MAINTAINING HUMAN EFFICIENCY IN INDUSTRY

THESIS FOR DEGREE OF M. E.

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THESIS

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Factory population

MAINTAINING HUMAN EFFICIENCY IN INDUSTRY.

A Treatise on the Engineering Phase of the Problem.

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THESIS

I. INTRODUCTION.

The basic element of productive industry is man. Considered from either the humanitarian or the economic standpoint the conclusion is inevitably the same. Supplementing the other elements by his power to exercise direction and control over them he constitutes the medium through which their latent possibilities are called into actual service. The most modern equipment and buildings and the best developed processes and schedules are but useless in the absence of the mental and physical faculties of man.

Yet, through the existence, within industrial plants, of working conditions which are inimical to the welfare of this most important element of production, an enormous waste of man power is constantly being registered. Large scale production with its general complexity arising from its multiplicity of occupations, each dependent upon the others, places on industry a great economic penalty for the existence of conditions which disable its workers and consequently require the substitution of others in their stead. The provisions of State and Federal laws relative to working conditions, the cost of "Labor Turnover" and the losses in production through absenteeism are the media through which this penalty is exacted. The solution of the problem of human waste in industry is, therefore, one of

prevention rather than of substitution or rehabilitation.

This is essentially an Engineering problem. Little permanent progress can be expected from those who seek to shift the responsibility for human conservation upon the workmen, themselves, by assigning such abstract terms as carelessness and disobedience as the major causes of waste. It must be admitted that these abstractions are not causes at all but are rather merely contributing factors which in certain cases prepare the way for the concrete cause, adverse working conditions, to act. The standardization of the choices of men in a field of broad selection is, to a large degree, a thing of proven impossibility. Likewise, to attempt to promote the cause of human conservation without limiting the choice of the workers in their possibilities of injurious action is but to deal with the superficial elements of the problem. The incorporation of the essentials of human waste prevention into the design, layout, construction and maintenance of factory buildings and equipment and into the development of processes, methods and schedules of operation is the logical method of attack for permanent results.

Underlying the incorporation of the essentials of human waste prevention into the operation of industry are certain fundamental principles. To determine these and set

them forth as the basic science of human conservation is the purpose of this treatise. With these general principles established, the Engineer may, through their application to specific industries or plants, interpret them in terms of the processes involved as a guide to the correction of existing adverse conditions or to their elimination in the planning of new processes or equipment. Recognizing the fundamental importance of introducing this phase of industrial activity into Engineering education, it is hoped that this treatise may prove of value in that regard.

II.THE PROBLEM.

With the general scope and purpose of this treatise defined the problem may be examined to determine the conditions with which its solution must deal. The basic requirement of industrial efficiency is a proper balance between the various elements of production. The maintenance of human efficiency in industry is, consequently, a problem of conserving such a degree of proper balance between man power and the other production elements, such as equipment, materials and processes, as is provided in the initial selection and subsequent development of the working force. It is, therefore, a problem of maintaining, by proper adjustment of working conditions, every advantage to production gained in such selection and development.

To maintain an established relation between man and the other elements of production, his physical and mental faculties must be conserved at the highest point of established development. In other words, these two human faculties must be maintained at the established balance. When either of these faculties become impaired there results a degree of incapacitation for work and the productive capacity of the disabled worker's operation is reduced. It will be readily recognized, without entering into medical discussion, that any of three general conditions may produce such incapacitation,

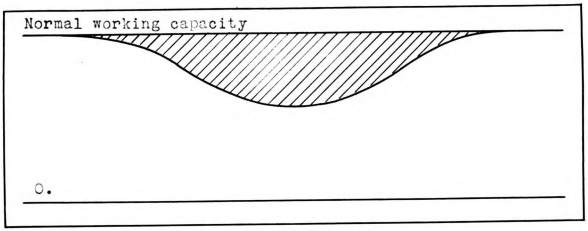

CHART # 1.
TEMPORARY PARTIAL DISABILITY CURVE.
Shaded area indicates reduction in operating capacity.

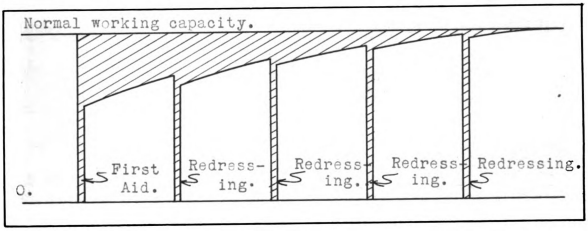

CHART # 2.
TEMPORARY PARTIAL DISABILITY FROM MINOR INJURY.

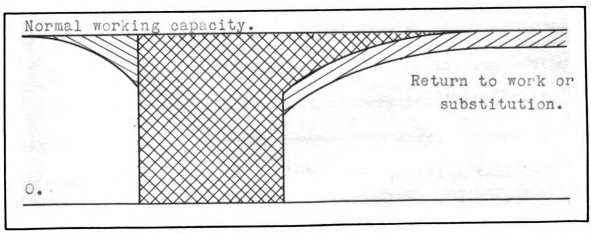

CHART # 3.
TOTAL DISABILITY CHART.
Lower right hand curve shows permanent partial recovery or unsuccessful substitution.

viz; ill health ranging from the most minor temporary indisposition to the most severe sickness; mental or physical fatigue resulting from failure to periodically recover completely from the fatigue of the previous period's labor; and physical injuries ranging, in severity, from minor scratches and bruises which require only first aid attention, to fatalities.

The exact effects of these mental and physical conditions upon industrial efficiency depend very much upon the nature and degree of disability, the manner of its development and the process of recovery or in the event of necessary substitution, the intervening period and the success with which the selection of a substitute is made. Four general terms which are used to define degrees of incapacitation will be of value in illustrating these effects, viz; partial, total, temporary and permanent. In any severe case a succession of two or more of these conditions usually exist as, for example, a partial incapacitation followed by a condition of temporary total disability and later by a permanently partial recovery. The accompanying charts will show graphically, in a relative way, the nature of the losses from incapacitation of industrial workers.

Chart # 1 illustrates temporary partial disability,

from sickness or fatigue, with the gradual development of the incapacitation with the attendant lowering of production until the point of lowest capacity is reached after a gradual resumption of normal working capacity takes place. The worker's condition does not require his absence from work. The shaded area of the chart shows the total loss in production when, in plotting the curve, abscissae represent time and ordinates show working capacity.

Chart #2 illustrates the effect, upon the worker's output, of a minor injury requiring first aid attention with subsequent redressings. During each visit to the first aid station his operation stands idle. Upon returning to his job inconvenience and timidity retard his production to some extent, which condition recurs in a decreasing degree with each redressing until normal conditions are restored. Except upon careful analysis the extent of the losses from minor injuries is little appreciated.

Chart #3 illustrates total disability of either gradual development as shown by the light shaded area or instantaneous occurrence as indicated by the vertical line. Idleness of the disabled worker's operation ensues until recovery permits his return to work or a substitute

is placed on the job. In either event normal operation is not immediately resumed but is gradually approached until the returned worker again develops his normal strength and dexterity or the substitute attains the capacity of his predecessor, if possible. If complete recovery of the disabled worker is impossible or if a substitute cannot develop the normal output of the operator whom he displaces a new normal capacity for the operation will be established, a permanent loss in production being sustained.

Though no definite values are assigned to the losses indicated in a relative manner by these charts owing to the varied nature of the conditions that determine them in individual plants it requires but little reflection to appreciate to what proportions these losses may extend when an entire working force is considered. It is not difficult to appreciate the effect of an epidemic or a calamity upon industry but it should be realized that very much the same effect may be distributed over a period of time through the human waste that is developed in ordinary plant operation and that such distribution makes the losses no less important.

The working capacity of each individual bears a distinct influence upon that of his fellow workers through the interdependence of the various operations in

-a given department or plant. Idle operations and inefficiently performed tasks destroy the normal balance of the initial layout of processes and jobs. This is an item which is not reflected in the charts although it constitutes a very appreciable portion of the total losses in production from the incapacitation of industrial workers.

For purposes of more ready analysis the problem of preventing this human waste may be separated into three major divisions corresponding to the three general conditions previously mentioned as causes of incapacitation for work. They are as follows:-

1. Prevention of the development and spread of disease due to improper working conditions;

2. Elimination of unnecessary fatigue in work;

3. Prevention of physical injury in the course of the worker's occupation.

For brevity these are commonly called Sanitation, Fatigue Reduction and Accident Prevention. Though they are distinct divisions of the subject they have an effective relation and bearing upon each other. Disease increases susceptibility to fatigue while fatigue lowers the resistance to disease and both make the worker an easier victim of existing accident hazards. This relation will be further emphasized by the duplucation, among the separate

divisions, in the fundamental principles that will be developed in making analysis. Conforming to this existing relation the entire problem may be singly stated, in outline, as follows:-

"To obtain the maximum production of the goods required by society with the minimum sacrifice and waste of human life, limb and working ability through the promotion of sanitary working conditions and practices, conservation of the strength of the worker by reducing to a minimum the necessary demands upon it and elimination of accident hazards from plant operation."

III. INDUSTRIAL SANITATION.

The medical profession tell us that the development of disease requires the introduction into the human body of more of the germs of that disease than the resisting powers of the body are capable of successfully counteracting. The prevention of the development and the spread of disease is then a problem of the two distinct phases, viz; maintaining the resistance of the human body at its maximum and minimizing the communication of disease germs from one body to another. Our interest, in this treatise, centers in the relation which the regulation of working conditions in industrial plants bears to this problem. The fundamental principle of industrial sanitation may be expressed as follows:-

Maximum reduction of the deteriorating influence of disease upon the working efficiency of the human element of industry requires the maintenance of the maximum excess in the resisting power of the workers' bodies to the attacks of disease germs over the power of these germs for injurious attack in such quantities as they gain admission to these bodies.

It must, of course, be recognized that, to a very appreciable degree, the accomplishment of this purpose depends upon influences wholly without the influence of

plant conditions. It must also be granted that physical examinations and medical attentions by plant medical departments also play important parts in conserving the health of the workers. The discussion of neither of these falls within the scope of this treatise. There is, however, a distinct Engineering phase to industrial sanitation, the essential elements of which it is intended to develop in this section to be discussed more particularly in a later part of this treatise in conjunction with the corresponding essentials of Fatigue Reduction and Accident Prevention.

1. Fatigue.

While this subject is treated at some length in a succeeding section the relation of fatigue to disease development should receive brief mention here. Through its demands upon the reserve powers of the body excessive or abnormal fatigue lowers the physical resistance and, consequently, makes the worker more susceptible to the attacks of disease. When the cumulative effects of continued fatigue are considered the real dangers of ungoverned or undirected freedom of the workers in exercising their own choices in the matter of labor is very manifest. In view of the subsequent discussion of this subject little need be said here concerning it except to state the principle

that the reserve strength of the workers should be maintained at its maximum.

2. Accomodating Physical Needs.

Promptness in accomodating the physical requirements as they arise during working hours is fundamental to maximum resistance to the attacks of disease germs. The satisfaction of thirst and the discharge of excreta from the body are normal and necessary functions of the human life the regularity of which is not so well defined as that of eating and cannot be safely made to conform to a fixed schedule such as is accomplished in the latter case through the medium of the regular lunch and rest period at the noon hour. Neglect of these physical needs adds to the discomfort of labor and impedes the natural means of discharging injurious wastes from the body. Proper means for the accomodation of these requirements should, therefore, be so located within the plant or distributed through it and so maintained that promptness in their satisfaction will be encouraged by maximum practical convenience.

3. Washing and Clothing Adjustment.

In many occupations the same clothing cannot, from a health standpoint, be worn both inside and outside the plant, changes being advisable, if not absolutely necessary, upon entering and leaving. Temperature and

humidity of atmosphere, splashing of oils, compounds, chemicals or water and other occupational characteristics governed by specific productive processes control clothing requirements. The degree to which the requirements of health in clothing adjustment are observed by workers will depend very largely upon the conveniences which are provided for changing and storing clothing as well as for washing the accumulated grease and dirt from the face, arms and hands and, in some cases, from the entire body. Through convenience, relative privacy and security against loss or theft, adjustment of clothing to the separate requirements inside and outside the plant and the removal of dirt and grease from the workers' bodies should be strongly encouraged by the facilities provided.

4. Contact.

Certain diseases are communicated by separate contact of persons with objects of common use, such as water closet seats, wash bowls and drinking facilities, the germs discharged from one body finding their way directly into another through the same members. Because of the extreme degree to which the element of common contact is involved in them the roller towel and the drinking cup have become practically obsolete in modern

factories, the individual towel dispensing devices and the drinking fountain taking their places. In the design or selection of sanitary equipment and the inauguration of sanitary practices, the reduction of this item of common contact should be made a governing factor.

5. Order and Cleanliness.

Germs of many diseases readily find their way into accumulations of filth, dirt or refuse where they find conditions very favorable to rapid multiplication. Upon agitation of these materials, as in sweeping or shoveling, these germs are scattered into the air. When this germ laden air is breathed into the bodies of the workers great numbers of disease germs gain admittance. It is through this means that the common practice of spitting into piles of dirt and refuse, into corners and upon factory floors, becomes so marked a menace to public health.

The respect which workmen hold for their working places is governed very largely by the appeal which the working environment (conditions which are almost wholly up to the employer to govern) makes to their sense of order and cleanliness. Dirty floors and walls, with disorderly arrangement of equipment and materials and with accumulations of refuse, invite unsanitary practices by the workmen, whereas clean, orderly working environment

encourages sanitary working habits. The response which the workers give to the efforts of their employers to provide clean working environment thus multiplies the benefits which accrue from them. This fact suggests then, as a sanitary requirement, the minimum accumulation of dirt, filth and refuse matters, accomplished by regular and frequent removal with the least practical amount of handling and agitation.

6. Atmosphere.

Purity, humidity and temperature of the working atmosphere are vital health considerations affecting directly the resistance of the body to disease attacks. Impure air often containing injurious gases, fumes and dust, abnormal temperature and humidity, impedes the normal functions of the body and increases its susceptibility to disease. The removal of such impure air and the introduction and proper distribution of pure air at as nearly the temperature and humidity normally required by the human body as the manufacturing process will permit should be accomplished in a systematic and properly regulated manner.

7. Illumination.

Darkness, by promoting and shielding the existence of dirt and dampness, increases the opportunity for germ life and multiplication and decreases the physical resistance of the workers' bodies to their attacks. Sunlight

is an enemy of germ life. Its introduction into and uniform distribution throughout working places should be promoted to the maximum practical degree. Where sunlight cannot be admitted in sufficient amount to properly illuminate all parts of a plant during working hours, artificial lighting must be employed to supply the deficiency. Such lights should be so located as to eliminate dark corners and spots where filth may accumulate unobserved.

8. Germicides.

In conjunction with certain sanitary practices and equipment germ destroying agents may be effectively employed. Through spraying processes these may at times be used to destroy the germs in the air in working places and by application to surfaces in common use by a large working force the possibility of injurious effect from common contact may be materially reduced. As a general principle it may be stated that germicides should be employed in every practical opportunity afforded for their use in sanitary practices.

9. Incentives.

The effectiveness of sanitary practices and equipment depends very largely upon the degree to which they employ the ordinary habits and tastes of the workmen as incentives to their use. Emphasizing an unsanitary practice or condition by means of contrast of its result or its existence with clean surroundings is almost invariably an

effective means of obtaining its discontinuance or correction. No opportunity to employ incentives in Sanitation, should be overlooked.

IV. FATIGUE REDUCTION.

Physical or mental exertion reduces fatigue. This fatigue is a limiting factor in the working capacity of the human element of industry. Efficient production requires such a balance between the scheduled output from a worker's labor and his capacity for producing that output as will enable him to maintain that schedule day after day. The maintenance of the schedule in the absence of such a balance may be accomplished for a time at the expense of the worker's reserve strength but, sooner or later, upon the exhaustion of this reserve production must drop to a schedule which can be maintained.

A decreased schedule which would conform to the ability of the worker under the given conditions might, of course, be suggested as the solution of the problem but it would only impose upon society the penalty of under production. It is rather proposed here to investigate the problem with a view to maintaining or even increasing the normal schedule by decreasing the demands upon the strength of the worker per unit of product through the adjustment of working conditions, facilities and practices. The following fundamental principle will serve as the basis of the investigation:-

"Maximum production from the normal working capacity of a

given force requires that the working conditions, practices, processes and equipment employed shall develop the minimum fatigue per unit of product.

1. Satisfaction of Physical Needs.

Under the section of this treatise devoted to Sanitation the importance of prompt satisfaction of the physical needs of the workman from a health standpoint, was discussed. It also has an important significance from the standpoint of fatigue. Unsatisfied thirst or unlischarged bodily excreta, through their interference with the normal functions of the body lower the mental alertness and physical endurance of the worker and, consequently, hasten the development of excessive fatigue. Hence, conservation of working capacity requires that facilities for the satisfaction of these physical needs be so located and maintained that prompt accomodation is encouraged.

2. Order and Cleanliness.

Clean, orderly arrangement of equipment and materials with clear, well defined aisles on floors that are kept free from dust, shavings, grease, water and other refuse products afford the maximum degree of freedom and ease in moving about from place to place as required by the worker. By reducing the danger of slips and falls through the elimination of its major causes - greasy, littered floors - the fatigue of strained positions in walking or standing is

greatly reduced. In addition many steps are saved with a material reduction in the fatigue that is experienced per unit of product. To promote these conditions a general layout, maintenance and operation should all be conducive to clear, orderly working environment.

3. Atmosphere.

Pure air, well distributed, at the temperature and humidity corresponding to the relative exertion of the workers in a given group of occupations is essential to mental alertness and physical strength. The problem of supplying such requirements is frequently complicated by processes which produce fumes or dust, abnormal temperature or improper humidity. The correction of these conditions must often be accomplished by specially adapted devices to remove or change them, before much can be successfully done in the way of introducing pure air, properly tempered. The atmosphere should be maintained at the highest possible standard of purity with temperature and humidity adapted to the requirements of the work involved.

4. Illumination.

Intensity, source and distribution of light have an important bearing upon the workers' endurance. Inferior illumination produces early fatigue through eye strain and uncomfortable positions of the body in the worker's attempts to adjust his vision to the light available. The fundamental

requirement of proper illumination is sufficient light, uniformly distributed and so directed to the work in question as to clearly illuminate it both individually and in relation to surrounding conditions with the minimum of glare or other cause of eye strain.

5. Concentration.

The mind that suffers the least confusion from conflicting ideas or impressions conserves its normal ability the longest and wastes the least physical strength upon superfluous and ineffective motions. Any condition in the working environment which divides the attention of the worker and causes him to either temporarily or regularly give first attention to it instead of his work confuses his mind, promotes dissatisfaction and causes him to seek the earliest opportunity for transfer to another job. Laboring under such environment, his job becomes a burden to him and furnishes no semblance of the pleasure which an interested worker shows in his work. Working conditions should be as nearly free as practicable from occasions for the divided attention of the individual workers subjected to them.

6. Adaptation of Facilities.

It is not uncommon, in factories to find equipment(tools, in particular) that is not properly adapted to the class of work in which it is being used. Pressed into

that particular service in an emergency, perhaps, it becomes regularly used, little attention being given to the waste of the user's strength that is involved. What it lacks in adaptation to its job, the operator supplies in the form of extra motions and added mental exertion to assure the correct performance of the cumbersome cycle of motions involved. The number of cycles of such operation which can be performed with normal fatigue in a day must be less than when properly adapted equipment is used. Consequently for maximum human efficiency the worker's facilities should be adapted to the job to which they are applied.

7. Minimum Exertion per Unit of Motion.

The performance of labor made up of numerous motions of an unrelated nature requires the expenditure of considerable physical strength in unnecessary or ineffective motions and mental exertion in constant planning of procedure. The complexity of such labor causes mental confusion with greatly retarded progress in its performance. Regularity and simplicity are consequently essential to efficient work. The amount of exertion that is required for all the separate motions in a given cycle of operation, determine the number of such cycles that can be performed within a given limit of normal fatigue. The ideal to be approached in determining the job of each worker is to make it consist of a successively recurring cycle of a minimum number of standardized, simple

motions each requiring the minimum expenditure of the worker's strength in its performance.

8. Comfortable Posture.

Each separate motion making up a standard cycle of action has its own peculiar characteristics which govern the position of the worker for its most efficient performance. If the cycle is so laid out that considerable change of position of the worker is required during its performance or that considerable reaching or lifting at a disadvantage is necessary, if one position is maintained for the cycle, excessive demands are made upon the worker's strength. The cycle should, therefore, be laid out with respect to the most comfortable position of the body compatible with the nature of the work and with the minimum occasion for shifting from one position to another during its performance.

V. ACCIDENT PREVENTION.

Physical injuries to the workman in industrial operation rigidly follow definite laws of cause and effect. The recurrence of conditions which once cause an injury will repeatedly result in injuries of like kind. Due recognition of this fact is fundamental to a proper investigation of the problem of preventing such injuries. The term, "accident", may be easily misconstrued with detrimental effects upon the progress of Safety unless its application to the occurrence of a physical injury is understood to convey the fact of its unforeseen nature and not to intimate any element of uncertainty as to its occurrence when the proper conditions exist.

Two elements are involved in the occurrence of an accident which inflicts injury upon a worker. The first is the simultaneous existence of the necessary conditions to inflict injury while the second is the presence of one or more members of the workers body within the effective zone of these conditions at the exact time of their simultaneous occurrence. When, in the course of a series of consecutive actions, these necessary elements of an accident simultaneously occur, injury is inevitably inflicted. The fundamental principle of accident prevention may, then, be stated as follows:-

"Accident prevention is fundamentally the prevention of

the simultanious existence of the separate elements of accident occurrence."

1. Minimum Human Fatigue.

Mental alertness and precision of action decrease with increased fatigue. Consequently, in the presence of accident hazards the safety of the worker decreases with the lapse of time from the preceeding rest period. From the standpoint of reduction of accident frequency and severity fatigue should be reduced to the minimum practical point.

2. Health.

Impaired health affects the safety of the employee in very much the same manner as fatigue and, for the same reasons, should be minimized through the control of working conditions to reduce the possibilities of disease development and communication.

3. Clothing.

Working apparel has a distinct bearing upon the safety of the worker. Clothing which may easily become entangled in moving machine parts should not be worn at work. In certain occupations the matter of protecting the worker from sharp or rough materials, heat, dust, liquids or flying particles requires specially adapted apparel or equipment. The facilities for storage of such equipment while not being actually used determine largely the degree to which they will be used by the workers. Through convenience security and

relative privacy in the matters of storage and changes, adjustment of clothing to the safety requirements of the various occupations of the workmen should be encouraged.

4. Order and Cleanliness.

Dirt, refuse and materials, stock, tools and machine parts scattered upon factory floors create slipping, tripping and falling hazards that are productive of many accidents. Poorly defined aisles and runways subject employees to hazards adjoining such aisles, which, were the runways straight and clear, would be sufficiently inaccessible, from the standpoint of the actual practices of the workmen, to practically eliminate them as hazards. Similarly, slippery floor surfaces increase the danger of adjacent hazards through the possibility of falls which throw workers directly into them. The ideal, therefore, to be approached in plant layout, maintenance and operation is orderly arrangement with well defined, straight aisles and runways and clean floors.

5. Illumination.

Many factory conditions which, when well defined by sufficient illumination, are not productive of injuries become, in the absence of proper light, points of distinct hazard. Illumination, consequently, governs largely the interpretation which the worker places upon the hazards of the conditions about him. Every point of existing accident hazard should be properly illuminated to assure

the probability of ready observation from every angle of accessibility.

6. Concentration.

Diverted attention, making the worker temporarily heedless of the hazards about him causes him to unduly subject himself to dangers which his sense of self-preservation would ordinarily prompt him to carefully avoid. In this connection the presence of numerous accident hazards about a workman may cause him to subject himself to one hazard while exercising his care to avoid another. Accident prevention requires that working environment be as free as practically possible from influences that divert the attention of the worker from his regular job.

7. Adaptation.

Failure of one or more of the elements of production in any given operation to function as required frequently causes the simultaneous existence of the conditions essential to the occurrence of an accident with resulting physical injury to the operator. The lack of adaptation which causes such failure is usually but once demonstrated to the worker, who places confidence in the ability of the equipment which has given him to properly function, and that only after it is too late to exercise the necessary precaution to prevent injury. The proper adaptation of all the elements of production to the work to which they are directed is essential to

the safety of the operators.

8. Control.

Closely allied to the requirement of adaptation is that of control. If the control of varying conditions to which the worker is subjected does not rest largely with him a great deal of uncertainty of action is introduced. Such uncertainty increases the opportunities for the coincidence of the elements of accident occurrence. Control of varying conditions to which workers are subjected should, therefore, to the largest practical degree, rest with the workers themselves.

9. Simplicity.

When a job is made up of numerous motions of a comparatively unrelated nature the element of uncertainty is introduced in large measure with a corresponding introduction of accident hazards. Similarly the rapid succession of a complex cycle of properly related motions in which two or more members of the workers body may be brought into simultaneous action readily confuses the mind of the worker, frequently causing combinations of actions which subject him to injury. As fatigue increases during the course of a day's performance of such jobs the uncertainty and confusion becomes greater and the hazards involved in the job increase. To minimize such hazards, the ideal tobe approached in determining the job of each worker is to

make it consist of a successively recurring cycle made up of a minimum number of simple motions.

10. Clearance.

The clear, accessible space between two or more objects is sometimes governed by the motion of adjacent equipment or by the practices of workmen. If sufficient clearance for the passage or presence of a worker's body or one or more of its members or of a movable object, to any of which the space is accessible under certain conditions, does not exist under all circumstances serious accident hazards may very unexpectedly develop and inflict serious injuries upon the workmen subjected to them. Consequently, under all conditions sufficient clearance for safe presence or passage should be assured to persons or members of their bodies or to movable objects, to any of which a given space is, under any conditions, readily accessible.

11. Inaccessibility.

In the design, construction and installation of equipment and in the layout and construction of buildings and other structures, conditions, which in the ordinary operation of the plant, are distinctly hazardous, are frequently developed. The extent and manner of exposure of workers to these hazards determines their seriousness. Many of these conditions may be rendered practically

inaccessible to the workers by means of barriers, safeguards or mechanical devices without altering the effectiveness of the regular operating practices. Minimum interference with normal production is, however, a fundamental requirement of a practical safeguard or safety device, for such interference defeats to a large degree the primary purpose of production from the economic standpoint. To the maximum practical degree compatible with efficient production all points of hazard should be rendered inaccessible to the workers in their normal occupations.

12. Stability.

Tipping, falling or overturning of materials or equipment due to instability in piling, loading or placing frequently result in accidental injuries to workers adjacent to such hazardous conditions. The ordinary vibration of floors and other supports due to running mechanical equipment, agitation from truck movements and the normal wear from constant operation serve to sufficiently disturb such conditions of relative instability as to cause failure. In the handling, piling, placing and installation of materials or equipment in industrial plants stable equilibrium is essential to safety.

13. Repair.

Equipment, though originally properly adapted in design to the job for which it is used, with all requirements

of safety correctly incorporated, will, in time, suffer wear, elastic fatigue or other deterioration which will render its use quite unsafe unless parts showing such deterioration are promptly replaced or repaired. The initial adaptation of equipment to job should be permanently maintained during its useful life. Working facilities should, therefore, be maintained in such condition of repair as will perpetuate the characteristics of their original design and construction or of such proper changes as may have been subsequently made.

14. Incentives.

Devices which emphasize the importance of safe practices may be used to advantage in accident prevention. They may be employed to very practical advantage in some instances in place of certain positive safety devices which would materially reduce production or otherwise interfere with normal operation. Such devices by their presence guide the practices of the operators along lines which will reduce their tendency to subject themselves to existing hazards, without complete isolation of the hazardous conditions. To the maximum practical degree incentives should be employed to emphasize, through appeal to the normal instincts and habits of the workmen, the possibility of conserving their lives, limbs and working ability through the prevention of accidental injury.

SUMMARY AND APPLICATION.

While, for purposes of analysis, treatment of our subject by divisions has been advantageous the practical application of the fundamental principles which that analysis has developed, to the problem of maintaining the efficiency of the human element of industry requires that those principles be so combined and adjusted as to refer to the subject as a whole rather than to its divisions. So combined and properly related they form sixteen governing principles in the design, layout, development, operation and maintenance of an industrial plant.

In the preceding sections very little reference was made to the possibilities and limitations involved in the practical application of the principles which were developed. While an exhaustive discussion of each principle is scarcely within the scope of this treatise some general reference to these possibilities and limitations will serve to more specifically define the nature of the principles. Consequently, in summarizing the contents of the preceding sections we shall take occasion to enlarge somewhat upon these principles from the standpoint of their application to practical industrial problems.

In the following discussion, after the several headings will be found references to preceding Sections

and Principles, by number, which indicate the previous discussions from which the general principles are drawn.

1. Satisfaction of Physical Needs (III 2; IV 1.)

"Facilities for accomodating the physical needs of the working force should be so located within the plant or distributed through it and so maintained that promptness in their satisfaction will be encouraged by maximum practical convenience."

Location of toilet rooms is largely governed by the double consideration of convenience and the tendency of workmen to congregate for "loafing" in such places. While the ratio of one closet seat to each fifty workers and one urinal to each one-hundred workers may be used as a general standard for average conditions the number of each which should be grouped in any toilet room will depend very much upon the distribution of the workers over the area to be served and the degree to which they are required to move about from place to place during their work. Close grouping of workers in sedintary occupations would require fewer rooms with more equipment per room than would a scattered grouping of workers in occupations requiring a greater range of movement. In determining the distribution of toilet rooms and equipment that is properly adapted to any given set of working conditions the fact that wide separation of toilet facilities from working places prevents a reluctance

in their use and the tendency to "loaf" while away from the supervision of the foreman, should be constantly borne in mind as fundamentally important.

The governing factor in the location of facilities for the satisfaction of thirst during working hours is convenience. Capacity is always so far in excess of demand when facilities are properly located that it does not enter into the problem. Such facilities should be so located with respect to other plant equipment that grease, filth or displeasing odors do not discourage freedom in their use. At the same time they should be readily accessible to all workers whom they are intended to accommodate. Distribution, density and mobility of the force at work and the arrangement of equipment are the factors that govern the degree of accessiblity of any individual location and the number of separate pieces of drinking equipment required to properly accommodate any given area.

2. Washing Facilities and Clothing. (III 3; V 3)

"The wearing of clothing, during working hours, which conforms to the health and safety requirements of the workers should be encouraged by convenient location of proper facilities for washing the hands, arms and face and, if necessary, the entire body and for changing and storage of clothing and other personal effects with reasonable privacy and security against loss or theft."

The percentage of any given working force which will use washing facilities upon leaving the plant depends to some degree upon the average distance between the plant and their homes. Many who live near the plant and, consequently, prefer to wash and change their clothing, as well as eat their noonday lunches at home will not take advantage of plant facilities for such purposes. However, those who live any appreciable distance from their work should be encouraged to wash and to change their clothing to conform to the separate requirements inside and outside the plant. Likewise those who eat their lunches at the plant should be encouraged to wash before doing so, both to promote personal sanitary practices and to afford them additional comfort during the noonday rest period. To accomplish these purposes washing facilities and lockers should be located convenient to all working places. Wash basins should be supplied in the ratio of about one to every five users while lockers must be individual.

Storage facilities should, if possible, accommodate clothing without folding, thus affording greater convenience and larger storage space, both of which are important assets at times when a large number of workers are changing their clothing and using adjacent lockers at one time. This would require sufficient height to accommodate the ordinary overcoat, which practically eliminates the "two-high" arrangement

commonly found where lockers are used.

3. Minimum Common Contact. (III, 4)

"Direct contact of those parts of workers' bodies through which germs of disease find easy access to and exit from those bodies, with objects of common use should be minimized through proper design, selection and installation of sanitary equipment and the inauguration of proper sanitary practices."

The present trend in the design of sanitary equipment is to eliminate the possibility of common contact. Very effective progress has been made in this regard in drinking and washing facilities in particular. In the former instance this is accomplished in certain cases by means of a jet of drinking water being projected some three or four inches at a small angle of inclination from the vertical, which keeps the mouth from contact with parts of the fountain and causes water that has been in contact with the lips to fall free from the nozzle into the bowl of the fountain. For washing, spraying nozzles of the type used in shower baths are placed at a convenient distance above the wash bowls, which are not equipped with stoppers, thus making it necessary to wash in the spray of water from the nozzle and preventing the common use of the bowls. Likewise automatic dispensing equipment is commonly used for towels

and soap. The use of individual lockers for the storage of clothing and other personal effects reduces the opportunity for common contact that exists when they are hung in groups about the plant.

Except when proper care is exercised the closet seat is an effective medium of disease communication. Workers should have impressed upon them the importance of placing between their bodies and the seat some effective barrier to direct contact, such as strips of toilet paper. Seats which, from the nature of their construction and use, will not permit of this practice should not be supplied. In addition to this precaution the seat should be periodically washed with some cleansing compound with pronounced germicidal properties. This measure should, in fact be regularly practised with all sanitary equipment.

4. Order and Cleanliness (III 5; IV 2; V4)

"General plant layout, maintenance and operation should promote orderly arrangement with well defined, straight aisles and runways and with the minimum accumulation of dirt, filth and refuse matters, accomplished by regular and frequent removal with the minimum of handling and agitation."

Most factory equipment lends itself very readily to orderly arrangement in straight lines in the order of the progress of material through production processes with

well defined, straight aisles and runways. Likewise, in sections of the plant used for the storage of materials, orderly arrangement may be followed in locating and constructing both temporary piles and permanent bins. The details of such orderly arrangement depend, of course, upon the nature of the industry but in any case the principle establishes the ideal to be approached.

Keeping floors as nearly free from materials, of all kinds, as possible aids materially to the possibilities of orderly arrangement and of simplicity in cleaning processes. This suggests that production materials should be maintained, throughout the process of manufacturing, as nearly as possible at the height at which they are used, by employing conveyors, trucks or containers, depending upon the nature of the materials and the manner in which they are employed in the processes involved. It also suggests the removal of refuse materials by methods that keep them off the floors through the use of such equipment as above enumerated into which they are deposited as produced, thus materially reducing and simplifying the manual labor that is required to maintain a clean plant. Dust, fumes, wood shavings and similar refuse substances that are easily carried in suspension by air currents may be very effectively removed, as they are produced, by exhaust systems properly applied as nearly as possible to their source.

To remove the dust, dirt, grease and similar refuse substances that are deposited upon walls, floors and equipment, by hand labor, requires the employment of such processes as sweeping, scraping, vacuum cleaning and scrubbing or mopping with specially adapted cleansing and disinfecting compounds. The nature of the deposit determines the methods or cleansing agents required for its removal but in any event the cleansing process that is employed should be performed in such a manner as to minimize the raising of germ bearing dust.

5. Atmosphere (III 6; IV 5.)

"The removal of impure air, fumes and dust from working places and the proper distribution of pure air at as nearly the temperature and humidity normally required by the human body as the manufacturing processes will permit should be accomplished in a systematic and properly regulated manner."

In the discussion of the preceding principle an important factor in the successful removal of dust and fumes produced in manufacturing processes was briefly mentioned, viz; the application of exhaust systems as nearly as possible at the source of their production. The nearer suction pipes or hoods can be applied to such sources the less will be the required volume of air displaced to effectively remove the injurious dust or fumes from the working place,

for the less will be the opportunity for them to become distributed through the general atmosphere. Excessive heat may also be removed by exhaustion of the heated atmosphere from the vicinity of its source.

In one large factory the excessive heat which resulted from the operation of a large battery of cyanide furnaces and which had been the cause of numerous heat prostrations among the operators, was effectively reduced by the installation of an exhaust system with leads to the separate units to remove the overheated air and a ventillating system for the introduction of fresh air properly tempered as to temperature and humidity through distributing conductors over the heads of the workers. This system placed them in a very comfortable working atmosphere with the consequent elimination of heat prostrations and increase in the working capacity of the operators.

The required temperature of the air for the comfort of the workers in any given operation depends upon the nature of the work. Strenuous labor requires lower temperature for comfort than does an occupation requiring little physical exertion. Consequently, in making temperature and humidity adjustments in the various parts of an industrial plant this fact should be taken into consideration.

6. Illumination (III 7; IV 4; V 5.)

"The fundamental requirement of factory illumination

is sufficient light uniformly distributed and so directed to the work in question as to clearly illuminate it both individually and in relation to surrounding conditions with the minimum of glare or other causes of eye strain and with distinct definition of all accident hazards from every accessible direction."

Compliance with this principle requires sufficient general illumination to accommodate the ordinary general needs of the working force with special illumination for certain jobs or locations. It is rarely possible to admit sufficient natural light to all parts of a plant or of an individual room of any appreciable size to make artificial light wholly unnecessary, even during the summer months. However, in this regard much depends upon the nature and color of the surfaces ofwalls, ceilings and equipment. Surfaces that readily reflect light give better diffusion and consequently cause it to penetrate further from the source into the interior than do surfaces which absorb it. This is quite as important with artificial as with natural illumination to afford more nearly equal distribution of light from separate sources. While it is definitely established that, for the best diffusion of light, surfaces must be smooth, the proper color for best results when all conditions are considered depends somewhat upon the nature of equipment and occupations involved.

To minimize eye strain the worker should not directly face the source of illumination of his work. In fact the last strain results from the greatest angle of diversion in the rays of light by the reflection by which objects or surfaces are viewed. This fact will, in actual practice, largely control the height of lamps, the type

of reflectors and the location of lights for special illumination of individual jobs and will be an important factor in the location of machines, benches and other working equipment.

7. Concentration (IV 5; V 6)

" Working environment and conditions should be as nearly free as practically possible from influences that divert the attention of the workers from the performance of their tasks."

Many of the principles and conditions that have been and will be discussed in this treatise relate in some degree to this phase of the subject and, consequently, its consideration as a separate principle may seem superfluous. It serves a definite purpose, however, in directing the attention of the Engineer to the problem from the viewpoint of the worker's own mental attitude toward the conditions surrounding him and the effect which that attitude has upon the output of his operation.

Under "Accident Prevention" brief mention was made of the effects of accident hazards upon workers in occupations more or less directly subjected to them. The emphasis upon the existence of such hazards, that is maintained by the frequent occurrence of accidents in similar working environment in other locations or plants,

keeps constantly alive in the minds of the workers that are subjected to them, fear for their own physical safety with the result that their divided attention detracts from their actual production, causes early fatigue and subjects them to dangers in their regular occupations, which undivided attention would enable them to properly avoid.

Improper lighting, excessive heat or cold, poor ventillation and similar sources of discomfort or injurious effects tend to divert the attentions of the workers from their tasks and direct them rather to the discomfort that is being experienced with resulting reduction in productive capacity and increase in risk of injury. In like manner certain occasional practices such as talking to machine operators and playing "practical" jokes produce similar results.

8. Adaptation (IV 6; V 7.)

" The proper adaptation of the elements of production to the work to which they are directed is essential to safe and efficient plant operation."

Undoubtedly in the vast majority of cases original designs, layouts and installations conform as closely to this principle as the progress that has been made in such practices permits. But in subsequent changes, particularly in those made under the stress of emergency, it is often

seriously violated with the result that the revised arrangement does not function as expected and inefficiency, accidents or even calamities follow. Overloads, overspeeding and similar infringements upon the practical limitations of original design are frequently the causes of such conditions.

An apt illustration of this violation of original design in actual application came to the writer's attention some time ago. A straightening press in which the ram was actuated by power derived from a compressed air cylinder in the base of the press and transferred to it by two oil cylinders, was being used to punch out a hole in a small piece of malleable stock, a loose punch being used beneath the ram. Being designed for straightening operations in which the stock would yield steadily to the pressure of the ram, impact was not a governing factor in design and the air cylinder, which constituted the sole support for the machine, was constructed of cast iron. However, in using the press for punching, impact resulted in each operation as the tool dropped through the stock. The air cylinder eventually cracked entirely around its circumference about one inch below the head allowing the machine to tip over and inflict severe injury upon its operator.

A common misapplication of tools is that of punching

with a wrench. The properly-turned free and balanced concentration of weight in the head of the hammer are not necessary in the wrench and hence are not incorporated in its design. Consequently the blows are awkward and uncertain imposing upon the practice the penalty of wasted energy and often of physical injury.

§ Control (V &)

" Control of varying operating conditions to which workers are subjected with resulting liability to injury should, to the maximum practical degree, rest with the individual workers themselves."

In certain types of mechanical equipment the application of this principle resolves itself into a matter of giving each worker control over the motive power that drives his machine, by a belt shifter, clutch, electric starting box or other similar equipment so located as to permit ready access to it from his operating position. With such an arrangement the operator is able to quickly shut down his machine in an emergency without moving from his normal position. In large units attended by two or more workers, such as are found in paper mills automatic engine stops or other similar control devices actuated by electric push buttons in convenient locations are desirable.

In certain classes of repair work, such as work inside of boilers, on electric circuits or on power transmission equipment the workers life may depend almost wholly upon the impossibility of the performance of certain acts by other persons. This condition may be established through the use of locks which hold the valve, switch, starting box or other controlling device in the "off" position, the key being held by the repair man performing the job until he has completed it.

1c. Minimum Exertion per Unit of Motion(IV 7; V8)

"The ideal to be approached in determining the job of each worker is to make it consist of a successively recurring cycle of standardized simple motions each requiring the minimum expenditure of the workers strength in its performance."

This principle is effectively applied in many cases to punch presses, used for small stock, through the installation of dial feeds. In the ordinary method of feeding the press the operator would be required to pick up his stock, place it in the die, trip the press after removing the hand from the dangerous zone and then remove the stock from the die. This cycle of motions would bring into consecutive or simultaneous action both hands and one foot if the foot trip press were used, a cycle which would be very

confusing and productive of large power losses through the impossibility of using every revolution of the press flywheel in productive manner.

"When the dial feed is used the operator picks up his stock and places it in the portion of the dial nearest his own position and farthest from the die of the press and removes a piece for the application of the next while the ram operates with each revolution of the flywheel. The motion of tripping the press is entirely eliminated and the distance of travel of the operator's hands is materially reduced, resulting in a material increase in production and practically safe operation with minimum fatigue. This general method of mechanical feed is being effectively applied to certain types of milling machine in which a revolving jig is used instead of the usual reciprocating table. The operator's hands are during operation, always engaged in removing and applying stock at the point farthest from the cutters while work is being constantly fed into the cutters at the proper speed for efficient operation, embodying in one device both efficiency and safety.

The general principle may be effectively applied to the transfer of stock from each productive operation to the next with material reduction in the amount of exertion required of the worker in actual handling of the

stock. The principle, formerly stated, that stock should be maintained throughout the process of manufacture as nearly as possible at the height at which it is conveniently used applies very effectively in this connection by minimizing both the amount of handling and the distance of travel of the hand in placing the stock in the machine or on the bench and in turning it to the tray, truck or conveyor used for transfer to the next operation.

11. Comfortable Posture (IV C).

"The cycle of motions peculiar to each operation should be so laid out as to permit the most comfortable position of the body compatible with the nature of the work and as to afford minimum occasion for shifting from one position to another during its performance."

This principle refers to the distribution about the working position of the operator, of those materials, utensils and equipment parts which he handles or manipulates in the normal performance of his operation. This distribution should be so designed that the minimum movement of the body or any of its separate members is required in the performance of the entire cycle of motions. The source of stock supply for the worker, the distance which he must reach to feed it into the machine and the location of such operating devices as levers, hand wheels, foot treadles and belt shifters are items which must be taken into consideration

in the application of this principle. The illustrations used in the discussion of the preceding principle apply equally well to this.

12. Clearance (V 12).

"Physical safety requires sufficient clearance between all paths of motion of adjacent objects, for safe presence or passage of persons, members of their bodies or of movable objects by which any given space is, under any state of condition, accessible."

Not infrequently, persons in industrial plants enter or thrust members of their bodies into temporarily accessible spaces which an instant later in a different phase of the motion of adjacent objects or parts are so reduced that serious injuries are inflicted. A recent example of this condition is that of a fireman who was adjusting the length of stroke of the pushers in the center unit of an underfeed furnace stoker while reaching beneath the ram of an adjacent stoker, the valve mechanism of which he supposed he had placed in a neutral position. In the advanced position of the pusher link there was considerable clearance between it and the head of the cylinder, admitting his arm while reaching the corresponding link on the next stoker. However, while making the adjustment, the link back of which his arm was reaching returned to

its initial position crushing the arm against the cylinder head and inflicting a seriously complicated fracture of the upper arm. Had there been greater clearance between the end of the link in this position and the cylinder head little, if any, injury would have resulted as the arm would have been merely pushed back to the end of the stroke and would still have remained free.

To avail themselves of "short cuts" in going from place to place about a plant, workers sometimes pass between machines, close to revolving shafts ends, pulleys and similar conditions which upon contact with clothing may inflict serious injury upon the wearer. With sufficient clearance between the machines such contact would be carefully avoided by the worker thus rendering passage comparatively safe but where the clearance is limited the probability of injury in such passage is greatly increased. This is an important factor in the definition of aisle and runways and, consequently, for safety, in every space that has any possibility of being so used sufficient clearance should be provided or such use should be effectively prevented by adequate barriers. This accords fully with our next principle.

13. Inaccessibility (V 11.)

"To the maximum practical degree, compatible with efficient production, points of hazard should be made inac-

sufficiently inaccessible to prevent the possibility of purely accidental injury."

It should be noted that the statement of this principle does not conform to the "fool proof" guarding theory that has been held by some in the interest of industrial safety. Foolhardiness is a condition to be guarded against not by mechanical safeguards but rather by wise selection in the choice of workers. It is consequently an employment problem. The underlying purpose in practical safeguarding is to interpose between the worker and adjacent accidental hazards only sufficient barriers to reinforce his normal sense of physical preservation in such manner as to permit him to direct his practically undivided attention to the primary object of his labor, the production of goods.

Many considerations enter into the determination of the type of guard for any given hazard, that is required to conform to this principle. Among these are the operations involved, the amount of clearance that exists about the point of hazard and the extent to which access to that point is required in normal operation. Effective safeguards may range from small pieces of sheet metal which deflect minute particles of steel from the eyeball to the position of the worker, to substantial steel bands that will retain in the flying parts of a bursting emery wheel or from single railings of iron pipe,

that will prevent passage through areas of danger, to complete enclosure of parts of hazardous gears. In every case the safety device or guard should, if possible, permit inspection, lubrication which is actually possible in the vast majority of cases. The dial punch press feed and revolving milling machine jig cited in illustration of a preceding principle are excellent examples of this principle also.

14. Stability (V 12)

"Every material object used in manufacturing processes should at all times be maintained in a condition of stable equilibrium."

While the importance of this principle is so readily recognized as an essential of fixed equipment that it is universally incorporated in the initial design and installation it is not infrequently seriously violated in the handling and transportation of such equipment before or during installation. In direct violation of this principle it is not uncommon to see tall machines transported about a shop upon narrow skids or trucks at a serious risk of injury to men working about them.

It is a matter of common knowledge that a tall object or pile of material standing on a base of small area

is very unstable and requires but slight disturbance to cause it to topple over. It is not uncommon, however, to find a large number of individual stacks of the above nature standing in a single group and consequently being considered as a large pile of relatively high stability, whereas the only result actually accomplished in the piling is to conserve space and define piles, for disturbance of one such independent pile may cause failure of the whole group with disastrous results. As an example, in plants manufacturing piston bike motors, pistons are frequently piled to heights of five or six feet in closely grouped independent piles, any one of which located at the outside of the group may easily be sufficiently disturbed to cause it to fall and in so doing possibly cause failure of the entire group.

Such groups may, however, be tied together in piling by changing the arrangement of the piles at regular intervals as the group is built up. In the piston illustration they might, with very little loss in space be piled to a height of two feet and then, after putting in form cribbing the distance of half the piston diameter covering each bottom piece in the upper arrangement to rest on four of the top pieces of the lower, be piled to the height of another two feet and so on until the desired total height is attained.

Where lumber or steel are available they may be inserted at regular intervals of height in one or both directions to constitute the bases for the piles above, the sides of the entire pile being maintained vertical.

Where space is a vital consideration such systematic piling as above described will permit of safe and economical use of vertical space to a materially greater height than with independent piles or height. Properly modified to conform to the practical limitations placed upon them by short hauls and brief periods of use, these principles may be effectively applied to stock transportation problems when the use of trucks, stock flats and other similar types of apparatus is involved.

15. Repair (V 15).

"Equipment should be maintained in such condition of repair as will perpetuate the characteristics of its original design and construction or of such proper changes as may have been subsequently made."

Wear, bending, loosening, decomposition or crystallization of equipment parts cause them to fail to function in their normal relation to other parts and to frequently develop combinations of conditions that produce inefficient, if not disastrous, results. The breaking of a pin which revolved the stock in a production grinder

permitting the piece to be revolved in the opposite direction at excessively high speed by its contact with the abrasive wheel. The piece of stock being eccentric with respect to the line of the point upon which it revolved, quickly developed sufficient centrifugal force to tear it from the centers and throw it from the machine in the direction of the operator, severe fractures and disfiguration of his face resulting. In starting each operation the driving pin turned through a part of a revolution before it engaged the projecting portion of the stock, the resulting impact producing bending with eventual breakage. Due recognition was not given this bending and unexpected failure to properly function followed, permitting a secondary condition, rapid revolution, which was the direct course of the accident.

Proper maintenance of equipment is a fundamental requisite of safe and efficient plant operation. In turn proper supervision of such equipment to catch the first indication of impending failure is necessary, for proper maintenance is a matter of repair before actual breakage occurs if it is at all possible to anticipate such failure rather than after breakage with its possible disastrous results.

16. Incentives (III 9, V 4)

"Practices and devices inaugurated and employed

in the conservation of life, limb and working ability of industrial workers should give due recognition to their normal tastes and habits as an incentive to their personal interest and pride in the preservation of their normal working facilities."

Painting schemes may be effectively employed to discourage the production and accumulation of filth and dirt, the disfiguration of sanitary equipment and the performance of other habitual practices of an unsanitary nature such as spitting in corners and around posts. They may also be used to define the limits of floor spaces used for aisles and runways and to thus discourage the accumulation of materials in such areas. In the vicinity of accident hazards the limits of safety may be defined in similar manner. Whatever may be the ultimate purpose for which such painting schemes are used color contrast is the medium through which the object is emphasized to the eye of the worker.

Comfort and convenience, items discussed at some length in preceding sections are important incentives to workers to use equipment, facilities or guards intended to promote their physical welfare. For example, guards that are so constructed that necessary access to the guarded parts is difficult to attain, will seldom be long used, for

their replacement after removal is easily neglected and they soon become discarded.

In certain types of equipment, either sanitary or productive, it is desirable that the user shall, upon completing his use of it, perform some definite act which will dispose of refuse matters or shut off power to prevent the development of serious health or accident hazards.This may in many cases be accomplished by so constructing the equipment that to use it requires pressure of the hand, foot or other part of the body, the removal of which is followed by automatic action of equipment parts to accomplish the desired purpose. Examples of this are waste cans with foot-lift covers, closet seats which discharge the contents of the bowl as the weight of the users body is removed and belt shifters or clutches on tool grinders, actuated by foot treadle while being used and returning to the "off" position upon removal of the foot pressure.

TABLE # 1.

Summary of general principles with their sources in the three Major Divisions.

No.	Principle.	III Industrial Sanitation No.	IV. Fatigue Reduction No.	V. Accident Prevention. No.
1.	Satisfaction of Physical Needs	2	1	
2.	Washing Facilities and Clothing	3		3
3.	Minimum Common Contact	4		
4.	Order and Cleanliness	5	2	4
5.	Atmosphere	6	5	
6.	Illumination	7	4	5
7.	Concentration		5	6
8.	Adaptation		6	7
9.	Control			8
10.	Min. Exertion per Unit of Motion		7	9
11.	Comfortable Posture		8	
12.	Clearance			10
13.	Inaccessibility			11
14.	Stability			12
15.	Repair			13
16.	Incentives	9		14

VII. CONCLUSION.

In concluding, two important considerations may properly receive brief attention. They deal with the agencies for applying the principles that have been developed in the preceeding discussion rather than with the principles themselves. The first is the means of relating this feature of plant organization to the older established divisions. The second is the future importance of engineering in this phase of industrial operation. These we shall treat separately in the order named.

Organization.

After noting the readiness with which our three initial divisions of the subject focus into a single code of principles for conservation of human efficiency in industry, little argument need be advanced to demonstrate the practicability of uniting the application of those principles under the activities of a single department of plant organization. The duplication of responsibilities and activities that arises from separation is little less than an effective neutralizing force that impedes the progress of either.They are activities that are alike in purpose and application and are, consequently, not subject to effective and efficient division into separate departments.

The relation of such a department to the other departments of the organization is equally well defined.

Though it is a division of plant activities often coveted by other departments to be interpreted in terms of their relation to the general organization, there is no excess of relationship in favor of any other plant activity which justifies its attachment to any other individual department. It must, in a distinctly cooperative manner, work in and through practically all departments of factory organization. It relates to design, layout, selection, construction, maintenance, operation and personnel. Interpreted in terms of any one of these its fundamental purpose and its relation to the organization become distorted from their true form by the limitations imposed upon them.

The proper position of this department in industrial organization is that of direct responsibility to the executive head of the factory activities, usually the Works Manager. In such a position the department has the advantage of direct relation to every other department with the added opportunity of laying directly before the executive head of the factory its plans and the records of its accomplishments. Such a position accords directly with all the requirements of effective organization.

The Part of Engineering.

The variety of items covered by the principles herein previously developed indicate to a large degree the

future importance which Engineering must assume in this phase of industry. As the application of these principles becomes broader with increasing recognition of the importance of human conservation in industry the responsibility for their correct application will shift more and more from the operator to the designer and the layout and maintenance Engineers.The present necessity for safe and sanitary practices in the presence of unsafe and unsanitary conditions as they are now found in many industries, must in the interests of efficient production be safeguarded by a different combination in which Safety and Sanitation will be largely promoted by the working conditions themselves, allowing the workers greater freedom of attention to the tasks before them.

The adjustment of working conditions upon the basic principles herein developed is distinctly an Engineering problem. While in inaugurating this great industrial movement many who are not Engineers did and are now doing most valuable service in presenting its humanitarian and economic features to industrial executives and in admonishing workmen to be mindful of the physical welfare of themselves and their fellow workers, the task of analyzing the problem, determining its fundamentals in terms of industrial development and solving it in a manner that gives each forward step

the proper degree of permanence, is being constantly more generally recognized as the task of the Engineer. In acknowledgement of this duty and responsibility the Engineering profession is putting forth effective efforts through its national societies and its institutions of technical learning to meet the problem squarely in a truly professional manner.

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