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MACHINE GUARDING
1946-1970
Part II – Pre OSHA – 1946 to 1970

THE IMPORTANCE OF SAFEGUARDING MACHINERY

The initial focus of the industrial safety movement beginning in the early 1900's was to protect workers by providing adequate safeguarding of machinery. Widespread public opinion was aroused in 1908 when the Russell Sage Foundation published the *Pittsburgh Survey* documenting the deaths of 526 workers and the permanent crippling of more than 500 others in the mills and factories of Allegheny County, Pennsylvania during a one-year period. The public response to the reporting of this information was dramatic. By 1915, the Federal Government and a majority of the states had enacted some form of worker compensation law, the U. S. Bureau of Mines was established, the Bureau of Labor statistics was created, the National Safety Council was formed, and the American Society of Safety Engineers was organized.

The following quotation is from the U.S. Department of Labor (Secretary James P. Mitchell) publication *Safety Subjects*, Bulletin No. 67, Revised 1956: [1] *Early factory inspection laws dealt exclusively with mechanical guarding - enclosure of belts, guarding of gears, railings around vats, etc. Today too, the State inspector is primarily concerned with the elimination of physical hazards, although the scope of his activities has been greatly increased to include guarding at the point of operation, better lighting, better housekeeping, safer handling of materials, and the numerous other details that make the plant a safer workplace. However, the elimination of physical hazards, including the guarding of machinery, still remains a basic purpose of his inspection.*

A BRIEF HISTORY OF "MACHINE GUARDING" CONCEPTS AND TECHNOLOGY - 1946 to 1970

Prior to 1946, the safety literature consisted largely of individually authored or edited texts with limited national distribution. Major texts included:

- Van Schaack, David, Editor, *Safeguarding for the Prevention of Industrial Accidents*, Aetna Life Insurance Company, 1910.
- Tolman, William H., and Leonard B. Kendall, Safety Methods for Preventing Occupational and other Accidents, Harper & Brothers Publishers, New York and London, 1913.
- Beyer, David Stewart, Industrial Accident Prevention, Houghton Mifflin Company, 1916.
- Heinrick, H.W., Industrial Accident Prevention: A Scientific Approach, 1931.

In 1946, the National Safety Council published its first edition of its *Accident Prevention Manual for Industrial Operations* [2] that attempted to compile in one volume a summary of previous and current concepts and technology regarding industrial safety and accident prevention.

This publication contains a chapter titled "Guarding and Operating Machinery." After stating that 25 percent of all permanent disabilities result from machinery accidents, this chapter states that ***positive guarding of point of operation hazards should be relied upon rather than a machine operator's consistent obedience to safety rules. Every effort should be made to make a guard so positive in action that human failure cannot cause an accident.***

Unquestionably, such a positive approach not only applies to point of operation guarding, but power transmission and functional component guarding as well.

Regarding guard construction, this text further states that, generally speaking, a guard should:

1. Provide positive protection.
2. Prevent all access to the danger zone during operation.
3. Cause the operator no discomfort or inconvenience.
4. Not interfere with operation.
5. Operate automatically or with minimum effort.
6. Be designed for the job and the machine.
7. Preferably be a built-in feature.
8. Provide for machine oiling, inspection, adjustment and repair.
9. Withstand long use with minimum maintenance.
10. Resist normal wear and shock.
11. Be durable, fire- and corrosion-resistant, and easily repaired.
12. Not constitute a hazard itself (without splinters, sharp [or] rough edges, or other sources of injury).
13. Protect against any contingency, not merely against normal operations.
14. Conform with the provisions of American Standards Association codes (now ANSI).

In 1949, the National Association of Mutual Casualty Companies (NAMCC) published the results of its landmark research related to machine guarding titled "Safe Openings for some Point of Operation Guards."[3] This publication pointed out that:

In the design of many types of point of operation guards, it is necessary to make provisions in the way of openings through the guard walls for the entrance of material, removal of finished parts and scrap, and for other purposes. If the material being processed is of such dimension that the opening for its passage must be of such size as to allow the operator to pass his hand through the opening when it is clear of material, and, thereby, to reach into the danger zone, a major portion of the guard's effectiveness is destroyed.

While earlier publications, such as the National Safety Council's 1946 Edition of the *Accident Prevention Manual for Industrial Operations*, present the requirement of machine guard design that the openings in **guards *should be small enough to make it impossible for the operator to place his fingers or hands in the danger zone when the guard is in place***, NAMCC's research sought to determine the various distances that small hands and long arms can reach through various sizes of openings in machine guard components. Given the guard opening size necessary to allow entrance of material to be processed by a machine, research results dictated the distance at which a particular guard must be placed from the danger zone so that when the question is asked, "Can the operator, under any circumstances, reach far enough into the guard to reach the danger zone? – the answer will be NO!" Shortly after the publication of this research, various tables and diagrams summarizing its findings have been reproduced in every major industrial safety text addressing machine guarding (first published in the National Safety Council's *Accident Prevention Manual for Industrial Operations* in 1955, and in all subsequent editions).

The following (safe distance to danger) table was constructed from the original 1949 NAMCC research:

Guard Location Based on Barrier Opening Size	
Distance from Danger (Inches)	Guard Opening Size (Inches)
1-1/2	¼
2-1/2	3/8
3-1/2	½
5-1/2	5/8
6-1/2	¾
7-1/2	7/8
12-1/2	1-1/4
15-1/2	1-1/2
17-1/2	1-7/8
< 30 inches	2-1/8
> 30 inches	6 maximum

In the 2nd edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations* published in 1951, Chapter 6 titled "Principles of Guarding and Transmission Guards," laments that:

Techniques and standards for safeguarding machines and mechanical equipment have reached an advanced stage of development. Nevertheless, for lack of application of these standards and techniques, injuries from operation of unguarded or improperly guarded machinery continue to be a major source of occupational injuries.

Further, Chapter 6 states that:

One of the important factors which impedes...correct machine guarding is the too[often] prevalent idea that it is enough to guard a machine so that the operator must be constantly alert to compensate for the inadequacy of the guard, and thereby escape injury. Dependence upon operators or other exposed workmen to use good judgment is neither positive nor permanent. Even after great effort establishes a healthy awareness and respect for mechanical exposures in the working force, impulse, snap judgment, distraction, or some other factor reduces or nullifies all the training and supervisory effort. The text goes on to say that, *it is illogical and an evasion of responsibility by management [machine designers] to expect the most reliable worker always to be alert when working close to unguarded, moving machinery. In such cases, if the condition is allowed to continue, an accident is virtually certain.*

Regarding guard design, this edition advocates that guards should:

Table 1 – NSC's Accident Prevention Manual for Industrial Operations, 1951

1. Conform to the standards of the ASA or the inspection department having jurisdiction (currently ANSI, OSHA, etc.).
2. Be considered a permanent part of the machine or equipment.
3. Afford maximum positive protection.
4. Prevent access to the danger zone during operation.
5. Not weaken the structure of the machine.
6. Be convenient; it must not interfere with the efficient operation of the machine nor cause discomfort to the operator.
7. Be designed for the specific job and specific machine, with provisions made for oiling, inspection, adjusting, and repairing of the machine parts.
8. Be durable, resistant to fire and corrosion, and easily repaired.
9. Be constructed strongly enough to resist normal wear and shock, and to withstand long use with minimum maintenance. It should not, itself, present hazards such as splinters, pinch points, shear points, sharp corners, rough edges, or other sources of injury.
10. If possible a guard covering rotating parts should be interlocked with the machine itself so that the machine cannot operate unless the guard is in place.

The 3rd edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations* was published in 1955. Beginning with this edition, the Council set forth certain "Ultimate Goals" for "Removing the Hazard from the Job" (Chapter 4), stating that the engineer's planning and follow-through process should include such measures as will attain one or more of the accident prevention goals listed as follows, **in the order of effectiveness and preference** (*Table 2*):

Table 2 – NSC's Accident Prevention Manual for Industrial Operations, 1955

1. Elimination of the hazard from the machine, method, material, or plant structure.
2. Guarding or otherwise minimizing the hazard at its source if the hazard cannot be eliminated.
3. Guarding the [machine operator] through the use of personal protective equipment if the hazard cannot be eliminated or guarded at its source.

The Council further stated that:

Policies should be such that safety can be designed and built into the job, rather than added after the job has been put into operation. Each level of engineering should be given the responsibility for building safety into the job, right through the production phase. Such responsibility should be extended to product design, machine design, plant layout and condition of premises, selection and specification of materials, production planning, time and methods study, and the various supervisory and worker job assignments [specific training].

Chapter 23 of the 1955 *Accident Prevention Manual*, titled "Principles of Guarding and Transmission Guards," continued to recognize the major importance of injuries resulting from unguarded or improperly guarded machinery for lack of application of machine guarding techniques and standards, and provided a list of "acceptable guarding requirements" as criteria for guard design (see Table 1).

Here the Council continued to lament that…

...too prevalent idea that it is enough to guard a machine in any fashion -- adequate or not, [and that] often the result is that the operator must be constantly alert to compensate for the inadequacy of the guard, in order to escape injury. Further, the Council stated that *accept[ing] the importance of machine safeguarding*

is the first great need on a countrywide scale. The second great need is to change the too universal attitude of "afterthought guarding" to "forethought guarding."

The 4th edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations* was published in 1959. Chapter 4, "Removing the Hazard from the Job," continues to list the "Ultimate Goals" as outlined in (Table 2) of the 1955 edition, and once again states that such measures, listed **in the order of effectiveness and preference**, should be engineered or *built into the job* by those responsible for plant layout and machine design. That is, *the drafting board is where safety begins as a part of the designer's concept.*

Chapter 23 of the 1959 edition, titled "Principles of Guarding and Transmission Guards," also reiterates the paramount need for machine guards presented in earlier editions stating:

If a method of guarding a hazardous mechanical condition or exposure is known, there can be no valid reason for not using it. Absence of injury from operating an unguarded or partially guarded machine for a period of time is not proof that the moving parts of the machine are not dangerous. The experience of fifty years of organized accident prevention had demonstrated that it is unwise to place principle reliance on cooperation, training, or constant attention on the part of the operator. Human nature is unpredictable, people are subject to mental and physical lapses, and not even a normally attentive and careful person can be relied upon all the time.

Chapter 23 of the 1959 edition of the *Accident Prevention Manual* points out that the basic purpose of machine guarding is to protect against injury from the following sources:

Table 3 – NSC's Accident Prevention Manual for Industrial Operations, 1959
1. Persons making [direct] contact with moving parts of machines.
2. Work in process making contact with personnel (kickbacks on a circular ripsaw, metal chips from a machine tool, splashing of hot metal or chemicals, etc.).
3. Mechanical failure.
4. Electrical failure [or other machine malfunctions].
5. Human failure (curiosity, zeal, distraction, fatigue, etc.).

As in earlier editions, a list of "acceptable guarding requirements" is supplied (see Table 1). This edition also extended the discussion of interlocking guards. The Council states that where a fixed guard cannot be used, an interlocking guard should be fitted onto the machine as the first alternative. The purpose of the interlocking guard is to prevent operation of the control that sets the machine in motion until the guard is moved into position so that the operator cannot reach the point of operation or the point of danger. To be effective, the Council states that *an interlocking device* (mechanical, electrical, pneumatic, etc.) *must satisfy three requirements:*

1. It must act to guard the dangerous part before the machine can be operated,
2. It must keep the guard closed until the dangerous part is at rest, and
3. It must always prevent operation of the machine if the interlocking device fails.

Also in 1959, the U.S. Department of Labor published its first edition of a machine guarding booklet titled *The Principles and Techniques of Mechanical Guarding*, designated Bulletin No. 197 -- later revised in 1973 as OSHA 2057, and in 1980 as OSHA 3067 -- for use by safety inspectors, safety engineers, and those who design or build machine guards. This publication outlined *the broad principles of mechanical guarding applicable to all guarding situations.*

This publication recognized that certain machine motions or mechanical actions are hazardous and *are not [particular] to any one machine or industry but are basic to mechanical devices used for productive purposes.* Common hazardous machine motions identified include *rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and parts that impact, shear, punch, or bend.* A particular hazard associated with machine components that rotate, identified as an *in-running nip [or pinch] point*, is also described as being created whenever machine parts rotate toward each other, or where one part rotates toward another stationary part.

When any of the discussed hazardous motions or actions are present in any machine, the Department of Labor states that *a means for providing protection for the operator and fellow workers is essential.* Methods of guarding are grouped under four main

classifications: (1) Enclosure Guards (both fixed and adjustable), (2) Interlocking Guards (enclosure, gates, or barrier guards combined with electrical or mechanical interlocking devices, or electronic presence sensing devices), (3) Automatic Guards (such as devices that push hands away from hazards during machine operation cycles, machine designs that limit unnecessary or undesirable movement, and devices that release pressure), and (4) Remote Control, Material Placement, Feeding, and Ejecting machine designs or devices (such as two-hand trip devices, automatic machine feed, use of special components of hold material being worked, or the use of special handtools).

In 1962, the National Safety Council published its first booklet similar to the Department of Labor's machine guarding series (Bulletin, 197; OSHA 2057, and OSHA 3067) titled "Guards Illustrated" (revised editions issued in 1969, 1973, 1981, 1987, and 1993). As in earlier Council publications, the 1962 edition recognized that even the most highly-trained and well-coordinated workers commonly sustain injuries on un-guarded or inadequately guarded machines and equipment, and that *this variable human element can be reduced or eliminated as a factor in machine accidents only by effective guarding.* Further, this edition cautions:

Many people believe that if a hazard is in a remote location, guarding is not essential because the possibility of exposure to the hazard is limited. The fallacy of this reasoning is amply demonstrated by the fact that supervisory, maintenance, and service personnel have sustained numerous injuries from hazards [that were thought to be] "guarded by location." Moreover, the frequent excuse that these persons acted "carelessly" or without authorization in no way helps to solve the problem.

The 1962 edition of *Guards Illustrated* continued to point out that the basic purpose of machine guarding is to protect against injury from a variety of sources (see Table 3). Like its Department of Labor counterpart (*The Principles and Techniques of Mechanical Guarding, 1959)*, the Council recognized in its 1962 *Guards Illustrated* publication (and later editions confirmed) that *all machinery movement basically consists of a few simple mechanical motions. Mechanisms employ rotary motion, reciprocating motion (back-and-forth motion), or a combination of the two. When these mechanical motions are clearly understood, all the danger points of a machine can be identified.*

The 1962 edition of *Guards Illustrated* also re-stated 10 basic characteristics of effective machine guards listed in earlier Council publications as covered (combined) in Table 1.

The 5th edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations* was published in 1964. Chapter 4, "Removing the Hazard from the Job" modified [upgraded] its earlier list of basic preventive measures as follows, again **in order of effectiveness and preference**:

Table 4 – NSC's Accident Prevention Manual for Industrial Operations, 1964
1. Elimination of the hazard from the machine, method, material, or plant structure.
2. Control the hazard by enclosing or guarding it at its source.
3. Train personnel to be aware of the hazard and to follow safe job procedures to avoid it.
4. Prescribe personal protective equipment for personnel to shield them against the hazard.

Expounding on this list, the Council maintained that:

If the hazard can be eliminated, none of the other steps need be taken. If all possibilities have been exhausted and the hazard is still not removed, then every effort should be made to enclose or guard the hazard at its source so that exposure to injury is controlled. In some cases, this measure can be just as effective as elimination of the hazard, but it is usually second best. If either of the first two measures can be successfully employed, the need for on-the-job training to protect personnel against hazards is either eliminated or greatly reduced, and use of personal protective equipment may be found unnecessary. As earlier stated, this edition recognized that *the drafting board is where safety begins as a part of the designer's concept*, and then added that *safety "designed" into equipment, processes, and plants reduces the need for training and supervision.*

Chapter 22 of the 1964 *Accident Prevention Manual*, titled "Principles of Guarding and Transmission Guards," updated its urging to rely on positive machine guarding over strict adherence to procedures to protect workers:

A hazardous mechanical condition or exposure is one which has caused or could cause an injury. Absence of injury from operating an unguarded or partially guarded machine for a period of time is not proof that the moving parts of the machine are not

dangerous. It is unwise to rely entirely on cooperation, training, or constant attention of the operator. Human nature is unpredictable, and not even an attentive and careful person can be relied upon all the time.

As in earlier editions, Chapter 22 of the 1964 edition also discusses various hazardous mechanical motions and the types of guards used to safeguard them, points out that the basic purpose of machine guarding is to protect against injury from a variety of sources (see Table 3), and provides a lists of "acceptable guarding requirements" (see Table 1).

Chapter 22 also continues to emphasize the need for "built in" guards and the general lack of application of advanced standards and techniques of machine guarding on the part of machine manufacturers, and by default, the necessity of machine owners to install after-purchase guarding. Depending on a purchaser's knowledge and expertise in this area, the need for such guards may not be recognized or the fabrication of the guards may be less than adequate. In contrast, the Council stated that *a manufacturer's guards usually are designed to be an integral part of the machine and are therefore superior to homemade guards*, and continues to stress and reiterate the primacy of removing hazards from equipment and facilities through engineering when it states that *the basic principles of safeguarding equipment are (1) engineer hazards out of the job, (2) guard the hazard, and (3) educate personnel to use the safeguards provided.*

The 6th edition of the National Safety Council's *Accident Prevention Manual for Industrial Operations* was published in 1969. This edition restates directives regarding the basic measures for preventing accidental injury, **in order of effectiveness and preference**, as were presented in their 1964 edition (see Table 4), and once again, extols the fact that *the drafting board is where safety begins* and that the goal is to *design environments and equipment, and to set up job procedures, so that employee exposure to injury will be eliminated or controlled as completely as possible during [its] manufacture, so the product can be used safely by the purchaser* without or minimizing the need for training and supervision. This reference simply states that *every effort should be made to find and remove potential hazards at the blueprint or planning stage* and that *if an engineer has left an avoidable hazard in [a design or job], he has not fully met his responsibility*.

Further, the 1969 edition of the Council's *Accident Prevention Manual***,** within its Chapter 24 regarding "Principles of Guarding and Transmission Guards," continues to stress the primacy of removing hazards from equipment and facilities through engineering means, reaffirms that adequate machine guarding must be concerned with more than point-of-operation and power transmission machine parts to address all hazards from a variety of sources *on or around machines* (see Table 3), and offers a list of desirable machine guard characteristics (Table 1).

On December 29, 1970, the President of the United States signed into law the **Occupational Safety and Health Act of 1970** (PL 91-596) that went into effect on April 28, 1971, the purpose of which was 'to assure safe and healthful working conditions for working men and women."

Under Section 5(a)(1) of the Act, every employer was given the general duty to "furnish to each of his employees employment and a place of employment which are free of recognized hazards that are causing or are likely to cause death or serious physical harm." Under Section 5(a)(2) of the Act, every employer was also given the specific duty to "comply with occupational safety and health standards [that would be] promulgated under the Act."

As of the date of this publication, the entire OSHAct of 1970 is available through www.osha.gov, or directly at:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=OSHACT&p_id=2743#5

The specifics of OSHA standards regarding the requirements for machine guarding for all machines, and select specific machines, will be addressed in the third publication in this series of three Nelson & Associates Fact Sheets titled "Machine Guarding, Concepts and Technology, Part III, Post OSHA, 1970 to Present."

See also Nelson & Associates Fact Sheets titled (1) "Machine Guarding, Historical References, Part I, Circa 1900 to 1946," and (2) "Machine Guarding Concepts and Technology, Part III, Post OSHA, 1970 to Present."