. A gradual transformation to individual motor drive of the machines is in progress. The position of machines throughout the shops was carefully determined when preparing the plans. Proper conduits for the reception of the electric wires were placed, with the result that as new machines are installed a connection is available from which electricity may be obtained with a minimum of difficulty and with practically no exposure of the wiring.

It is becoming more and more a settled feature of such construction that it shall be fireproof. The building in question is reenforced concrete, brick, and tile throughout. It has been found by experience, however, that concrete floors are exceedingly tiresome to the workman who must stand upon them all day. To avoid this and at the same time keep down the fire hazard this expedient was adopted: At the location of each machine a depression in the concrete was formed to a depth equal to the thickness of the flooring desired. This depression was filled with a carefully laid wooden floor. The floor, having no air space under it, would burn very slowly in case it took fire, and since the area about each machine is isolated from other areas by broad strips of concrete, the spread of fire is rendered nearly impossible.

The second type of shop is illustrated by the building of the Cincinnati Milling Machine Co. It may be called the suburban type. Some years ago a number of machine-tool builders removed from their urban location in the city of Cincinnati to the suburb of Oakley. With the lesser cost of ground area they were able to secure adequate space without resort to many-storied structures. When, however, a large ground area is covered, lighting becomes a matter of consideration. It is sometimes solved by long and rather narrow buildings, in which the center of the room is not so far removed from the walls as to reduce the light unduly. In the case of this machine shop the result was secured by the use of the saw-tooth roof. The part of the building fronting on the street is several stories in height and serves for office purposes and for some of the shop operations. In the rear is the large one-story structure in which the adequate distribution of light is secured by the form of roof mentioned. A building of this sort standing by itself presents a rather hopeless problem from the architect's point of view, but from an operative standpoint it has many things strongly in its favor.

Erecting does not demand any special features in the buildings in which it is done, except in the case of locomotives. With them, of course, a large area of ground space is essential, and lighting by some overhead device, either the ordinary louver or saw-tooth construction, is essential. One of the most impressive industrial spectacles to be seen anywhere is the erecting shop of the Baldwin Locomotive Works at Eddystone, which will accommodate over a hundred large locomotives at one time.

In general it may be said that the machine-building concerns considered in this report are well housed and that some of the buildings of recent construction represent the best so far attained in safety from fire risk, sanitary convenience, and adaptation to efficient operation. Unfortunately it will appear in the course of the report that while doing considerable for the safety of their operations, it can not be said that these firms have been leaders in safeguarding except in individual instances.

SAFEGUARDING IN MACHINE SHOPS.

A later section under machine design is devoted to machine-shop equipment. In view of this fact only those forms of equipment will be here discussed which do not appear in the discussion of design.

No single change in shop equipment has more strikingly modified conditions than the introduction of electrical drive. It has repeatedly been assumed that this introduction adds to the dangers of the shop. The argument practically is that there is now added to the existing hazards the chance of burns and shocks from the electric current. This takes no account of the dangers removed. A moment's consideration will show that these are many and that they far outweigh those added.

Plates 5 and 6 give an idea of the different appearance of shops belt driven and motor driven. Inspection is enough to show the elimination of shafts and belts, generally recognized as a frequent source of injury. A considerable amount of severe injury has constantly occurred in connection with the oiling of shafts and the adjustment of belts. Group electric drive reduces this hazard, and individual drive eliminates it altogether. More important than the elimination of shaft and belt hazard is the control over the machine. A very frequent cause of injury in the old-type shop was the unex-

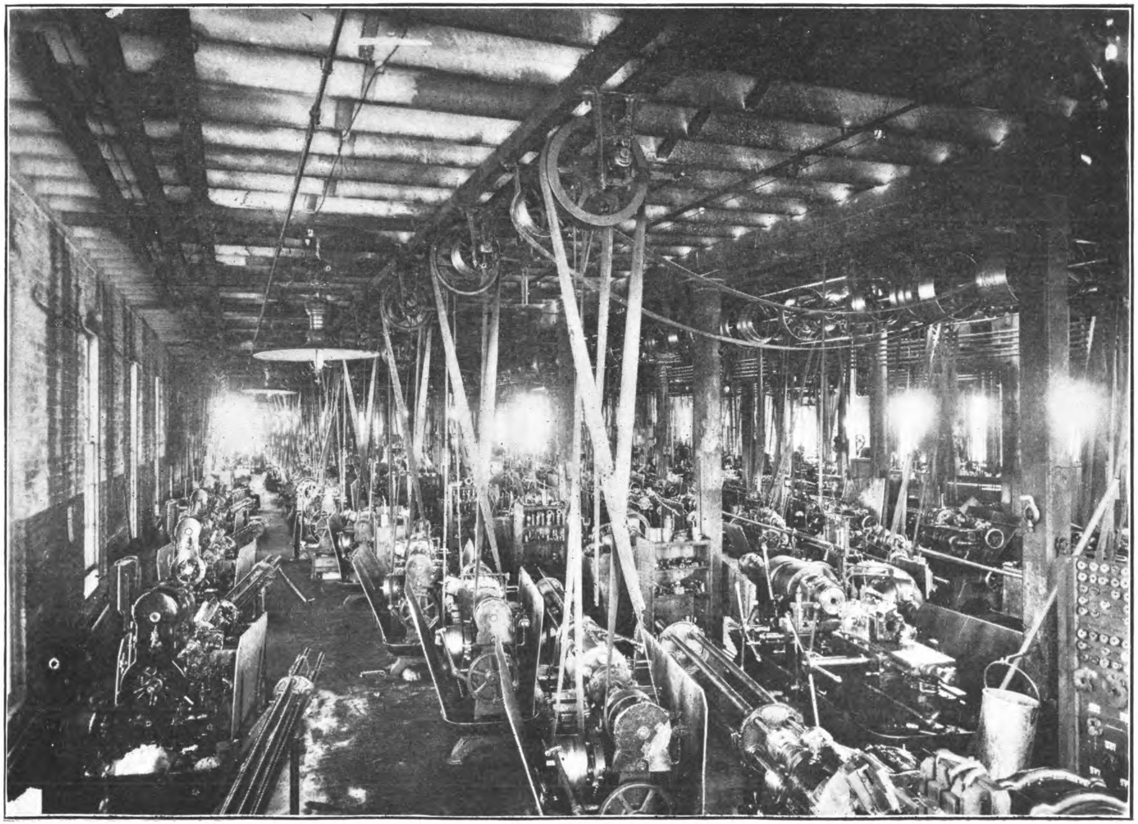

PLATE 5.—BELT-DRIVEN SCREW MACHINES.

PLATE 6.—LATHES DRIVEN BY INDIVIDUAL MOTORS.

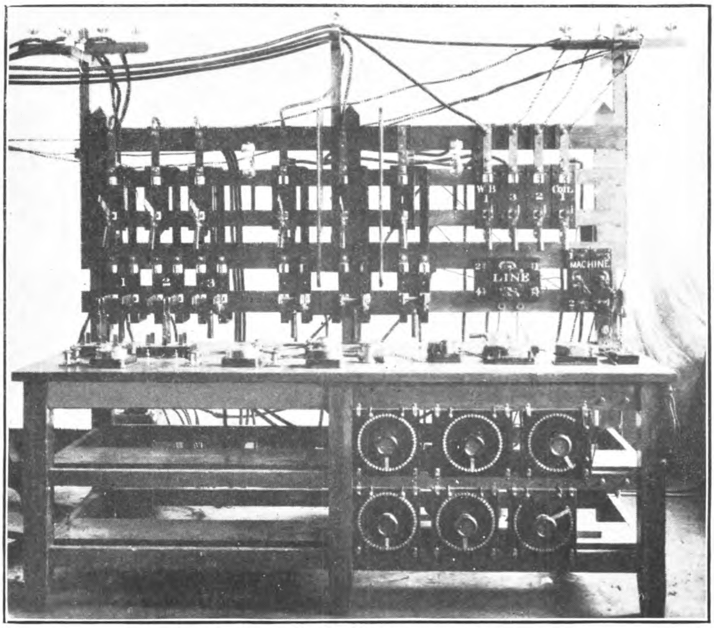

PLATE 7.—OLD TYPE OF TESTING SWITCHBOARD.

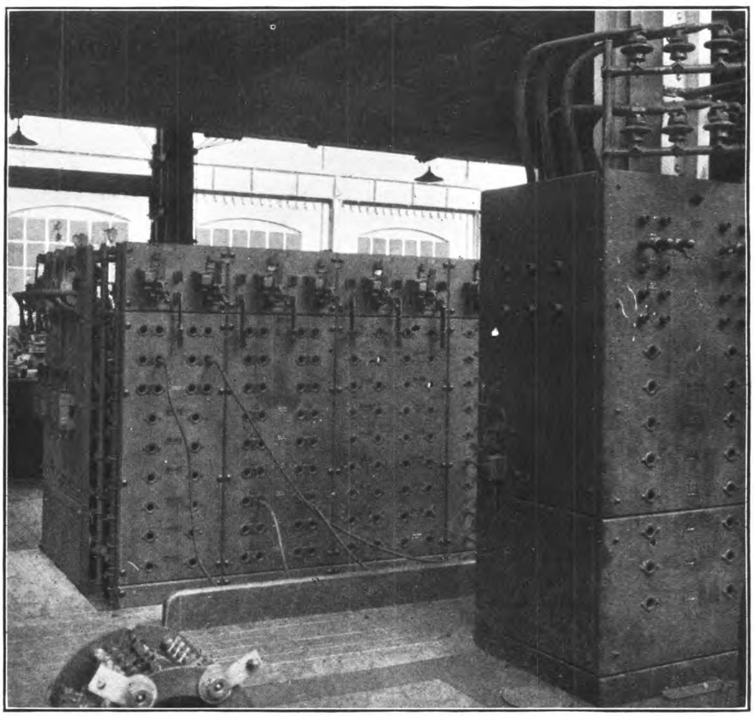

PLATE 8.—STANDARD TESTING SWITCHBOARD.

pected starting up of the machine. This may occur when a shaft, stopped for some cause, begins to revolve or the belt of the particular machine may creep from the loose pulley to the tight one. Such unexpected starting is practically impossible when the machine is set in motion by the closing of a switch.

Not only does the workman have perfect control of his machine, but it is perfectly feasible to extend this control so that it can be exercised at several points. The stoppage of a machine promptly from several points in its vicinity may make the difference between serious, even fatal, injury and complete escape.

Another element of safety is the ready and exact adjustment of the amount of power to the demands of the work in hand. This is accomplished with mechanical drive by means of cone pulleys, gears, clutches, and other devices, but in no case can it be done with the precision possible by the use of electricity.

It is still a matter of discussion whether the use of individual motors is an economy of power. The claim is made that the operation of a given group of machines can be conducted with an expenditure of about 80 per cent of the power required by mechanical drive. Whether this saving would offset the higher cost of electric installation would be a question to be settled onlv by a study of the individual case.

Although less serious in results than in the chipping of castings, there are several machine-shop operations in which fragments are apt to fly.

Grinding wheels are an important adjunct in machine-shop operations. Two items are worthy of attention in the safeguarding of these: First, proper mountings, and, second, hoods inclosing the wheel, so that if it explodes the pieces will not fly.

SAFEGUARDING IN ELECTRICAL MANUFACTURE.

In the production of electrical apparatus the foundry and the machine shop play an important part. These have already been discussed. In addition, there are two operations in the production of electrical apparatus which require particular attention, namely, testing and the use of power presses.

The testing department of every important electrical manufacturer has at some time presented cases of severe injury and in most cases some fatalities. This occurrence of fatal burns and shocks has, with the growth of the industry, led to a revolutionary modification of testing apparatus and testing methods. The subject is too technical for discussion in any complete fashion in this connection.

Plate 7 shows the earlier form of testing switchboard and plate 8 that now regarded as standard. The most important differences are the bringing of the cables to the latter form at a higher level and in a more substantial manner and the method of making the contacts. In the older switchboard the live parts are carried on the front of the rack, where the hands of the operator may easily touch them. In the newer form these contacts are all behind the slate boards. When it is desired to make a particular connection a rod is thrust into the opening in the board and the current completed at a point some distance from the hands of the operator and which is perfectly screened.

One large manufacturer of electrical apparatus had been having one or more fatalities annually in testing operations prior to the installation of improved apparatus. Since the change no fatalities have occurred in strictly testing operations.

In the production of electrical apparatus there are a great number of parts blanked out and formed upon the punch press. A previous study [1] brought out the excessive danger of this operation and the figures now available show that in spite of much improved methods it still remains hazardous.

Two devices designed and in use by one large electrical company deserve mention. On very heavy presses two buttons are provided at the edge of the press table. Both of these must be pressed at the same time to release the press. Both hands of the operator being occupied at a position out of the danger zone, injury is impossible. The second device is a suction handle, by which small parts may be adjusted under the press. At the end of the handle is a disk, to the center of which a tube running through the handle extends. The handle is connected by a flexible tube with an exhaust pump. In use the disk is applied flat upon the surface of the piece of metal and a small knob on the handle is pressed by the thumb, opening a valve. The suction causes the metal to adhere, when it can be placed upon the machine and the suction released. The machine is then tripped in the ordinary manner by a foot treadle. One edge of the disk is prolonged into a hook or horn, by which the formed part may be pried up and thrown from the machine. Both of these devices are effective in keeping the hands away from danger.

Other devices operate by preventing the action of the press whenever the hands are in a dangerous position. These devices may be combined with others releasing the press upon a positive removal of the hands.

An important feature of electrical manufacture is the winding and forming of coils and the application of insulating material, but the hazards of these operations are not sufficiently serious to justify special reference to the safeguarding methods observed.

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[1] Condition of Woman and Child Wage Earners in the United States (S. Doc. No. 645, 61st Cong., 2d sess.), Vol. XI.

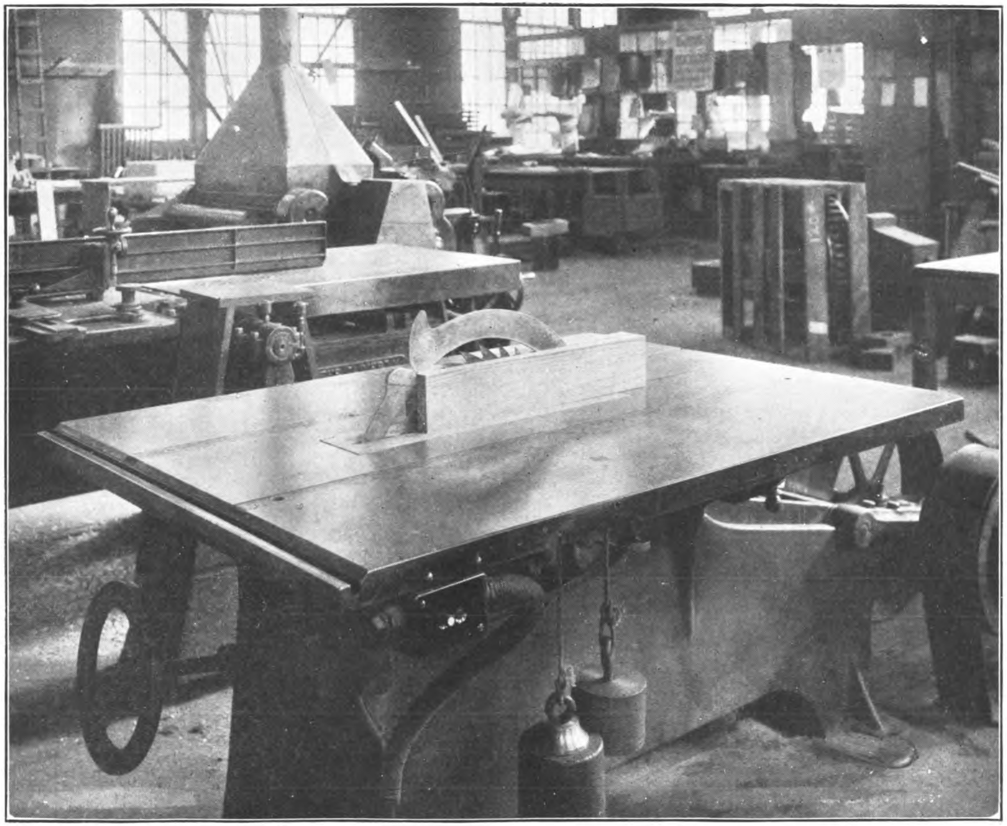

PLATE 9.—RIPSAW GUARD—POSITION WHEN SAW IS USED.

SAFEGUARDING IN WOODWORKING SHOPS.

These shops contribute but little directly to the products now under consideration, but their indirect contribution in the making of patterns, templets, etc., is of such considerable importance that a brief statement of safeguarding devices observed in them is necessary.

Plate 9 presents a view of a saw guard which has some unique features. This guard consists of two curved arms, mounted so that they revolve about the same center as the saw. Upon pushing any piece of lumber of whatever thickness against the free end of the arm above the saw it revolves, the free end rising until it rests upon the surface of the lumber. Plate 9 shows two things: First, how the arm in front of the saw comes into action, maintaining at all times a complete screen in front of the saw teeth; second, that the arm above the saw not only serves as a guard above the teeth, but acts as a splitter behind the saw, so preventing the "kick back" which is one of the most serious happenings with a saw. If the lumber is thicker than the exposed portion of the saw, and it is desired to saw a groove in it, the arm above the saw simply retreats entirely and disappears beneath the table. The arms are actuated and kept in proper position by counterweights.

The features of this guard may be summarized as follows: (1) It can not be removed by the operator; (2) every operation possible with an unguarded saw is possible with the guard; (3) the guard does not interfere with any necessary view of the work during operation; (4) a constant screen is maintained over every part of the saw edge; (5) it effectually prevents "kick backs."

The band saw quite early came in for attention, since, when the saw ran unscreened, very ugly accidents would occur when the saw broke and the free end came flying out into the surrounding space.

CHAPTER V.—MACHINE DESIGN AS A FACTOR OF SAFETY.

The machine-building plants covered by this report are engaged in the production of machines for use in various manufacturing and transportation industries—such machines as cranes and hoists, engines, boilers, dynamos, locomotives, and machine tools. The extent to which these machines will be a source of danger to those who later have to operate them is dependent, in considerable degree, upon the manner of their construction in the machine-building shop.

In response to the demand for safer machines the builders have done two things. They have (1) applied safeguards to their existing designs similar to those developed by the users of their machines, and in other cases they have (2) undertaken a radical revision of their designs in order to secure the desired result. It is difficult to draw a line between these two methods and for practical purposes it is unnecessary. All changes made by the maker which result in safer operation will therefore be considered without reference to the distinction mentioned above.

MACHINERY FOR THE STEEL INDUSTRY.

In the course of this investigation the building of ore unloaders, of rolling-mill equipment, and wire-mill machinery came under particular scrutiny.

In the matter of ore-unloading apparatus the chief modifications have been directed to increased efficiency, and their effect upon accidents has been due to a reduction of the shoveling crew who in the earlier types were exposed to material falling from the grab buckets and were endangered by the swing of the buckets themselves. Nearly as important has been the modification in the structure of the ore-carrying boats, making them more accessible and requiring fewer men in the operations.

The degree of change in ore-handling equipment is shown by the fact that in a large ore yard 289 men were required in 1905 and 93 in 1910, although the quantity of ore handled was much larger in 1910.[1]

The only machine used in distinctively steel works' operations which came particularly under observation was the open-hearth charging machine. The manufacturers are now providing fenders for the truck wheels, covers for the gears, and other similar devices, bringing

[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. 132.

their apparatus up to the standard set by the steel mills. Probably the most important modifications concern the electrical portion of the machine. They involve improvements in switches and controllers, better arrangements for carrying the feed wires, and more reliable and better inclosed motors. It is impossible to point out precisely the modifications which contribute directly and intentionally to greater safety, but the general truth that the more efficient machine may easily be made also the safer machine is clearly evidenced.

In rolling-mill machinery certain changes, designed primarily to secure greater tonnage, have benefited the working conditions. This is well illustrated by the case of the sheet mills. In 1892 when this department of the industry was gaining a foothold in this country, the roll housings in use weighed about 5 tons each. The rolls were 22 inches in diameter, with 16-inch necks. Those seen in process of manufacture have rolls not less than 28 inches, and in some cases 32 inches. This increase in size of rolls and an accompanying change in housings have materially reduced breakage of rolls which was a frequent cause of accidents. Breakage has been still further reduced by the introduction of a device by which a uniform temperature of the rolls may be maintained.

The peculiar hazard of wire mills is in connection with the wire-drawing process. The wire-drawing bench had undergone no material change for many years until the demands for safety directed attention to it. In the iron and steel report [1] is shown an automatic stop. This was connected below the floor to the treadle by which the revolving block was stopped. This did not prove entirely satisfactory since the force necessary to apply was so considerable that a tangle might be pulled into or through the handle of the stop strongly enough to do considerable damage. Accordingly the stop was modified by carrying a rope up from the handle over two pulleys and down through the top of the bench. Below the bench top it is attached to a strap collar around the shaft which drives the blocks. A comparatively slight pressure on the handle or upon the cord at any point of its course will tighten this collar and cause it to revolve with the shaft. The collar is connected with the treadle and easily exerts sufficient pressure to pull it down and stop the block. In this modified form the stop facilitates operation since the wire drawer can use it to stop his machine at a distance from the block. Such a stop is important, since it can be applied to old-type installations where the machinery is still so useful as to make it undesirable to replace it.

Plate 10 shows an old-style drawing bench with fixed die boxes and positive clutches. There are no stops. With this type of equipment

[1] Conditions of Employment in the Iron and Steel Industry in the United States (S. Doc. No. 110, 62d Cong., 1st sess.) Vol. IV, plate 56.

PLATE 10.—OLD STYLE WIRE-DRAWING BENCH.

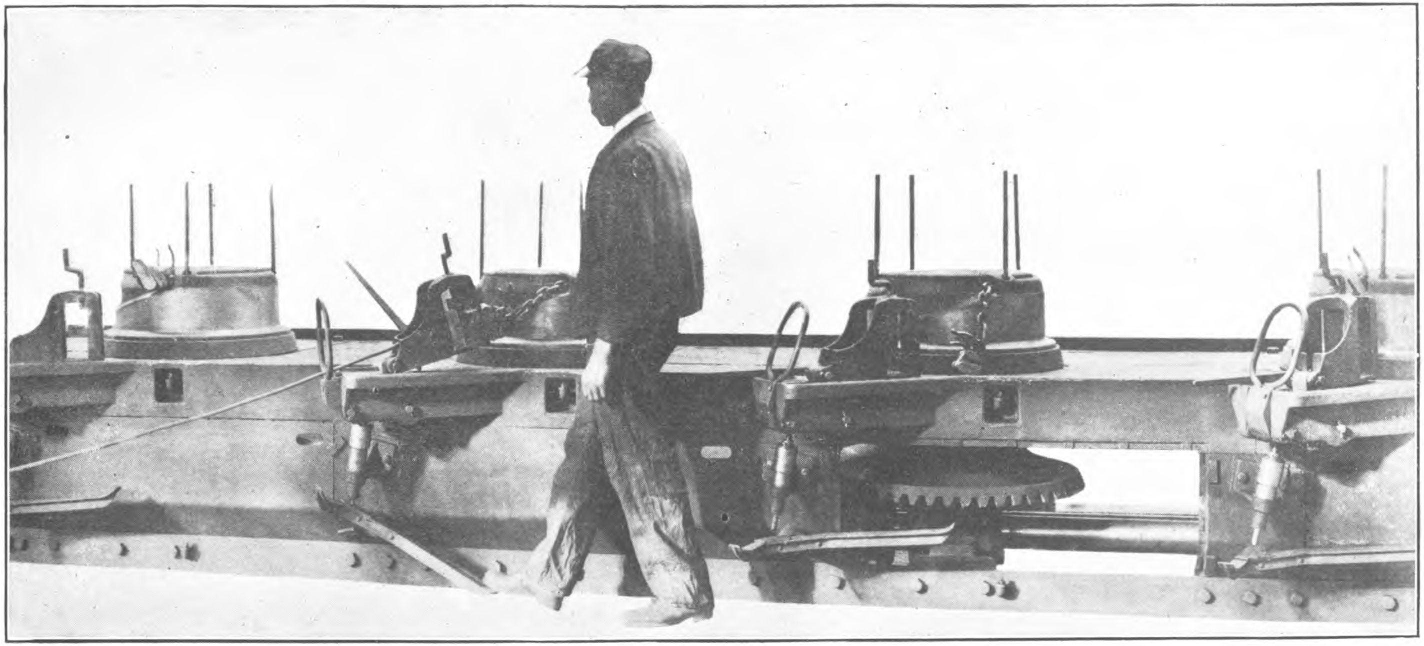

PLATE 11.—MODERN WIRE-DRAWING BENCH.

it happens very frequently that the operator is caught by hand or foot in a tangle of wire and drawn against the die box. When this occurs, the loss of the member can scarcely be avoided. Plate 11 shows a drawing bench in which the entire mechanism has been modified. The changes affect materially the efficiency of the machines, but nearly all of them have bearing upon safety. A conspicuous feature of the design is the automatic stop built as part of the machine. On each of three blocks the loop through which the wire is carried appears and upon that by which the workman stands the wire is shown in place. The clutch which operates the block is thrown in or out by a double-ended treadle. The workman is depressing the starting end. By depressing the other extremity in the same manner the block is stopped. The automatic stop operates as follows: A tangle of sufficient size to endanger the worker would pull the loop through which it passes toward the block, as seen at the right of the picture. This would act upon a plunger, seen below the loop, forcing it downward. This acts upon the stopping end of the treadle and releases the clutch. The necessary force is determined by a spring whose tension can be modified to suit conditions. The position of the stop is so convenient and its action so satisfactory that it becomes the usual means of stopping the block for ordinary purposes. Other features of the design, such as the arrangement by which the block stops automatically if the wire breaks, add to the safety of its operation, but these features are not apparent in the illustration and therefore description is not attempted.

CRANES AND HOISTS.

In the machine-building industry cranes and hoists stand third in accident frequency and fourth in severity. In the iron and steel industry they are fourth in frequency and second in severity. It is probably true that faulty methods of operation have been more responsible for this record than has faulty construction. The degree to which construction has needed modification is clearly indicated by the specifications adopted by the iron and steel electrical engineers.

The gantry crane has been responsible for a great many injuries from the fact that the track on which it moves is at the ground level. A wheel guard is now being incorporated in the design.

The chief implement of transportation in these shops is the overhead traveling crane. Its importance is so great that although its structure and operation are thoroughly known to everyone familiar with shops, it is desirable to present a brief description for the nonindustrial reader.

The use of the traveling crane has brought about a marked change in shop-building construction. Since the walls must bear the weight of the apparatus and of the loads conveyed by it they must be made sufficiently strong and also given height enough to permit the transit of materials above any obstructions which may be upon the floor. Indeed, in some erecting shops where large work is handled cranes may travel at two levels one above the other.

The elements of an ordinary traveling crane are the bridge and the trolley. The bridge consists of two girders strongly fastened parallel to each other, the size and distance apart being governed by the weights intended to be lifted and carried. At each end of the bridge are truck wheels which rest upon rails securely fastened to the walls of the building. In the case of outdoor cranes the walls of buildings are used, when convenient, otherwise special structures are provided. The truck wheels are operated by a shaft running the length of the bridge, to which is geared the bridge motor. By the action of this motor conveyed through the shaft the bridge is propelled along the rails in either direction.

The trolley (plates 12 and 13) moves from end to end of the bridge. Upon it are mounted commonly two hoisting drums, a main hoist used for weights up to the capacity of the crane, and an auxiliary hoist applied to lesser weights and frequently used in conjunction with the main hoist in the manipulation of the loads.

A moment's consideration will make it clear that this combination of movements, the translation of the entire crane through the length of the building and the transverse movement of the trolley, make it possible to reach every point upon the floor below.

The operation of the crane is accomplished from the crane cage suspended below the girders. In this cage are usually four controllers by which the craneman starts and stops and determines the amount of power applied to each of the four motors, namely, the bridge motor moving the entire crane, the trolley motor actuating the trolley transversely, the main hoist motor revolving the main drum, and the auxiliary hoist motor operating the secondary hoist.

It is desirable to present in general terms some of the dangers and their remedies. Beginning with the craneman the first essential is safe access to his crane cage. One steel company presents three pictures as illustrating the stages of their evolution in the matter of access to the cage. In the first is shown a craneman climbing a column; in the second he is seen going up a ladder; and the third shows him carrying a basket of tools up a flight of stairs with apparent ease. The elements of safety in this matter of approach are stairs, a well placed and properly railed landing platform, and a railed extension of the cage floor from which there is easy access to the landing platform. The cage should be of noninflammable construction, and the electrical devices should be so inclosed as to mini-

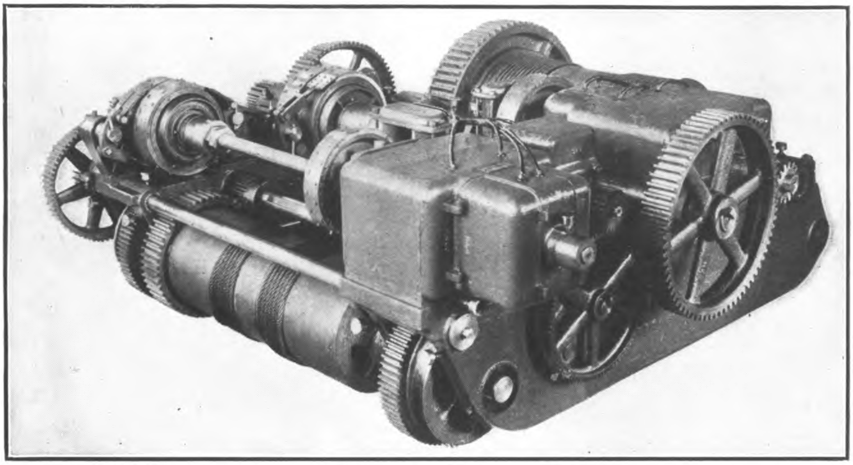

PLATE 12.—CRANE TROLLEY, UNGUARDED.

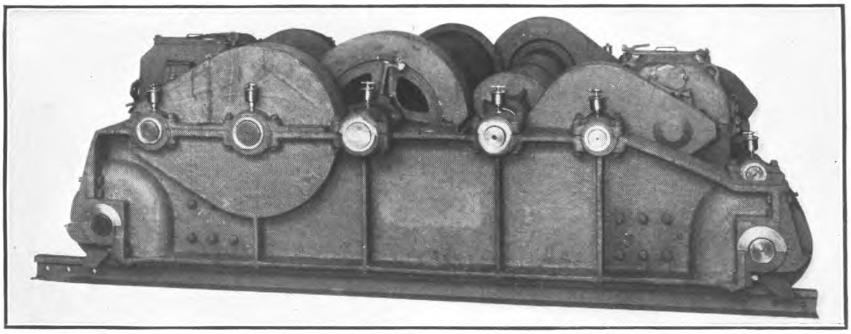

PLATE 13.—CRANE TROLLEY, GUARDED.

mize the chance of burn or shock. In cranes used for the constant transportation of large quantities of hot metal either provision should be made for the escape of the craneman to an outside gallery if necessary, or, perhaps better, a fireproof chamber should be provided into which the craneman can easily enter in case of emergency and from which he can manage his crane. Such provisions are imperative in steel mills and may properly be considered in foundries where large quantities of metal are handled.

Safety in inspection and repair should be the next consideration. In the older type of crane these essential processes could be carried out only by climbing on the girders and making way precariously to the place of work. All cranes should be provided with adequate foot walks. With some small cranes to which such walks could with difficulty be applied repair platforms should be constructed at the ends of the run. To the danger of falling during the process of repair was added in the old type crane the chance that the machine might be unexpectedly started from the crane cage. To guard against this either a lock removable only by the repairman could be used on the switch in the cage, or a special switch which could be thrown open when repairs began could be installed upon the top of the crane.

What the chances were of being caught when such starting occurred may be judged by reference to plate 12. Not only did the gears of this trolley menace the man who was working upon them but the overhung gears would from time to time break and the falling fragments have not infrequently caused fatal injury to workmen below.

Plate 13 illustrates the thorough revision which has taken place in the design of this piece of machinery. The two pictures are of machines produced by the same company at different times. The present construction not only safeguards the man who must work upon the machines, but there is nothing which can fall in case of breakage, and the inclosed gears, protected from grit and dust and running in oil baths, operate more smoothly and have a longer life.

It might seem that with these improvements in design and with high standards of quality in the materials and workmanship enforced the chief difficulties of the overhead-crane menace had been met. This, however, is far from being the case. These structural improvements ward off many serious accidents, but the larger number of those occurring are due to faulty method, to swinging loads, falling loads, to sudden or unexpected raising and lowering, and to improper management of the chains and slings by which loads are carried. One large steel company was led to make a study of the signaling system in use in their works only to find that there was no system. The same signal was being used for different operations and different signals for the same operation. The result of the inquiry was the development and introduction of a definite code which became the standard practice in all the company's mills.

Beside the cranes above described which serve large areas and move heavy weights there are many types of small hoists which have in recent years been much improved and which greatly facilitate and make safer the handling and transportation of less weighty objects.

ELECTRICAL APPARATUS.

It is somewhat difficult to decide whether the turbo-generator should be considered as an electrical machine or under the heading of engines. But in view of the fact that the manufacture of these generators is largely in the hands of electrical companies, they will be here considered.

Plates 14 and 15 present two power houses, one equipped with a reciprocating engine belted to the generator, the other having an installation of turbo-generators. It is not possible to convey by the pictures a complete impression of the contrast presented in the matter of moving parts which constitute the source of danger in power houses. In all types of turbo-generators the number of exposed moving parts is very few, and in some nothing moving can be seen. Beyond question then, the substitution of this form of prime mover for the older form with its flywheel and belt reduces power-house hazards.

The number of power-house and boiler-house accidents is comparatively small. It is easy to draw the conclusion that they are not important. Chart C, page 33, shows that in frequency of injury in relation to the number employed they stand seventh, while in severity they are third among the departments. It is clear, therefore, that the reduction of their dangers demands serious consideration.

Beside the moving parts which are dangerous there is another point in the majority of power-house installations which deserves consideration. This is the flywheel. As a moving object its hazard may be very nearly eliminated by proper fencing.

Such precautions, however, would do nothing to prevent the "racing" of the engine, which might cause the flywheel to explode. This subject clearly belongs in the section on engines, but it may be here discussed.

At times the mechanism controlling the speed of the engine becomes deranged, permitting the flywheel to revolve at a dangerous speed. The strain on the wheel may become so great that it breaks, and the flying fragments may wreck the adjacent machinery and the building. A recent case will serve to illustrate the destructive possibilities of such an event. In a rolling mill, while the attention of the engineer of one of the engines was momentarily directed elsewhere,

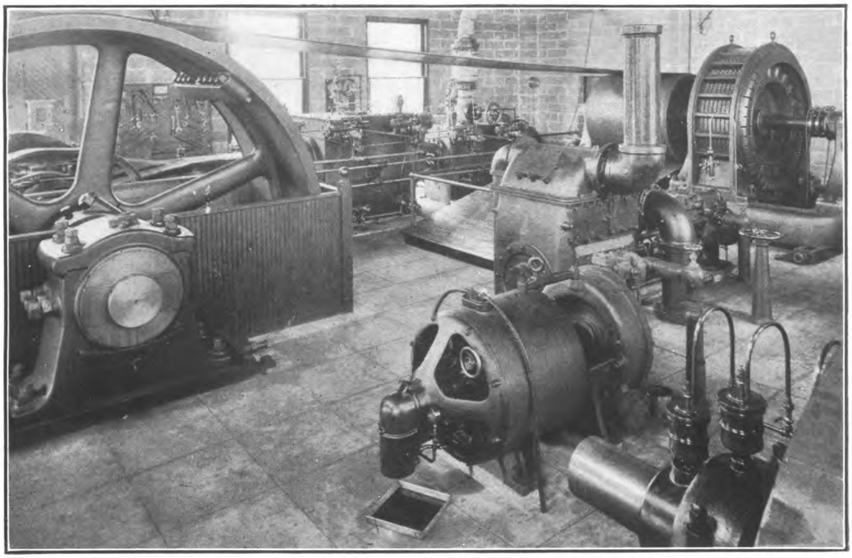

PLATE 14.—POWER HOUSE, WITH RECIPROCATING ENGINE BELTED TO GENERATOR.

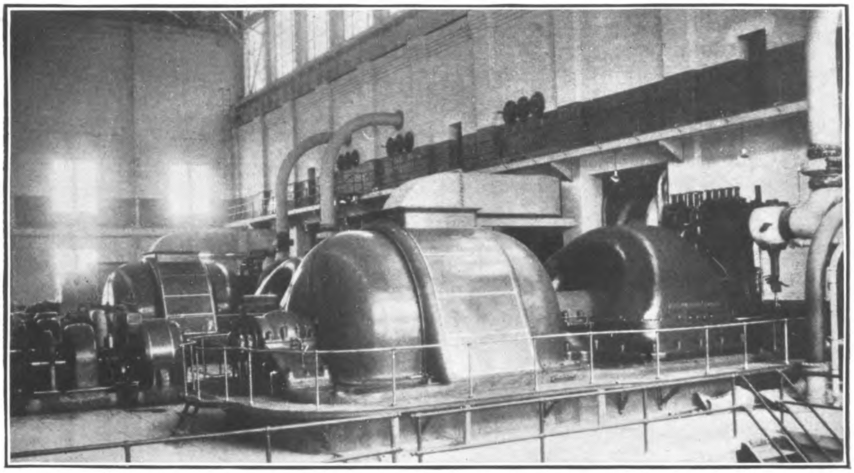

PLATE 15.—POWER HOUSE, WITH TURBO-GENERATORS.

the speed of the engine rose, and before he could apply the stop provided the wheel had exploded. The rim was broken into several pieces and the spokes of the wheel detached from the rim and also from the hub. The surrounding structures were badly shattered, but more serious than this the controlling apparatus of another engine was disabled and its flywheel also burst. A fragment of this second wheel in its flight through the mill severed the lower part of the roof trusses, allowing the roof to collapse for some 200 feet upon the wreckage below.

Manifestly, two procedures would afford some protection against such an occurrence. First, the generation of electric energy by means of a turbo-generator and its application to the rolls by means of motors. Second, the use of some effective engine stop which upon increase of speed would automatically shut off the steam and so bring the engine to rest. These stops will be further discussed at a later point.

There are serious difficulties with each of these plans for the particular mill in which the accident occurred. It is not necessary to elaborate upon these since the occurrence is described simply to give point to the assertion of this kind of danger and to emphasize the need of adequate attention.

Deep-seated flaws in the wheel are sometimes the underlying cause of explosion. Inspection is the only safeguard.

In generators and motors it is noticeable that recent patterns inclose and screen the moving parts much more perfectly than was formerly the case. In fact accidental contact with such parts is almost impossible in the cases which came under observation.

The proper installation of the wiring by which the electric current is conveyed to the machines is important both from the standpoint of fire hazard and because where open wiring is used workmen engaged in other operations may come in contact with wires upon which the insulation has become worn or otherwise imperfect. The general use of metal conduits for all machine feed wires greatly reduces these risks.

Danger to machine operators and others controlling the ultimate application of the current arises almost entirely in the manipulation of switches and controller handles. These are now usually completely inclosed.

Another element of safe operation resulting from improved electrical construction is impossible to present by illustration. Its character is indicated by a case occurring in a mill whose product is tubes. At one step of the process the tubes were conveyed by an electrically actuated transfer. Occasionally this transfer would move too far and cause the load of pipes to spill into a passageway. The solution was found in the introduction of an improved electrical equipment which could be more promptly and exactly controlled. The installation was made with no other idea than that of removing the risk incident to the operation of the original apparatus. When it was put into action it was discovered that it permitted an increased production.

LOCOMOTIVES.

From the manufacturing standpoint locomotives are essentially like other machines. Their construction involves the same operations and shop problems. Since these are necessarily on a comparatively large scale the establishments devoted to this form of construction afforded excellent opportunities for prosecuting the inquiries essential to this study.

When the locomotive is considered from the operative standpoint it seems to be in a class by itself. The engineer and fireman are exposed to comparatively few of the sort of dangers which appear in the operation of other machines. With the single exception of the valve-shifting levers, the moving parts are so placed that the engineer is not menaced thereby. His danger arises almost entirely in the peculiar purpose for which his machine is designed. In the liability to explosion of the boiler the engineer and fireman share a hazard to which others in power-house operations are exposed. The breaking of a driving rod which in its revolution destroys the side of the cab and kills the engineer might be compared with the explosion of a flywheel as heretofore described. Consideration of these elements of danger common to locomotive operation and the workings of other machines serve rather to emphasize than otherwise the essential dissimilarities.

While the dangers, which have been more or less modified by changes in design, lie in the field of transportation, and accordingly rather outside the scope of the present study, it is desirable to indicate some of them.[1]

The increase in size has produced for the engineer an increasing physical strain accompanied with some chance of physical injury in the operation of his reversing lever. The size and weight of the valves to be shifted have necessarily kept pace with the other increases in dimensions. To offset this there has been reintroduced a steam reverse. This was tried out some years ago, but the advantages under the then existing conditions did not suffice to keep it in use. A common form used at present has a small lever whose movements are precisely similar to those of the hand reversing lever. The engineer has only to set this lever in the proper position and the mechanism does the rest. This may be regarded as a change in design which both relieves the man of undue stress and contributes in some measure to his safety.

[1] The facts presented are largely drawn from a paper presented to the Franklin Institute on "Recent development of the locomotive," by Mr. Geo. R. Henderson, consulting engineer of the Baldwin Locomotive Works.

The development of mechanical stokers and the use of oil as fuel, which requires only the proper adjustment of valves, have proceeded under the impulse of the necessity to keep the firing operations within the compass of the activity of a single fireman. These changes have either improved the working conditions or prevented them from becoming so bad as to be intolerable. They have not greatly modified the liability to such accidents as were likely to happen under earlier conditions.

Some structural features recently incorporated have a bearing upon accidents due to breakdown of the machine. For example, until recently the use of what is known as the Stephenson valve movement has been almost universal in this country. This involves the use of eccentrics on the axles and the adjustment of certain working parts in the space below the boiler and between the driving wheels. The utilization of this space for this purpose rendered it impossible to brace the frames as securely as their increasing size demanded. Coincident with this need for greater strength the Walschaerts valve motion was being adopted. Since its working parts are entirely outside the frames it left clear a space for extra bracing and so provided a needed factor of safety in the development of the locomotive.

The replacement of cast iron and to a considerable extent of forgings by cast steel has contributed more than any other single item to the maintenance of a factor of safety commensurate with the increasing size. Prior to the development of the open-hearth process steel of a suitable quality for castings was obtainable only from crucible furnaces. The small quantity thus produced necessarily limited steel castings to parts of small size. Now locomotive driving wheels, frames, saddles, and other large parts are made in cast steel, with a great saving in weight and increase in strength. Further progress in this direction is likely to occur from the introduction in locomotive construction of the alloy steels which have a still higher degree of strength.

As before suggested, the dangers to workmen who operate locomotives lie in the field of transportation and their consideration would lead too far from the subject of the present study. What has been given above serves only to indicate some of the changes which have tended to keep down the accident hazard.

OTHER PRIME MOVERS.

Certain of the dangers attendant upon the operation of the common reciprocating engine have been already presented in the section on electrical apparatus and need not be further considered. Plate 14 shows the need of certain precautions in an engine room where the prime mover is of this character.

Going back a step it is pertinent at this point to consider a few of the methods adopted by manufacturers of boilers which tend to the safety of those employed about them. At the present time there is in progress an important effort to determine standards of construction suitable for general adoption. In this effort the American Society of Mechanical Engineers has had a most prominent part.

Installations for the production of industrial power have been undergoing a development similar to that, already outlined, in the case of the locomotive. The demand for increased power more economically produced has led to great increases in boiler capacity, which in turn has led to the use of stronger materials and the use of more reliable structural methods. On the whole these changes have kept pace with or gone beyond the increase in size. As a result the modern boiler room is much less likely to be the scene of a wholesale disaster from explosion than was the case some years ago, while the introduction of mechanical stokers and fuel-handling devices has appreciably reduced the danger of minor injury.

The effect of the introduction of the turbo-generator in reducing almost to the vanishing point the exposed moving parts of engines has already been sufficiently indicated.

It remains to speak briefly of the effect upon safety of the rapid development of internal combustion engines, both gas and oil. In general it may be said that such engines present fewer exposed moving parts which the attendant is required by his duties to approach than was the case with former types. There is one added hazard which experience proves must be considered. The gas used or produced in the operation of these engines is frequently noxious and has caused a number of deaths from asphyxia. It will not do to depend upon what are called natural means for preventing the accumulation of these harmful emanations. Mechanical means of ventilating and a rigorous enforcement of a rule that men shall not go alone into places where the gas may possibly accumulate are necessary. This matter has not received as much attention as it deserves.

Steam pumps have the features characteristic of prime movers and require similar safeguards.

MACHINE TOOLS.

The term "machine tools" applies to a great variety of apparatus used in the machine shop. Since the modifications in design are more conspicuous than in any other of the groups in which product has been considered it is desirable to present them in greater detail. Accordingly the forms will be briefly described, their particular hazards noted, and the methods of protection indicated.

METAL PLANERS.

A metal planer consists of a horizontal bed upon which a platform travels back and forth. The upper surface of this platform has slots and openings by which the work to be machined may be fastened securely in place. The tool or tools are carried upon an arm, or may be attached to a crosspiece supported by uprights on either side of the bed. Elaborate means are supplied for raising and lowering the tool-carrying bars and for shifting the tools laterally. The size of the castings which can be machined is limited only by the width of the platform and the height to which the tool can be raised. The application is mainly to rather heavy work which requires modification in the form of cuts in one direction.

The dangers in operating these machines are: First, one which pertains in varying degrees to all machining processes, namely, flying fragments projected from the tool. These may be thrown off with sufficient force to penetrate the flesh but more frequently are harmless except when the eye is struck; second, contact with exposed belts and gears; third, being caught by the tool when inspecting, measuring, or brushing off chips; fourth, and most serious, being caught by the moving platform or the work thereon.

The use of goggles by machine operators has already been discussed. Against the third danger no provision can be made except the care and caution of the workman. The openings in the planer bed offer a serious menace. Illustrations will best show its nature. A shop foreman was standing on the moving platform observing the progress of the work being done on the machine. As he stepped backward a nut or some other fragment upon the platform caused an unexpected disturbance of his footing and he stepped down in front of this moving platform, losing his leg. In another case the workman had some tools in the end compartment of the bed. Reaching in, his foot slipped and he fell head forward into the space and was fatally crushed. A third case happened during the shop studies made preliminary to this report and the writer had an opportunity of personal inspection. The workman in this case was entirely alone and so there is no evidence on some points. Apparently he leaned forward to take a measurement and slipped, falling in front of the casting. He was drawn against the upright and killed.

The second and third illustrative cases call attention to a hazard which undoubtedly underlies cases of accident which appear as due to other causes, namely, insecure footing. The oily floors in the vicinity of machines may probably have caused serious accidents which here appeared mysterious. The magazine "Safety Engineering" has recently been doing good service in centering attention upon this possibility. The safeguard may be in proper construction of the floor, or in the shoes worn, or both. This cause of injury deserves more serious attention than it has yet received.

BORING MILLS.

The name of these machines does not convey an exact idea of their function to those not acquainted with them. A boring mill may be described briefly but quite properly as a planer whose platform rotates instead of moving back and forth. Plate 17 shows the essential features. The tools are carried in a manner exactly similar to that adopted in the planer and the arrangements for clamping the work to the platform are the same. Whereas the planer permits extended longitudinal cuts the boring mill allows those of a circular form, the size being determined by the diameter of the platform. As originally designed the machine was intended for producing or machining out cylindrical openings in the castings, hence the name. Its function has now been so much amplified as to render this name not fully descriptive.

The most important changes are due to the application of electricity as a motive power (plates 16 and 17) and to the introduction of high-speed steels making possible deeper cuts. Both of these items have influenced the demands regarding strength and rigidity of construction.

The dangers are (1) flying fragments, (2) gearings, (3) injury when inspecting or cleaning work, (4) a possibility of falling on the platform and being bruised or crushed between work and uprights.

Inspection of the plates will show the provisions made in the later types against the danger of being caught in gears. Crushing injury is mentioned as a possibility although no case of such injury has come under observation. It is evident that such occurrences are not so likely to happen with this machine as with the planer.

Plates 16 and 17 show the rear of the machine and those modifications of the application of the motive power which make for greater safety.

It will be noticed in plate 17 that the gearing at the top of the mill is fully covered. It is sometimes urged that this is needless. There are three justifications: (1) An oiler must sometimes approach these gears when in motion; (2) where electric lamps are used about the machine at the end of long leaders these sometimes become entangled in open gears, and the machine may be seriously damaged; (3) gears so covered wear longer and run better than when not covered. In even a very clean shop there is a good deal of dust and grit in the air. The exclusion of this is a distinct advantage.

It is sometimes urged that counterweights such as appear in these plates should be arranged so that in case the chain breaks their fall

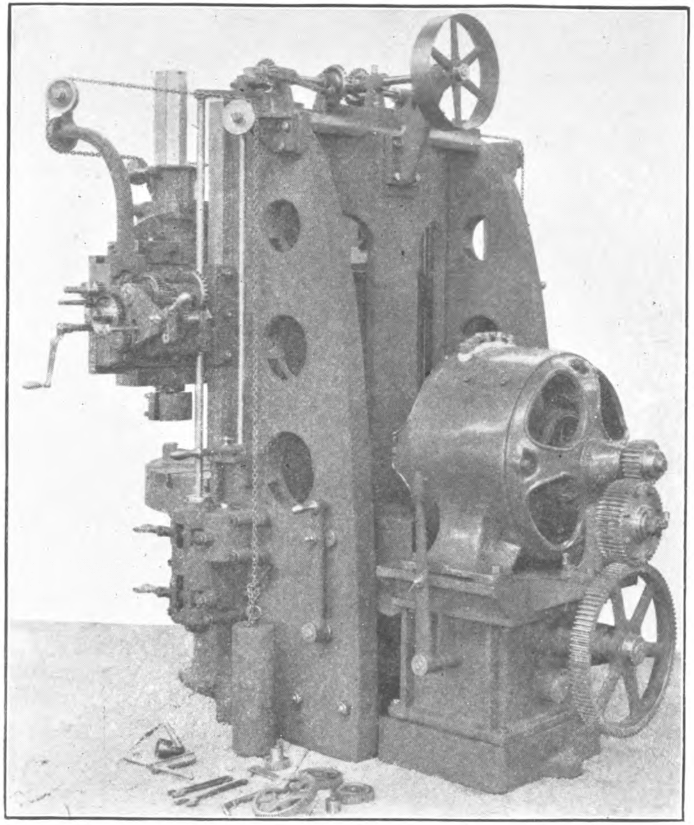

PLATE 16.—BORING MILL, WITH UNGUARDED GEARS.

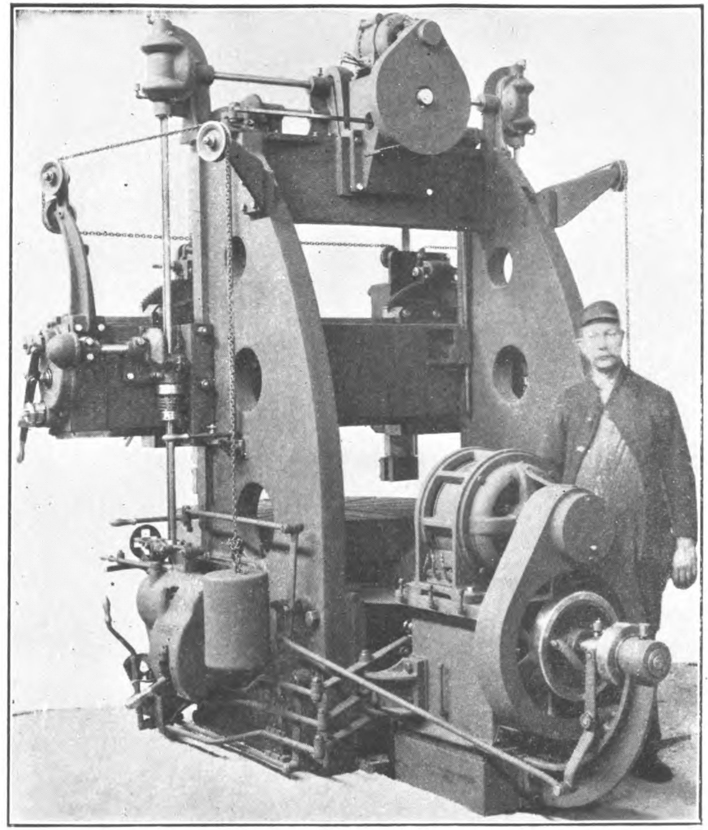

PLATE 17.—BORING MILL, WITH GUARDED GEARS.

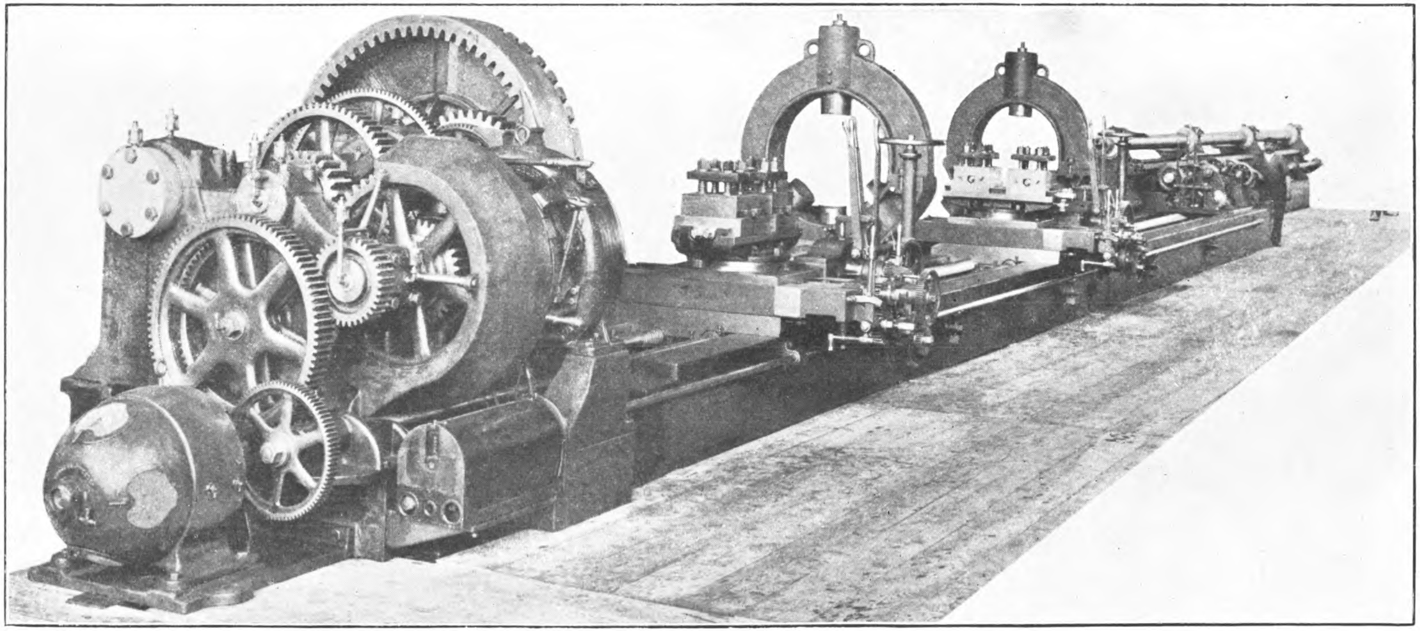

PLATE 18.—LARGE GUN LATHE, WITH UNGUARDED GEARS.

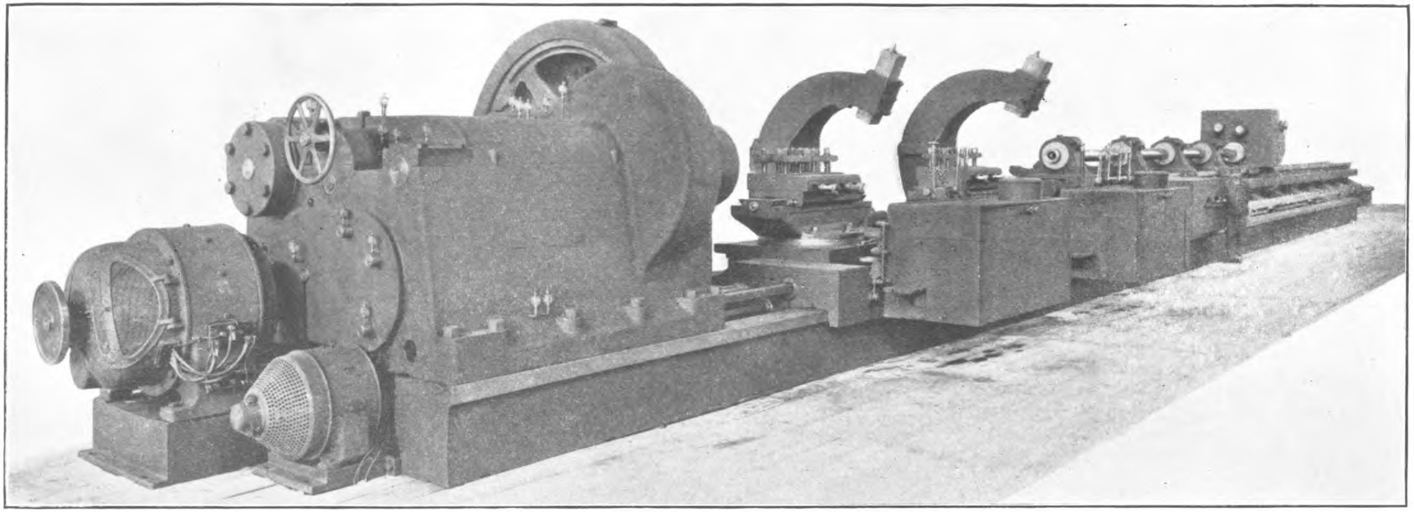

PLATE 19.—LARGE GUN LATHE, WITH GUARDED GEARS.

will not endanger the workman. Careful scrutiny of the records fails to disclose instances of such injury in the operations of tools of this kind. The case is different where the weight is very frequently shifted and a strain thus put on the chain likely to cause deterioration and final breakage. However, some cases have been observed where a pit was made below the floor and the counterweight chain extended so that the weight moved in the pit. This removed even the remote danger due to the breakage of the chain.

LATHES.

The essential elements of a lathe are the bed, the head stock, the tail stock, and the tool holder. The tail stock and tool holder are movably mounted upon the bed so that they can be adjusted to different points of its length. In general the lathe is used to produce changes in shape of cylindrical objects, such as shafts, rolls for rolling mills, and similar parts.

The head stock contains the mechanisms by which the speed of rotation is determined and the motion of the tool holder along the bed is accomplished. The tool is moved up to the work either manually by the workman or by automatic devices.

A modification of the ordinary lathe, much used where a large number of pieces of the same form are to be produced, is the turret lathe. Upon the tail stock is mounted a revolving turret bearing a number of different tools which in succession perform operations necessary to the formation of the required part. The turret is revolved by a handle operated by the workman. From this type of lathe has been evolved a number of machines which perform all the operations automatically. The hazard of their operation is so small that no attention has been given to them in this study.

For special processes suitable types of lathe have been produced. Plates 18 and 19 illustrate lathes for the turning of large harbor defense and naval guns. They were made by the same firm. Plate 19 represents a lathe now in use in the gun shop at the Washington Navy Yard.

Comment upon the differences between these pieces of apparatus is scarcely necessary. It may be pointed out, however, that plate 19 represents a more radical revision of the entire design than anything heretofore presented.

The dangers arising in the operation of lathes are those already enumerated and in addition one not hitherto encountered. With all revolving cylindrical objects there is danger that some loose portion of the workman's clothing may be caught. This is not very serious with metal-working lathes since even in the most rapid operation the rate of revolution is not high enough to be seriously dangerous. When, however, there are projections on the revolving part injuries may occur. These have been most frequent from the set screw of the dog used to hold the work in place against the stress of the tool.

Several forms of dog in which either no set screw was used or the set screw was securely covered have been developed in the shops, but apparently no lathe manufacturer had given the matter serious thought at the time when the field work for this study was in progress.

DRILLS.

A number of different forms of apparatus for carrying these tools are in use. Plates 20 and 21 present one of these in an early and one in a recent condition of development.

In the earlier form the familiar cone pulley will be noticed in a position liable to cause injury sometimes even when shifting of the belt is not occurring. The many exposed gears at various points are obvious. In the modern form delineated the application of power is by a constant speed pulley, variations in transmitted speed being accomplished by gears in the box shown. The almost complete invisibility of the various actuating gears is noteworthy.

When all these precautions have been taken there remains a source of danger scarcely possible to provide against in the drill itself. This may be illustrated by a case or two. A workman operating a horizontal drill of rather large size drew the drill back from the work to make some measurement. As he bent forward the point of the drill touched his overalls just below the hip. Instantly he was snatched from his feet and whirled around on the drill. Before the machine could be stopped by his fellows his head was repeatedly struck against the iron platform to which the work was attached, with fatal results. The foreman in charge of this work afterwards devised a drill chuck in which the drill ran free except when the drill was pressed against the resisting work. Some difficulties developed in the operation of this chuck and so far as known it has not been successfully applied in practice.

In another instance a young apprentice reached around an upright drill and was caught by the sleeve. The twist of the drill gathered in the cloth, tearing it as it did so, until his garments were entirely removed except his shoes.

Almost the only possible safeguards appear to be the wearing of close-fitting clothing, and extra care on the part of the operator. Safeguards thus far tried have either proved ineffective or have so seriously interfered with the usefulness of the machines as to be impracticable.

MILLING MACHINES.

The development of this machine has been of great importance in the recent history of shop practice. Its essential element is the toothed cutter. This may be regarded as a special form of saw

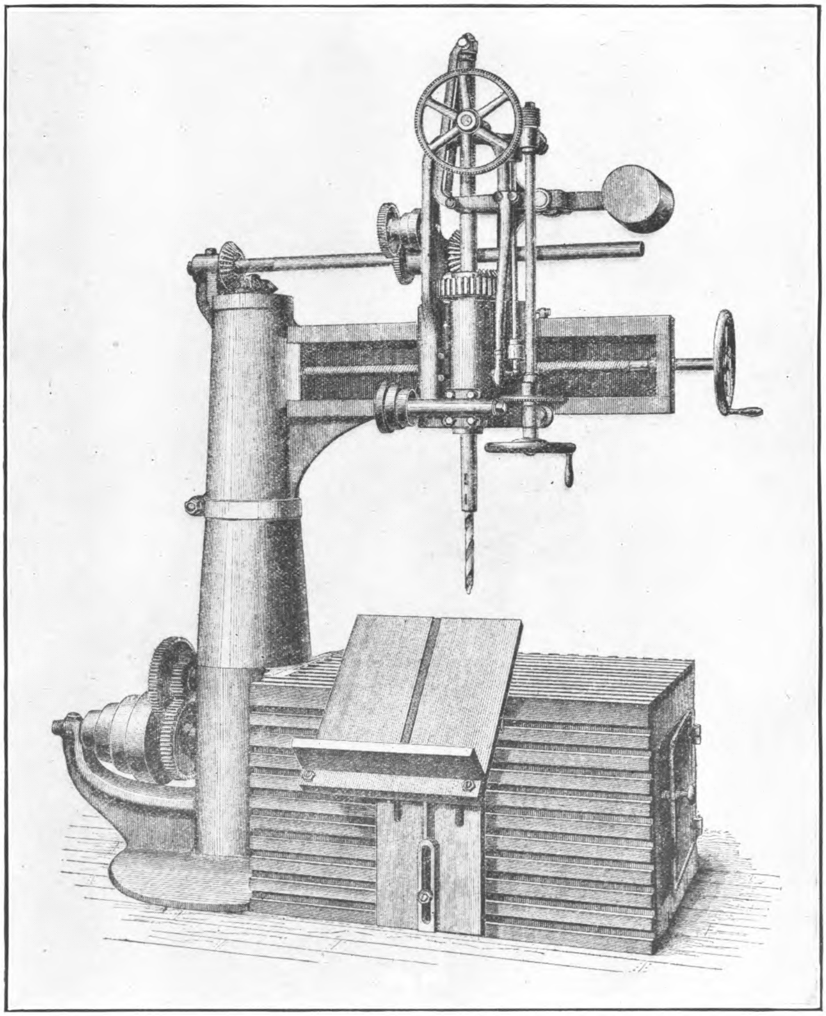

PLATE 20.—OLD TYPE OF DRILL, WITH UNGUARDED GEARS.

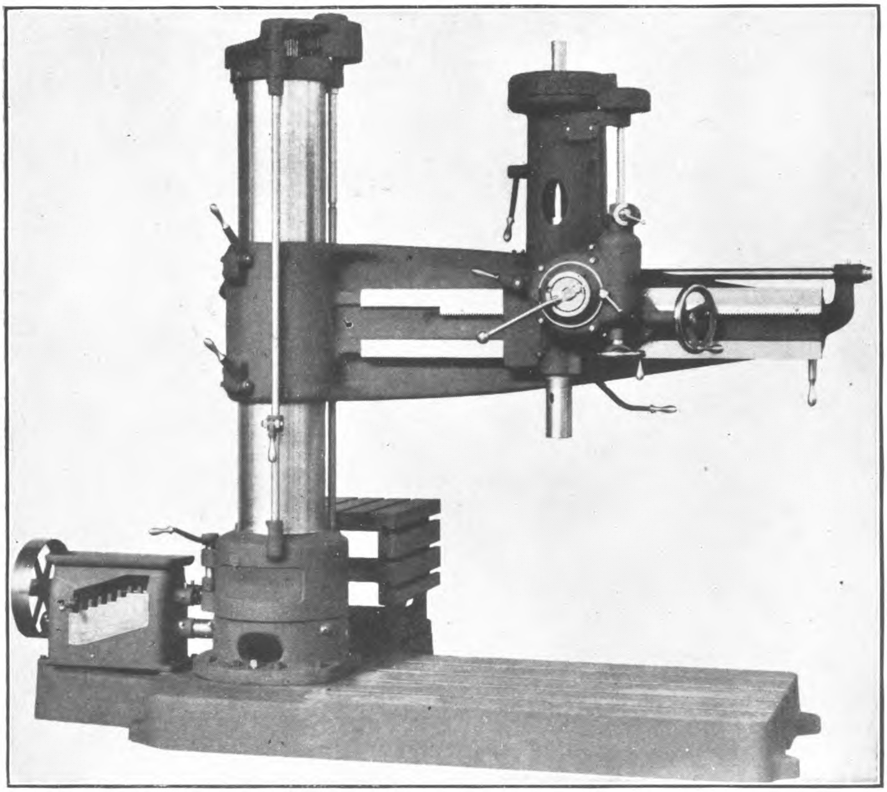

PLATE 21.—NEW TYPE OF DRILL, WITH GUARDED GEARS.

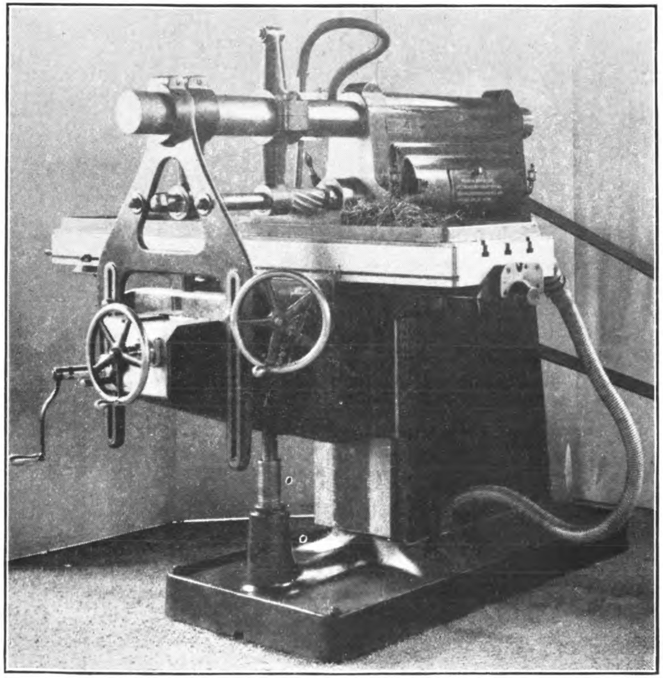

PLATE 22.—MILLING MACHINE, WITH UNGUARDED CUTTER.

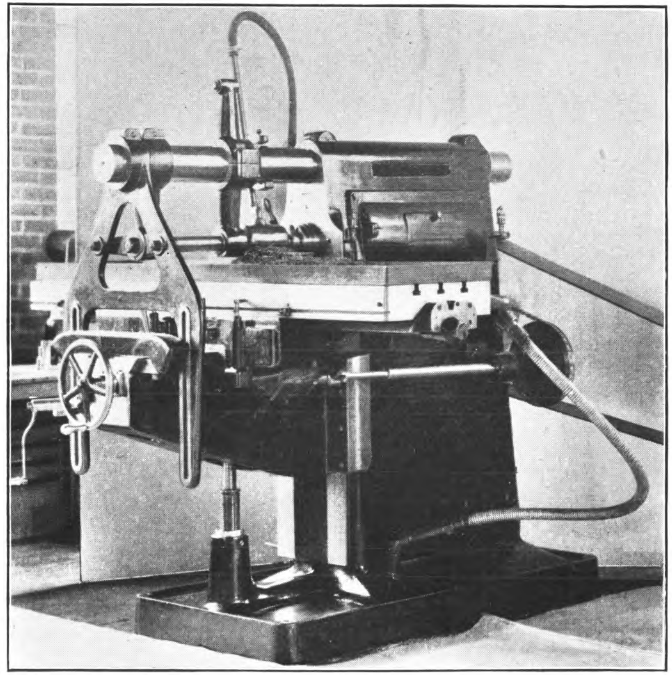

PLATE 23.—MILLING MACHINE, WITH GUARDED CUTTER.

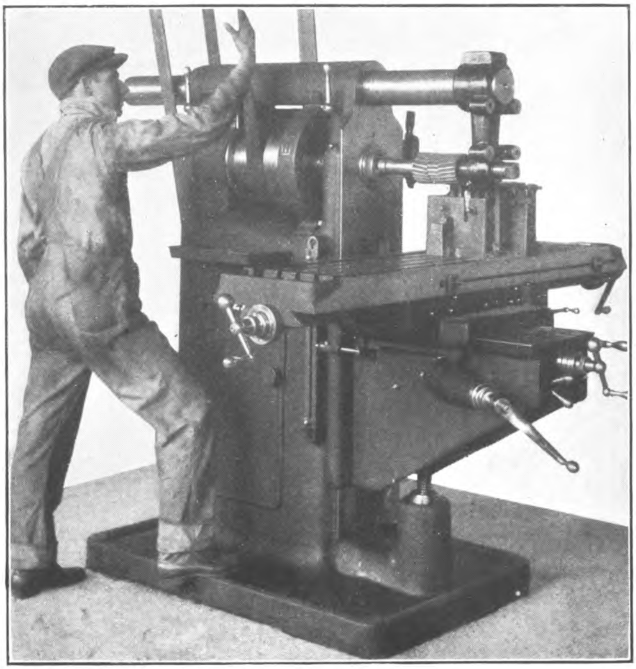

PLATE 24.—BELT SHIFTING BY HAND.

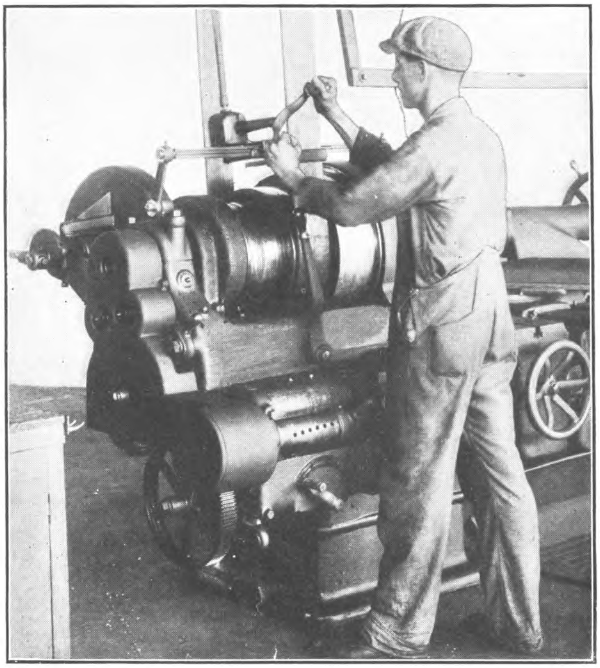

PLATE 25.—BELT SHIFTING WITH SHIFTER.

since the teeth of the revolving cutter are brought into successive relation with the work in precisely the same manner as the teeth of a saw. It is evident that the possible speed of work in cases to which the machine is adapted would be materially greater than that with the methods of reduction already described.

Plates 22 and 23 illustrate a case in which a development secured for improvement of production has in part solved a safety problem. Plate 22 shows a machine with a spiral cutter as usually operated. Plate 23 shows the same machine with a hood over the cutter, the lubricant delivered through a pipe being confined by the hood and made completely to flood the cutter. Very important advantages are secured in rapidity and smoothness of action by this method of lubrication. It will appear at once that this covering of the cutters by a hood lessens in a material degree the chances of accidental contact and injury.

MACHINE TOOL ACCESSORIES.

Loose pulleys on the driving shaft, with a fork by which the belt may be shifted from the loose to the tight pulley and reverse in starting and stopping the machine, have now been in use so long that the fact of hand adjustment is almost forgotten. Early safeguarding laws, by requiring such appliances, bear witness to the fact that machines were once operated without them.

Changes of speed by the cone pulley are still secured by the method shown in plate 24. The dangers of the operation are twofold. Any roughness on the belt will by its swift motion be liable to cause laceration of the hand, and in case of motion in certain direction the workman runs a risk of having his hand drawn between belt and pulley. He would be fortunate if the injury were confined to his hand.

Plate 25 shows a compact and simple shifter by which both upper and lower cones are cared for by rotating a handle. A careful test of this shifter on work which required somewhat frequent shifts showed a very considerable increase in output.

TRANSMISSION GEARING.

The great and rapidly increasing use of electrical distribution and application of power has already been pointed out. In spite of this development there remains an immense field in which mechanical transmission will for a long time, if not permanently, be of great importance.

In conveying power from the prime mover to the first point of application some form of belt was formerly the exclusive method. With increasing size of engines it became difficult to produce belts in proportion. This led in one direction to direct connection for the generation of electricity and in the other to the substitution of rope drive.

Such a drive requires complete housing to be safe. This instance is on record: A strand of the drive broke, the loose end wrapped around a railing, tore it from its fastenings, and, carrying it to the far end of the drive, struck a man standing there, inflicting serious injury. Since the safeguards in this case can not be made an integral part of the machine the manufacturer's duty becomes that of giving proper advice to his customer rather than that of modifying his design.

Following the distribution of power still farther, the line shaft is reached. The primary danger from this is to the oiler who must approach the swiftly revolving shaft in the prosecution of his duties. This involves danger in any case, but it is aggravated when the shaft has projecting set screws. This danger is obviated when these screws are of the safety pattern or are properly covered. A still more effective safety device is the use of self-lubricating bearings. These when properly constructed need no attention for considerable periods and any necessary attention can easily be given when the mill is not running. These self-oiling bearings can be attached not only to line shafting but to countershafts as well, and thus entirely do away with a very dangerous practice.

The secondary danger of shafting arises in connection with the belts by which power is finally brought down to the machines. If a workman is caught by such a belt it becomes of the utmost importance that he or his fellows be able promptly to stop the movement of the shaft. If to do this requires communication with the power house the stoppage will probably be useful only for the removal of the injured man. Both for safety and for economy in the use of power the subdivision of the power transmission into small units which can be independently brought to rest is of the highest importance. This control of reasonably small portions of the transmission equipment is made possible by the use of friction clutches. Arrangements, mechanical or electrical, can be installed for the operation of these at various points so that in case a man is caught some one will be able promptly to disconnect the portion of the transmission involved from the source of power.

Such clutches have been in use for a long time, but the present demand for safe operation has stimulated improvement in the apparatus and has led to a marked extension of their use.

OTHER PRODUCTS.

The divisions of mining machinery and shipbuilding need not be considered from the standpoint of machine design, this being somewhat outside the primary purpose of this study.

In conclusion, it may be said that, in every particular, American machinery has made a notable advance since the publication in 1880 of Volume XXII of the Tenth Census, which has been used in this chapter as a point of reference.

The manufacturers of machines are now ready to furnish machines safe so far as mechanical device can make them. It remains for users of machines to put into their shops only those which embody these safeguards. Unsafe machines can still be bought at some saving in price. A single accident might wipe out years of such saving.

APPENDIX A.

RESULTS OF ACCIDENTS IN 194 MACHINE-BUILDING

Departments of plants and products.	Number of 300-day workers.	Accidents resulting in—											
			Permanent injury.										
			Loss of—										
		Death.	Great toe.	1 joint of great toe.	Other toe or toes.	1 joint of other toe or toes.	Foot.	Both feet.	Leg.	Both legs.	Thumb.	1 joint of thumb.	1 joint of finger or fingers.
DEPARTMENT OF PLANT.													
Boiler shops	2,994	6	1		3		1					1	8
Electric shops	20,144	4									1	6	32
Erecting shops	11,373	6	1		1	1						1	20
Forge shops	2,776	3										1	5
Foundries (brass)	717												
Foundries (iron)	12,307	4	2		2		1				3		19
Machine shops	37,595	7			2		1				4	3	73
Maintenance	1,468												
Power	877	2											1
Woodworking	3,571	1									2	5	9
Yards	1,221	3	1						1				3
Unclassified	20,660	1	1								2	1	16
Total	115,703	37	6		8	1	3		1		12	18	186
PRODUCT.													
Machinery for the steel industry	2,692	1									2		7
Cranes and hoists	4,362	1											15
Generators and motors	35,674	5	2		1				1		3	8	42
Engines	31,229	22	4		7	1	3				4	8	50
Machine tools	24,359	3									2		47
Mining machines	3,994										1		6
Transmission	2,226												5
Ships	6,615	3											4
Unclassified	4,552	2										2	10
Total	115,703	37	6		8	1	3		1		12	18	186

APPENDIX A.

PLANTS IN 1912, BY DEPARTMENTS AND BY PRODUCTS.

Accidents resulting in— Permanent injury. Loss of First finger.	Second finger.	Third finger.	Fourth finger.	Hand.	Both hands.	Arm.	Both arms.	Eye.	Both eyes.	Other permanent injuries.	Total.	Temporary disability (loss of 1 day or over) terminating in— First week.	Second week.	Third week.	Fourth week.	Fifth week.	Sixth to thirteenth week.	Fourteenth week or later.	Duration of disability not known.	Total.	Grand total.
4	1	...	...	...	...	1	...	7	...	2	29	362	112	47	30	16	46	2	21	636	671
16	4	...	...	...	...	...	...	1	...	5	65	929	263	117	67	36	65	5	97	1,579	1,648
7	2	1	2	3	...	...	...	10	...	7	56	1,118	330	160	89	55	105	13	92	1,992	2,054
1	...	...	1	1	...	...	...	2	...	2	13	248	71	32	20	13	24	3	28	439	455
...	...	...	...	...	...	...	...	...	...	......	...	24	8	5	1	1	1	1	11	52	52
4	1	...	...	...	...	...	...	6	...	11	49	926	290	113	81	30	63	14	153	1,670	1,723
18	3	4	...	1	...	1	...	8	...	14	132	2,627	537	198	131	56	118	23	233	3,923	4,062
...	...	...	...	...	...	...	...	1	...	......	1	71	21	16	4	1	9	1	14	137	138
...	...	...	1	...	...	...	...	...	...	......	2	36	19	5	5	4	5	1	12	87	91
6	1	...	2	...	...	...	...	...	...	2	27	148	37	18	11	14	16	2	18	264	292
...	...	...	...	...	...	...	...	...	...	2	7	136	44	19	13	11	16	2	19	260	270
6	...	...	...	...	...	...	...	1	...	3	30	1,025	316	139	60	35	72	14	499	2,160	2,191
62	12	5	6	5	...	2	...	36	...	48	411	7,680	2,048	869	512	272	540	81	1,197	13,199	13,647
4	1	...	...	...	...	1	...	...	...	1	16	271	83	22	10	6	15	3	28	438	455
...	...	...	...	...	...	...	...	...	...	......	15	498	82	37	19	4	21	4	148	813	829
24	4	1	1	...	...	...	...	4	...	9	100	1,983	624	259	137	86	154	19	193	3,455	3,560
15	5	4	5	5	...	1	...	22	...	26	160	2,597	657	258	195	103	208	29	301	4,348	4,530
13	1	...	...	...	...	...	...	2	...	3	68	1,037	196	84	61	19	35	8	46	1,486	1,557
3	...	...	...	...	...	...	...	...	...	2	12	456	137	85	30	13	27	7	......	755	767
1	...	...	...	...	...	...	...	3	...	......	9	112	32	11	6	6	9	6	4	186	195
2	...	...	...	...	...	...	...	5	...	4	15	596	209	94	48	30	62	3	380	1,422	1,440
...	1	...	...	...	...	...	...	...	...	3	16	130	28	19	6	5	9	2	97	296	314
62	12	5	6	5	...	2	...	36	...	48	411	7,680	2,048	869	512	272	540	81	1,197	13,199	13,647

APPENDIX B.

RESULTS OF ACCIDENTS IN A MACHINE-BUILDING

Occupations.	Number of 300-day workers.	Accidents resulting in—											
			Permanent injury.										
			Loss of—										
		Death.	Great toe.	1 joint of great toe.	Other toe or toes.	1 joint of other toe or toes.	Foot.	Both feet.	Leg.	Both legs.	Thumb.	1 joint of thumb.	1 joint of finger or fingers.
PRODUCTIVE.													
Bench and vise hands	2,937	...	...	...	...	...	...	...	...	...	...	1	1
Blacksmiths and helpers	4,350	2	1	1	2	...	...	...	...	...	3	1	4
Boiler makers and helpers	2,413	1	...	...	...	...	...	...	...	...	...	1	3
Calkers and chippers	1,769	1	...	...	...	...	...	...	...	...	...	1	1
Drillers and helpers	3,269	1	...	...	...	...	...	...	...	...	1	1	11
Erectors and helpers	2,360	2	1	...	...	1	2	...	...	...	1	2	4
Machinists and helpers	18,534	5	1	...	1	...	1	...	...	...	2	3	22
Machine hands	1,290	1	...	...	...	...	1	...	...	...	...	1	1
Reamers, riveters, and helpers	2,734	3	1	1	...	...	...	...	1	...	1	1	5
Sheet-iron workers	1,946	...	...	...	...	...	...	...	...	...	...	...	...
Occupations with less than 1,000 exposures	7,035	3	1	...	1	...	...	...	1	...	1	1	7
Total	48,637	19	5	2	4	1	4	...	2	...	9	13	59
NONPRODUCTIVE.													
Carpenters	1,074	...	...	...	...	...	...	...	...	...	1	2	5
Core makers	920	...	...	...	...	...	...	...	...	...	...	...	...
Cranemen	1,011	3	...	...	...	...	...	...	...	...	1	1	...
Laborers	10,035	14	3	...	2	2	5	...	2	...	1	7	24
Pattern makers	1,246	1	...	...	...	...	...	...	...	...	3	3	4
Occupations with less than 1,000 exposures	2,377	6	1	...	...	...	...	...	1	...	1	2	4
Unclassified	7,236	13	2	...	...	...	...	...	1	...	...	3	5
Total	16,663	24	4	...	2	2	5	...	3	...	7	15	37
Grand total	72,536	56	11	2	6	3	9	...	6	...	16	31	101

APPENDIX B.

PLANT 1907 TO 1913, BY OCCUPATIONS.

Accidents resulting in— Permanent injury. Loss of— First finger.	Second finger.	Third finger.	Fourth finger.	Hand.	Both hands.	Arm.	Both arms.	Eye.	Both eyes.	Other permanent injuries.	Total.	Temporary disability (loss of 1 day or over) terminating in— First week.	Second week.	Third week.	Fourth week.	Fifth week.	Sixth to thirteenth week.	Fourteenth week or later.	Duration of disability not known.	Total.	Grand total.
...	...	...	...	...	...	...	...	2	...	......	4	109	18	13	3	4	2	1	24	174	178
2	...	...	2	3	...	...	...	...	...	......	19	187	36	22	17	10	10	.....	36	318	339
1	1	...	2	...	...	...	...	3	...	1	12	354	75	42	24	16	18	.....	78	607	620
...	1	...	...	...	...	2	...	3	...	1	9	214	39	11	2	1	8	1	35	311	321
1	4	...	1	...	...	1	...	...	...	2	22	268	44	22	17	5	11	.....	62	429	452
3	3	1	1	1	...	...	...	5	...	1	26	256	30	21	12	4	15	1	69	408	436
11	5	4	2	2	...	1	...	7	...	3	65	816	147	54	43	21	24	.....	196	1,301	1,371
1	...	...	...	...	...	...	...	3	...	1	8	136	21	7	5	3	3	.....	50	225	234
2	...	...	1	...	...	...	...	2	...	3	18	291	63	22	21	16	10	.....	67	490	511
...	1	...	...	1	...	...	...	...	...	......	2	32	6	2	1	1	2	.....	2	46	48
...	...	...	1	...	...	1	...	...	...	1	15	165	49	18	15	7	17	.....	63	334	352
21	15	5	10	7	...	5	...	25	...	13	200	2,828	528	234	160	88	120	3	682	4,643	4,862
3	3	...	1	...	...	...	...	1	...	1	17	45	15	5	2	6	4	.....	20	97	114
...	...	...	...	...	...	...	...	...	...	......	....	7	2	.....	1	1	.....	.....	1	12	12
1	...	...	...	...	...	...	...	...	...	......	3	34	3	5	1	1	4	.....	7	55	61
4	7	4	5	...	...	1	...	3	...	3	73	715	136	76	20	25	43	3	260	1,278	1,365
3	2	...	2	2	...	...	...	...	...	1	20	18	5	·1	1	1	.....	.....	2	28	49
2	1	1	...	...	...	...	...	...	...	......	13	159	39	14	6	7	10	2	54	291	310
3	...	...	...	...	...	...	...	2	...	......	16	147	27	16	12	4	10	2	74	292	321
13	13	5	8	2	...	1	...	4	...	5	126	978	200	101	31	41	61	5	344	1,761	1,911
37	28	10	18	9	...	6	...	31	...	18	342	3,953	755	351	203	133	191	10	1,100	6,696	7,094

APPENDIX C.

NUMBER OF 300-DAY WORKERS AND OF ACCIDENTS COVERED, BY VARIOUS GROUPS.

DEPARTMENTS OF MACHINE-BUILDING INDUSTRY.

Groups.	Number of 300-day workers.	Number of cases.			
		Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
Boiler shops	2,994	6	29	636	671
Yards	1,221	3	7	260	270
Erecting shops	11,373	6	56	1,992	2,054
Forge shops	2,776	3	13	439	455
Foundries (iron)	12,307	4	49	1,670	1,723
Machine shops	37,595	7	132	3,923	4,062
Power	877	2	2	87	91
Maintenance	1,468		1	137	138
Woodworking	3,571	1	27	264	292
Electric shops	20,144	4	65	1,579	1,648
Foundries (brass)	717			52	52
Unclassified	20,660	1	30	2,160	2,191
Total	115,703	37	411	13,199	13,647

OCCUPATIONS IN A MACHINE-BUILDING PLANT.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
PRODUCTIVE.					
Bench and vise hands	2,937		4	174	178
Blacksmiths and helpers	4,350	2	19	318	339
Boiler makers and helpers	2,413	1	12	607	620
Calkers and chippers	1,769	1	9	311	321
Drillers and helpers	3,269	1	22	429	452
Erectors and helpers	2,360	2	26	408	436
Machinists and helpers	18,534	5	65	1,301	1,371
Machine hands	1,290	1	8	225	234
Reamers, riveters, and helpers	2,734	3	18	490	511
Sheet-iron workers	1,946		2	46	48
Other occupations	7,035	3	15	334	352
Total	48,637	19	200	4,643	4,862
NONPRODUCTIVE.					
Carpenters	1,074		17	97	114
Core makers	920			12	12
Cranemen	1,011	3	3	55	61
Laborers	10,035	14	73	1,278	1,365
Pattern makers	1,246	1	20	28	49
Other occupations	9,613	19	29	583	631
Total	23,899	37	142	2,053	2,232
Grand total	72,536	56	342	6,696	7,094

SAFETY ORGANIZATION.[1]

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
ELECTRICAL APPARATUS.					
Class A	23,012	2	55	1,441	1,498
Class B	9,538	2	32	1,735	1,769
Unclassified	3,124	1	13	279	293
LOCOMOTIVES, ENGINES, ETC.					
Class A	4,971		17	577	594
Class B	19,355	19	112	2,610	2,741
Unclassified	31,229	22	160	4,348	4,530
MACHINE TOOLS.					
Class A	6,769		8	277	285
Class B	1,955		6	235	241
Unclassified	15,635	3	54	974	1,031

[1] For description of classes see p. 43.

APPENDIX C—Continued.

NUMBER OF 300-DAY WORKERS AND OF ACCIDENTS COVERED, BY VARIOUS GROUPS—Concluded.

NATIVITY OF WORKERS IN A MACHINE-BUILDING PLANT.

Groups.	Number of 300-day workers.	Number of cases.			
		Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
American born	22,556	11	35	1,320	1,366
Foreign born	18,039	16	82	1,737	1,835
Total	40,595	27	117	3,057	3,201

NUMBER OF 300-DAY WORKERS AND OF ACCIDENTS COVERED, BY YEARS.

GOVERNMENT SHOPS COMPARED WITH PRIVATE SHOPS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
GOVERNMENT SHOPS.					
Arsenals:					
1912	3,992	1	10	[1]192	203
1913	3,950	3	13	[1]190	206
1914	4,612	1	14	[1]226	241
Total	12,554	5	37	[1]608	650
Navy yards:					
1912	15,608	19	25	[1]1,063	1,107
1913	15,226	14	32	[1]1,181	1,227
1914	15,094	12	32	[1]1,058	1,102
Total	45,928	45	89	[1]3,302	3,436
PRIVATE SHOPS.					
Machine building:					
1912	115,703	37	411	3,279	3,727
Shipbuilding:					
1912	6,615	3	15	635	653

FIVE MACHINE-BUILDING PLANTS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
1907	22,023	17	124	1,668	1,809
1908	8,261		27	297	324
1909	11,303	4	41	668	713
1910	18,729	9	80	1,553	1,642
1911	16,481	20	53	1,256	1,329
1912	17,233	12	81	1,651	1,744
Total	94,030	62	406	7,093	7,561

FOUR MACHINE-BUILDING PLANTS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
1910	28,584	11	122	2,072	2,205
1911	25,997	17	91	1,777	1,885
1912	28,042	13	110	2,415	2,538
1913	32,101	5	97	2,671	2,773
Total	114,724	46	420	8,935	9,401

[1] Temporary disability, over 2 weeks.

APPENDIX C—Concluded.

NUMBER OF 300-DAY WORKERS AND OF ACCIDENTS COVERED, BY YEARS—Concluded.

ELECTRICAL ASSEMBLY SHOPS.

Groups.	Number of 300-day workers.	Number of cases. Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
GROUP A (2 SHOPS).					
1910	7,109	1	28	358	387
1911	6,636		23	299	322
1912	7,688	1	28	462	491
Total	21,433	2	79	1,119	1,200
GROUP B (3 SHOPS).					
1912	18,219	3	56	1,360	1,419
1913	19,033	2	69	1,529	1,600
Total	37,252	5	125	2,889	3,019

FORGE SHOPS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
1912	1,255	2	6	145	153
1913	1,359	1	7	128	136
Total	2,614	3	13	273	289

IRON FOUNDRIES.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
GROUP A (4 PLANTS).					
1907	2,222	1	13	118	132
1908	993			31	31
1909	1,363		5	52	57
1910	2,010		5	118	123
1911	1,709	5	2	97	104
1912	1,826		4	134	138
Total	10,123	6	29	550	585
GROUP B (5 PLANTS).					
1912	3,542	1	5	225	231
1913	3,427	2	12	378	392
Total	6,969	3	17	603	623

MACHINE SHOPS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
GROUP A (5 SHOPS).					
1907	7,817	1	48	660	709
1908	3,520		9	96	105
1909	4,747		15	256	271
1910	6,688	1	28	624	653
1911	6,303	1	21	449	471
1912	6,647	1	20	543	564
Total	35,722	4	141	2,628	2,773
GROUP B (8 SHOPS).					
1912	9,676	2	38	1,048	1,088
1913	10,472	3	27	1,230	1,260
Total	20,148	5	65	2,278	2,348

WOODWORKING SHOPS.

Groups.	Number of 300-day workers.	Death.	Permanent disability.	Temporary disability (1 day or over).	Total.
1912	1,442		14	90	104
1913	1,561		9	111	120
Total	3,003		23	201	224

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