ISSN 1041-9489

SAFETY BRIEF

February 2000 Volume 16, No. 3

Triodyne Inc.

Consulting Engineers & Scientists – Safety Philosophy & Technology

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Power Transmission Safety Standards

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ABSTRACT

The development of the Safety Standard for Mechanical Power Transmission Apparatus has been plagued by changing definitions and a penchant for expanding the scope of power transmission applications. The current code gives examples of devices which do not transmit power and, in some cases, represent points of operation. Power transmission hazards are increasingly being defined in terms of motion. The notion that mechanical hazards may be characterized as either point of operation or power transmission is a fundamental error that persistently plagues the "rule making" process.

INTRODUCTION

Moving mechanical elements are always hazardous; they produce injuries by such well-known mechanisms as impact, crushing, abrading and shearing. To minimize the number of these injuries, exposure to the moving elements is prevented by a variety of risk control countermeasures such as barrier guards, pullback devices, light curtains and proof testing protocols. Succumbing to the urge to break things down into basic building blocks, some rule makers and standards developers have attempted to organize motion hazard counter-measures. Unfortunately, they have chosen only two categories which are not jointly exhaustive – point of operation and power transmission.

Mechanical work or energy is created when a force moves through a distance. Power is the amount of work performed per unit of time. Machines deliver power to perform functions such as shaping workpieces or removing material. To direct or focus power to accomplish their objectives, machines must transfer the power from some source, say an electric motor, to specific locations on the machine, like drive wheels or saw blades. The mechanical contrivances which transfer power are called Power Transmission Apparatus. Those points at which cutting, forming or other functional changes of processed materials occur are collectively referred to as the "point of operation." Ironically, having honed our students to finally understand that a point has no dimensions, we continue to incorrectly use point of operation to identify a spatial volume.

To demonstrate that the two categories, point of operation devices and power transmission apparatus, are not mutually exclusive and jointly exhaustive, a number of fundamental examples will be discussed:

A. Rectilinear Translation

According to Newton's First Law, "Every body continues in its state of rest or of uniform motion in a straight line except insofar as it may be compelled by force to change that state." [Ref. A] Consequently, we may have a motion hazard without force, without work, and without power. There is no point of operation and no power transmission.

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This paper will be published in the Proceedings of the American Society of Mechanical Engineers' International Mechanical Engineering Congress and Exposition in November of 2000.

B. Motion Indicators

A speedometer monitors motion; it transmits information, not power. Furthermore, it does no processing of workpieces. It is not a point of operation device and it is not a power transmission apparatus. Its safety may, nevertheless, be governed by power transmission standards. Mechanisms such as cables and gears transfer machine motions to the speedometer and in the process absorb energy due to internal friction. No net power is delivered to the speedometer. It should be noted that a speedometer may be located somewhere between an energy source and a point of operation.

C. Milling Machine Cutters

Figure 1 shows a milling machine cutter. According to the American National Standards Institute standard for milling machines, ANSI B11.8-1983, the portion of the cutter in contact with the workpiece is called the point of operation. [Ref. B] The teeth that are rotating in the air are not transmitting power to anything. They certainly constitute a hazard, but they are not power transmission apparatus nor are they point of operation devices. The ANSI B11.8-1983 standard does not consider the cutter to be a machine component.

D. Lathe

Lathes used for shaft work, i.e., workpieces supported between the head stock and the tail stock, provide an example where the workpiece itself provides the power transmission to the point of operation at the stationary tool. The workpiece has the appearance of an ordinary rotating shaft and presents the same dangers. Nevertheless, the various power transmission standards have never addressed workpieces.

One normally appeals to specific machine standards for rules regarding workpiece and point of operation safety. For example, the following admonitions may be found in the American National Standard for Lathes, ANSI B11.6-1984 [Ref. C]:

> 5.2 *Point-of-Operation Hazard*. The point of operation on lathes will not require safeguarding. The chips generated, the coolant, the rotating workpiece, and trapping area that exists when the tool approaches the workpiece may constitute a hazard.
>
> 5.3.1 *Other Hazards Associated with the Work-Holding Device and Workpiece*. All hazards associated with the work-holding device and rotating workpiece shall be eliminated or minimized where possible. Where the hazard cannot be eliminated by design or protection, precautionary instructions shall be given.

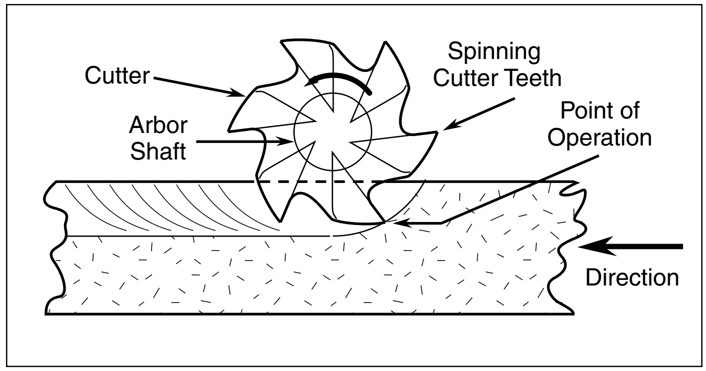

Figure. 1: Milling Machine Cutter

It should generally be noted that in cases of conflicting rules dedicated safety standards always take precedence over the general power transmission standards. Further, dedicated standards may address any hazard within their purview whether they are neatly classified or not.

E. Drill Bit

The American National Standard covering drilling machines, ANSI B11.8-1983, defines the point of operation as follows:

> 2.20 *Point of Operation*. That point or area where the cutting edge(s) of the tool is in contact with the workpiece.

During drilling, one of the functions of the exposed portion of the drill bit shank is to transmit torque and power to the point of operation. For this reason, it is regularly argued by the plaintiff's bar that such shafts with their aggressive flutes fall under the aegis of the power transmission standards. On the other hand, the drilling standards say the drill bit is not a machine component. Furthermore, according to ANSI B11.8-1983, no safeguarding is required in the manual mode even though the rotating bit is a recognized hazard:

> 5.2 *Point-of-Operation Hazard*. The point of operation on machines, as defined in this standard, will not require safeguarding. The chips generated, the coolant, the rotating cutter(s), and the trapping area that exists when the tool approaches the workpiece may constitute a hazard.
>
> 5.3 *Rotating-Cutter Hazard*. A guard, guarding device, or awareness barrier shall be required when rotating-cutter teeth are exposed on a machine in the automatic or semiautomatic mode and when it is necessary for any part of the operator's body to be within 1 foot of the rotating cutter for the purpose of loading, unloading, adjusting, measuring, cleaning up, or other similar duties that would place the operator in the hazard area...

There is an important distinction between classical power transmission shafts and the shank of a drill bit. The former is a single purpose device, whereas the drill bit shank is multifunctional. The flutes in the shank provide for chip removal and cooling. The bending stiffness of the shank controls the spatial location of the drill point and prevents the development of whipping instability. Finally, the stability of the shank allows the drill bit to be thrust into the workpiece without buckling.

F. Prime Movers

Prime movers are the power sources in machines; they do not transmit power. The earliest literature on power transmission machinery appeared in 1916 and 1918 and did not include prime movers. [Refs: D, E & F] The first code to include them with power transmission equipment appeared in 1924 as Bulletin No. 364, U.S. Bureau of Labor Statistics: Safety Code for Mechanical Power-Transmission Apparatus. [Ref. G] This code began the long torturous slide into irrationality which continued unabated into 1996.

G. Flywheels

A flywheel is a mechanical battery for storing work as kinetic energy. Its job is not the transmission of power. The construction of flywheels often incorporates spokes that augment the usual hazards associated with rotary machinery. Power may be delivered or removed from flywheels through belts or shafts. The belts and shafts themselves are single purpose devices for transmitting power; their safety falls within the scope of the power transmission standards.

Despite the fact that the flywheel does not transmit power, every code and standard on power transmission apparatus includes the flywheel.

H. Counterweights

Almost every power transmission code and standard includes counterweights. The 1996 version of the Mechanical Power Transmission Apparatus standard promulgated by the American Society of Mechanical Engineers, ASME B15.1-1996, depicts the counterweight hazard shown in Fig. 2. Counterweighted apparatus usually include air springs, mechanical springs or actual weights. They invariably operate cyclically, i.e., they always return to their starting positions. Because these systems are conservative, no net energy is transferred. For example, the energy expended in lifting a weight is recovered when the weight is lowered. During its cycle there is, of course, a transfer of power into and out of the system.

Counterweights are never point of operation devices. They are often regulated by dedicated safety standards such as ANSI B11.8-1983 for drilling, milling and boring machines, e.g.:

> 3.3 *Antimotion Mechanisms or Counterbalance*. Antimotion mechanisms or counterbalance systems shall be provided to prevent or retard unintended motion where the motion will create a hazard. In the event of failure, unintended motion shall not exceed the maximum designed rapid-traverse rate or travel beyond an end limit.
>
> 3.3.1 *Counterweights*. Counterweights shall be designed, located, or guarded so they will not present a hazard to personnel.
>
> 3.3.2 *Spring Counterbalance*. Spring counterbalance systems, when used, shall incorporate a safe means for disassembly. A warning sign shall be provided if improper disassembly can create a hazard to personnel.
>
> 3.3.3 *Hydraulic or Pneumatic Counterbalance Systems*. Hydraulic or pneumatic counterbalance systems shall include a self-energizing locking or retarding mechanism when the motion could constitute a hazard.

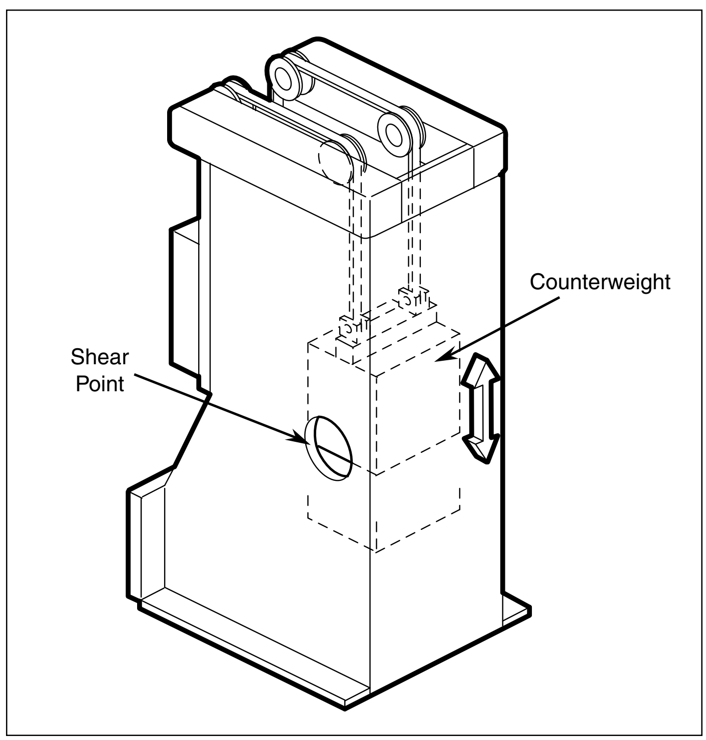

Figure 2: Counterweight Example (ASME B15.1-1996)

3.3.5 *Counterweight Support Chains or Cables*. Guarding shall be provided to prevent a hazard from whipping of counterweight support chains or cables in case of failure.

Observe that only paragraph 3.3.1 is covered in the power transmission standards. Fortunately, the more complete admonitions are contained in a dedicated standard that takes precedence.

The examples make it abundantly clear that motion hazards exist that cannot be classified as point of operation hazards or power transmission hazards. Rotating shafts may appear as workpieces, tooling, point of operation devices or power transmission devices; they all present the same hazards and they all transfer power. Some are covered by dedicated machine standards, some by power transmission standards and some fall outside the scope of both. Counterweights, which deliver no net power, may be covered by both dedicated and power transmission standards. Devices that do not transfer energy, but are used exclusively for the storage of mechanical energy or motion indication, may nevertheless fall within the purview of power transmission standards.

For the motion hazards addressed in the various examples, the focus and treatment of their associated dangers is illogical and inconsistent. There is only one common denominator among the various examples: safety. Using safety as a unifying concept, the European Community has approached the regulation and guidance of danger countermeasures without reference to the function of candidate contrivances.

POINT OF OPERATION - DEFINITIONS

The term "point of operation" is not used, defined or required in the first power transmission code which was issued in 1918 by ASME or in the various OSHA regulations 29CFR1910.219 promulgated after 1970. In July, 1923 and in November, 1926, the U.S. Department of Labor, Bureau of Labor Statistics and the American Engineering Standards Committee developed safety codes entitled "Safety Code for Mechanical Power-Transmission Apparatus." These codes adopted the following definition of point of operation:

> Point of Operation - the term "point of operation" shall be understood to mean that point at which cutting, shaping, or forming is accomplished upon the stock and shall include such other points as may offer a hazard to the operator in inserting or manipulating the stock in the operation of the machine.

The American National Standards Institute utilized this definition in their 1927, 1935 and 1953 power transmission standards designated as ASA B15-1927, ASA B15-1935 and ASA B15.1-1953 respectively.

In 1972, ANSI published a new definition of point of operation in their standard ANSI B15.1-1972: [Ref.H]

> Point of Operation. The term "point of operation" shall be understood to mean that point at which cutting, moving, forming or other functional change is accomplished upon the processed material.

In subsequent safety standards for mechanical power transmission apparatus, ANSI/ASME B15.1-1984, ANSI/ASME B15.1-1992 and ASME B15.1-1996, ANSI dropped the word "moving" from their definition of point of operation: [Refs: I, J & K]

> Point of operation: shall be understood to mean that point at which cutting, forming, or other functional change is accomplished upon the processed material.

It took 57 years to adopt this latter definition which, finally, conforms to that used by the rest of the safety profession.

We shall see in the following section that the scope of power transmission standards excludes point of operation. As a consequence, devices erroneously included in the definition of point of operation are automatically removed from the jurisdiction of the power transmission standards; this may compromise a machine's safety. For example, the first definition of point of operation would exclude a power transmission device from the power transmission standard simply because it exposes an operator to a hazard during manipulation of the stock. Good Grief!

POWER TRANSMISSIONS STANDARDS - SCOPE

In the preparation of codes, standards, statutes and regulations, the goal when writing the "scope" is to clearly and accurately define the extent of coverage and the applicability of the associated documents. This is usually accomplished using statements of coverage, exclusions, exceptions and examples. Scope writers must ever be mindful of the forces wishing to either extend or restrict the range of a scope into unintended areas.

The following sequence of power transmission codes and standards is an odyssey marked by ever decreasing intellectual substance. The various "scopes" are internally inconsistent and the proffered examples tend to mystify rather than illuminate the general statements:

1918 - "A Code Of Safety Standards for Power-Transmission Machinery," <u>ASME No. 1598</u>. American Society of Mechanical Engineers.

Scope: **Rules and requirements for the protection of industrial workers from hazards commonly presented by mechanical equipment used for transmitting and distributing power from the prime movers to the various power-utilizing machines, tools and devices.**

The following specifications describe standard guards for all power-transmission equipment hereinafter mentioned, and apply to all main shafting, jack shafting, drive shafting and counter shafting, and their belts and other attachments up to but not including belts actually driving machines.[1]

[1] Belts actually driving machines will be considered "machine belts," and therefore a subject for machine codes.

This first code is singular because it focuses exclusively on power transmission devices. It does not cover prime movers and it does not address machines and devices that do not utilize power. No definitions of point of operation or power transmission apparatus are included in the code; none are necessary since the code speaks only to the devices specified. It is noteworthy that every device addressed is a single purpose or single function contrivance.

1923 - "Safety Code for Mechanical Power-Transmission Apparatus," No. 364. U.S. Department of Labor (Tentative American Standard).

Scope: **This code applies to all moving parts of equipment used in the mechanical transmission of power, including prime movers, intermediate equipment and driven machines, excluding point of operation.**

Note - The safeguarding of all connecting rods, cranks, flywheels, shafting, spindles, pulleys, belts (except flat belts 1 inch or less in width or round belts one-half inch or less in diameter), link belts, chains, ropes and rope drives, gears sprockets, friction drives, cams, couplings, clutches, counterweights, revolving or reciprocating parts, up to but not including point of operation, also all bolts, keys, set screws, all cups or similar projections shall be included in and be in accordance with the provisions of this safety code for mechanical power-transmission apparatus.

The first half of the opening sentence of the scope restricts its focus to moving equipment used in the mechanical transmission of power. The second half of the sentence goes on to include prime movers which do not transfer power and which are not exclusively mechanical. Furthermore, it also includes intermediate and driven machines which may or may not transfer power. The note associated with the scope statement embraces flywheels and counterweights which are not power transmission devices. It even includes a general reference to revolving or reciprocating parts up to the point of operation; such parts do not necessarily transfer power, e.g., governor balls which are treated in the text. The text of the code also includes ladders.

Following the 1923 code, three additional codes and standards were published in 1926, 1927 and 1953; U.S. Department of Labor No. 463, ASA B15-1927 and ASA B15.1-1953 respectively. In each case the wording of the scope statement is almost identical to that of the 1923 code.

1972 - "Safety Standard for Mechanical Power Transmission Apparatus," ANSI B15.1-1972. American National Standards Institute.

Scope: **1.1 This standard provides for the protection of people from the motion hazards associated with equipment used in the mechanical transmission of power in industrial and commercial establishments such as factories, construction sites, and business establishments whose premises have limited accessibility to the general public. Installations to be guarded include sources of mechanical power, the associated and intermediate equipment and the driven machines up to, but excluding, the point of operation. This pertains to revolving, oscillating, reciprocating, or other moving parts such as, but not limited to, actuators, backstops, belts, brakes, cams, chains, clutches, collars, compressors, counterweights, couplings, cranks, eccentrics, engines, flywheels, gears, lead screws, motors, power cylinders, pumps, pulleys, shafting, sheaves, spindles, sprockets, turbines and winches.**

The general formulation of the scope follows the spirit of the 1923 code, No. 364, in the sense that point of operation hazards are excluded and power transmission devices are addressed. Further, both codes embrace certain motion hazards that fall into the no-man's-land that is neither point of operation nor power transmission; for example, both include sources of mechanical power.

Although the 1972 scope is equivalent to those promulgated in 1923, 1926, 1927 and 1953, the standard itself is not equivalent. The 1972 standard represents a departure from earlier formats because it presents "performance" criteria rather than specific rules for particular devices. As a consequence, the scope of the 1972 standard is not bolstered by examples of typical power transmission devices such as those found in previous editions of the standards. This places a greater burden on the scope writers to be definitive. Unfortunately, they have not risen to the challenge; instead, they have further confounded the notion of power transmission by referencing actuators, brakes and lead screws.

1984 - "Safety Standard for Mechanical Power Transmission Apparatus," ANSI B15.1-1984. American National Standards Institute.

Scope: **The requirements of this standard apply to any source of hazard to personnel from the operation of mechanical power transmission apparatus on machines, equipment, or systems that are stationary in their use, other than the point of operation. This standard applies to the sources of mechanical power, and also to pulleys, gears, and other mechanical components used to transmit power to the point of operation. Where other standards take precedence by specific reference to**

power transmission apparatus, this B15.1 standard shall not apply.

Definition: Mechanical power transmission apparatus - the mechanical components which, together with a source of power, provide the motion to an element of a machine or equipment.

At first blush there is nothing remarkable about the 1984 scope statement; it tracks very closely the requirements of the earlier standards. It is only when account is taken of the unusual definition of the term "mechanical power transmission apparatus" that the radical nature of the 1984 scope reveals itself. Observe that mechanical power transmission apparatus no longer transfer power; they provide motion to machine elements. We have already established that motion does not imply the transfer of power. The untoward implications of this new standard can hardly be overstated. This new transmission standard is often represented in product liability actions as the governing regulation for a hitherto uncovered class of motion hazards; namely, those that are neither point of operation nor power transmission. Unfortunately, the standard is not competent to embrace this ambitious extension of its scope. Its thirteen pages may be compared to the 1988 British Standard [Ref. L] which directly attacks motion hazards without any artificial classification; it is 161 pages in length and is the standard bearer for the European Community.

The 1984 and almost identical 1996 standard, ANSI B15.1-1996, both utilize a format that provides explanatory information about the various standard requirements. With respect to the scope, the following information is presented in paragraph E1.1 to both clarify and amplify the scope statement:

E1.1 Scope: Hazards to people pertain to the rotating, oscillating, reciprocating, transversing or other motions associated with equipment used in the mechanical transmission of power (see Fig. 1 through 11).

One of the referenced illustrations in the 1984 and 1996 standard is depicted in Fig. 3.

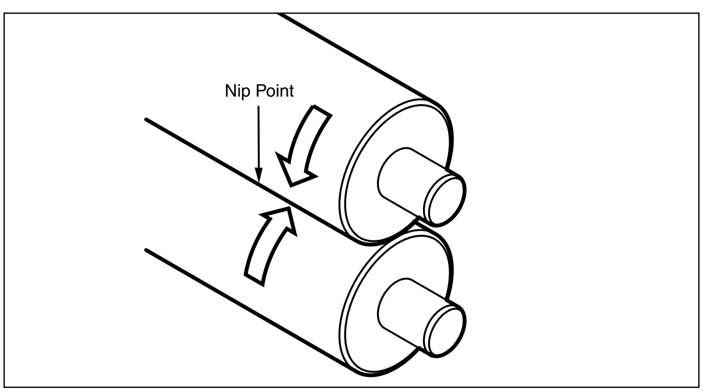

Figure. 3: Rollers - Point of Operation

An inrunning nip point is shown between two rollers which are clearly not being used for the transmission of power. The rollers, in fact, provide a point of operation which is excluded from the scope of every power transmission standard. Another illustration from the 1984 standard appears to be a calender which is a point of operation machine that provides both thickness control and surface texture to a web. This machine, shown in Fig. 4, is expressly excluded from power transmission standards. It is, nevertheless, included as an example of a power transmission apparatus in the 1984 standard; it does

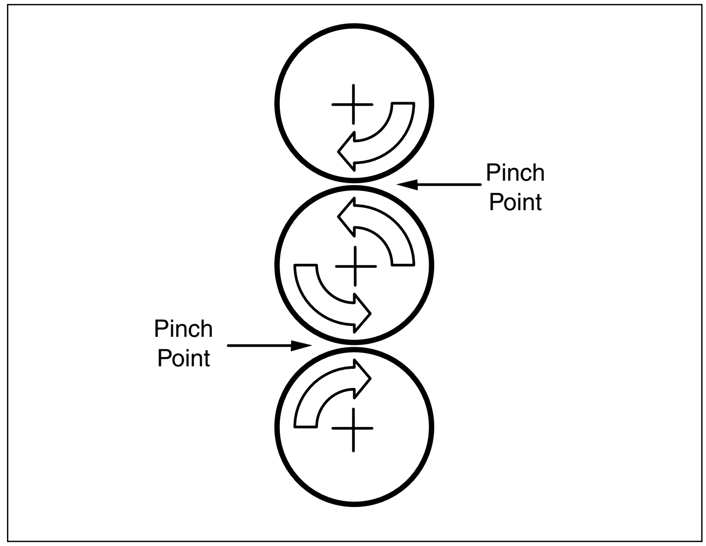

Figure. 4: Calendar - Point of Operation

not appear in the 1996 version. The 1984 standard presents the sliding table/cover mechanism shown in Fig. 5. This device represents a motion hazard that is neither a power transmission apparatus nor a point of operation device. Its

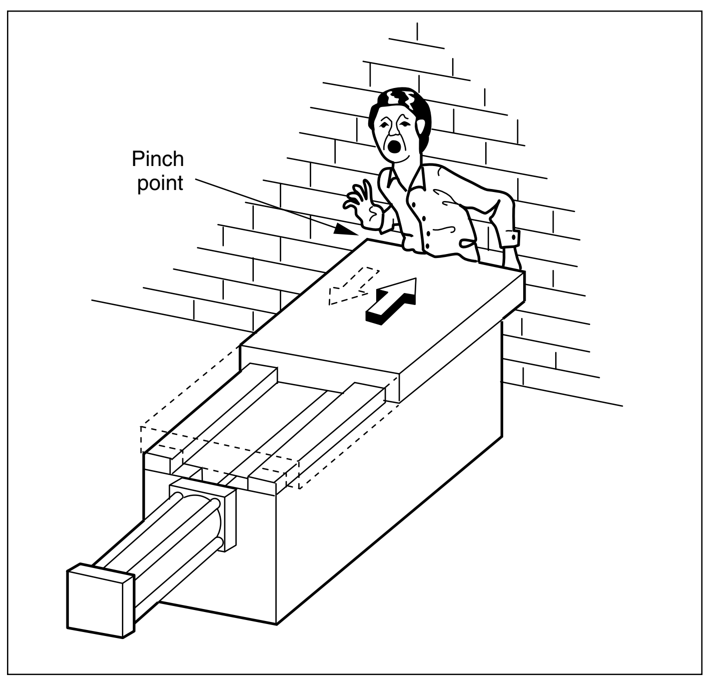

Figure. 5: Sliding Table Cover

presence in the standard is un-fathomable; it too was omitted from the 1996 standard. Figure 6 illustrates a positioning handwheel that is referenced in section E1.1 of both the 1984 and 1996 power transmission standards. It was included to explain the type of equipment used for the mechanical transmission of power. It does not, of course, transmit power.

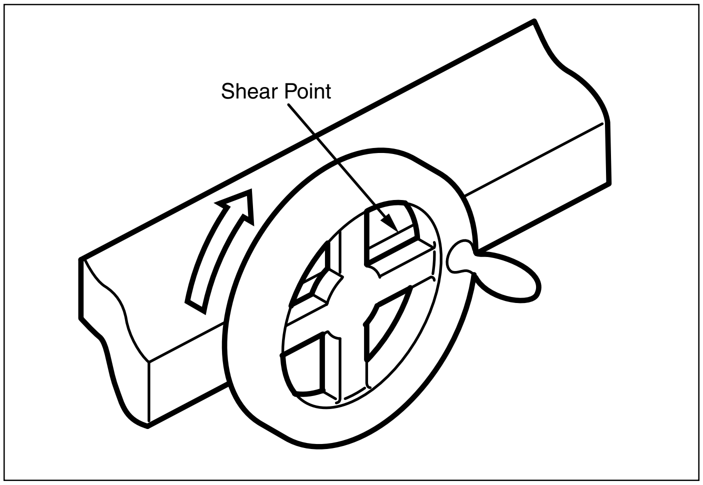

Figure. 6: Handwheel

In summary, the explanatory examples of mechanical power transmission apparatus contained in the 1984 and 1996 standards are pathetic failures; some are point of operation devices specifically excluded from the scopes in these standards, some are proper power transmission equipment, some represent motion hazards that fit the proposed definition of mechanical power transmission apparatus, some are motion hazards that do not meet this definition and some, such as the counterweight shown in Fig.2, are equivocal.

The 1998 regulation, **"Mechanical Power - Transmission Apparatus," 29 CFR 1910.219 Occupational Safety and Health Administration** doesn't include a scope statement. Further, there are no definitions given for point of operation or power transmission apparatus. The regulation launches immediately, without preamble, into detailed rules and admonitions for specific devices. The standard only considers the following apparatus: belt, rope and chain drives; flywheels; cranks and connecting rods; tail rods and extension piston rods; pulleys; shafts; belt tighteners; suspended counter-weights; gears and sprockets; friction drives; keys; setscrews; oil cups; keyways and other projections in revolving parts; collars; clutches; couplings; belt shifters; shippers; poles; bearings and belt perches. Almost every one of these devices may be characterized as follows:

1. They transmit power or they service apparatus that transmit power.

2. They are not point of operation devices.

3. They are uni-functional.

The flywheel, counterweight and the clutch are exceptions; the flywheel stores energy, no net power is transferred by the counterweight and the clutch is a multifunctional device.

The OSHA regulations apply to employers and, unlike the voluntary ANSI standards, have the force of law.

CONCLUDING REMARKS

A. According to the American National Standards Institute, the safety standard for Mechanical Power Transmission Apparatus is the most universally applicable standard concerned with safeguarding mechanical equipment.

B. Mechanical power is a fundamental technical concept that is defined unequivocally. Furthermore, the word "transmit" has a perfectly straightforward definition. In spite of this, every power transmission code and standard embraces devices that do not transmit power. The latest standards have the temerity to redefine "mechanical power transmission apparatus" solely in terms of motion. So much for scholarship!

C. The OSHA regulations and the very first power transmission code from 1918 do not define the phrases "point of operation" or "mechanical power transmission apparatus." They explicitly list the equipment they regulate. All of the remaining codes and standards establish their scopes using various definitions of point of operation and mechanical power transmission apparatus. They also use illustrations and specific references to machine components. The result is an inconsistent hodgepodge of components that may be stationary or moving, that may or may not transmit power and that may or may not be point of operation devices.

D. Every code and standard for mechanical power transmission apparatus covers the titled devices. On the other hand, each new edition of the codes and standards expands its scope into the general area of motion hazards. In addition to power transmission equipment, examples may be found of controls (belt shifters), energy storage (flywheels), prime movers, apparatus repair (ladders), regulators (governor balls) and adjustors (handwheels). Even point of operation devices have crept into the latest standards.

E. Two hallmarks of technology are challenged by the power transmission standards: exacting definitions and consistency.

F. Motion hazards which are not associated with power transmission are treated with more sophistication by dedicated codes and standards than by the power transmission standards.

G. Motion hazards cannot be classified as either point of operation or power transmission. These categories are not jointly exhaustive or mutually exclusive. This fact is a root cause of the logical failure of the standards on power transmission.

H. Setting aside questions of focus, the standards for power transmission are quite emphatic in their demands for machinery protection. The plaintiff's bar seizes upon this characteristic whenever they sense that "dedicated code machines" or "standard free machines" don't address some motion hazard. To obtain the "advantage" of a code violation they will insist that the power transmission standards apply to their particular motion hazard which may include moving workpieces, cutting tools, point of operation devices, etcetera.

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February 2000 – Volume 16, No. 3

Editor: Paula L. Barnett

Illustrated and Produced by

Triodyne Graphic Communications Group