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SAFETY BRIEF

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The Dependency Hypothesis (Part I)

by Ralph L. Barnett[1], Gene D. Litwin[2], and Peter Barroso Jr.[3]

Abstract

This article discusses the types of changes in the man/machine interface which accompany the incorporation of safety systems into a machine. Safety systems introduced to meet narrowly defined safety objectives may give rise to broad secondary effects that subtly or profoundly influence the machine's overall safety and function. Designers and lawmakers alike must understand these secondary effects so they can weigh them against prevailing value systems to determine the overall desirability of safety devices. Some new criteria are described to aid in the evaluation of proposed safeguards.

I. Introduction

When safety systems are imposed on a device, alterations in the man/machine interface occur that may well go beyond the intended effects. **The Dependency Hypothesis** provides a unifying thesis under which observations of safety system effects can be made in an organized manner. Our ultimate concern is that the side effects of safeguards do not compromise the overall system safety. Safeguards which increase danger under some circumstances have been classified as Types IV and V by Barnett and Barroso and are discussed in reference 4. A critical review of almost twelve thousand accident investigations over the period from 1969 to 1983 has revealed the following relationship:

Dependency Hypothesis – Every safety system gives rise to a statistically significant pattern of user dependence.

This may be stated in legal jargon: "User dependence on safety systems is foreseeable." User dependence on safety systems commonly results in three forms of system misuse: **misuse as control systems, misuse in kind, and misuse in magnitude.** In addition, people properly use and depend on safety systems that are in fact, inadequately designed for their intended uses.[5]

II. Misuses as Control Systems

Many safeguarding systems protect by *overriding normal machine operation*. They may, for example, freeze motion, prevent start-up, return members to home base, or temporarily remove hazards. As users become familiar with the characteristics of these safety systems, a certain percentage of them will use the safeguards to control the machines.

1. Elevator Door Problem Almost the entire community of elevator users knows that conventional elevators have a safety device in the leading edges of their doors which will stop and/or reverse the closing door when the door edge contacts a passenger. It has become a classical misuse of the "safety edge" to employ it as a

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[4]*Proceedings of the Thirty-Seventh Annual Meeting of the National Conference on Fluid Power*, Chicago, Illinois, 1981.
[5]Inadequate design will be addressed in Part 2 of this article, in an upcoming *Triodyne Safety Brief*.

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control device for manually interrupting the closing door to accommodate passengers arriving late.

2. Anti-Two-Blocking Device For several decades, overhead cranes have incorporated upper limit switch devices which prevent the movable hoist block from contacting the stationary members of the hoisting system. Without such devices, the resulting "two-blocking" enables the hoisting mechanisms to develop excessive line pulls (e.g. stall torques of electric motors are often an order of magnitude greater than normal torques) which frequently fracture the hoist line. The upper limit switch was introduced as a *back-up* for the operator who might accidentally hold the "hoist-up" control too long.

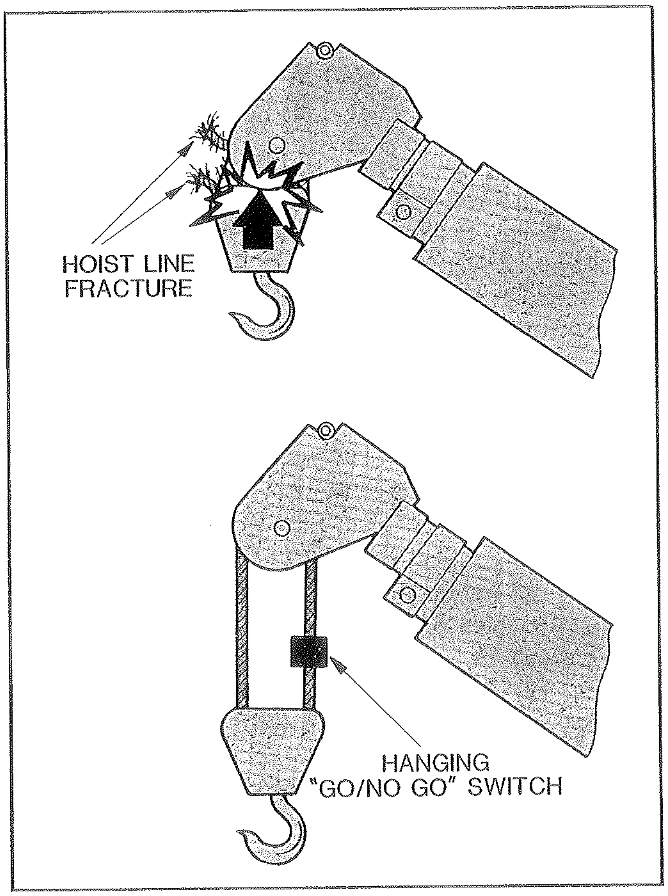

Fig. 1. Anti-Two-Blocking Device

In fact though, operators regularly *depend* on the anti-two-blocking devices to automatically shut off the hoist mechanism when the hook is raised as high as possible. This use of the safety device as a *control* enables the operator to concentrate on "other things" instead of watching the movable block or load as recommended universally as proper crane safety practice. The safety device thus becomes a *substitute* for the operator rather than a *back-up* to the operator.

There is nothing intrinsically wrong with using anti-two-blocking devices as controls if their reliability is sufficiently high. This, however, does not currently appear to be the case. The following excerpts from the crane literature caution against dependence on such devices as controls:

(a) "Overhead and Gantry Cranes," 29 CFR 1910.179, Washington, D.C., Occupational Safety and Health Administration, November 7, 1978, p. 325.

"...(ii) The hoist limit switch which controls the upper limit of travel of the load block shall never be used as an operating control...."

(b) "Operating Rules," Title 8, Register 80, No. 3, Para. 1587.11(b), Construction Safety Orders, Division of Industrial Safety, State of California, (1-19-80), p. 160.13.

"...(b) The limit switch shall never be used as an operating control unless designed for such use, in which case there shall be a second limit switch located behind the operating control limit switch...."

(c) Grove: Anti-Two-Block Warning System.

"Operator awareness of the hazards of two-blocking is the most important factor in preventing the condition."

"The Grove Anti-Two-Block System is intended to assist the operator in preventing dangerous two-block conditions. It is not designed as a replacement for operator awareness and competence."

(d) Krueger Crane Systems Inc.: Anti-Two-Block

WARNING

THE SYSTEM UTILIZES A SERIES OF ELECTRICAL AND MECHANICAL COMPONENTS AND CANNOT BE 100% FAIL-SAFE.

WARNING

DO NOT CONSIDER THE SYSTEM A SUBSTITUTE FOR GOOD JUDGMENT, EXPERIENCE, AND ACCEPTED SAFE CRANE OPERATING PRACTICES.

3. Interlocking Barrier Guards There is a class of barrier guards which is monitored by *go/no go* devices such as electric limit switches. These so called interlocks function principally either to prevent powered operations when a shield is open or to remind users to replace barriers before operating a machine. Frequently, operators will shut off a machine by opening a shield rather than by depressing a stop button located at a control station. Indeed, home laundry dryers are shut off almost exclusively by opening and closing the access door/guard. Fortunately, the hazard created by a home dryer's drift, or run-down, is miniscule. This is not the case with most industrial equipment.

3. Pull-back Devices The classical pull-back safety devices found on punch presses are essentially cable systems which attach to wristlets and draw the operator's hands back, away from the point of operation, whenever the ram descends. If the operator forgets to remove his hands during the dangerous portion of the punch press stroke, the pull-backs will extract his hands to prevent injury. It is not uncommon on slow machines for operators to leave their hands in the point of operation and depend on the pull-back device to extract their hands at the appropriate time. Here, the pull-backs are misused to overcome operator laziness. Instead of backing up the operator, the pull-back devices replace the operator's personal diligence.

4. Clutch Safety Shoulders: Redundancy On full revolution punch presses, many of the clutches incorporate a safety shoulder, or interference device, which blocks the motion of the crankshaft in the event of brake failure. A small percentage of punch press users allow the brake system to become totally ineffective but continue to use the punch press. They depend entirely on the safety shoulder to stop the cycle after each stroke. The safety shoulder eventually breaks down under this type of use and fails to stop the cycle, allowing the ram to descend while the user is removing a finished part.

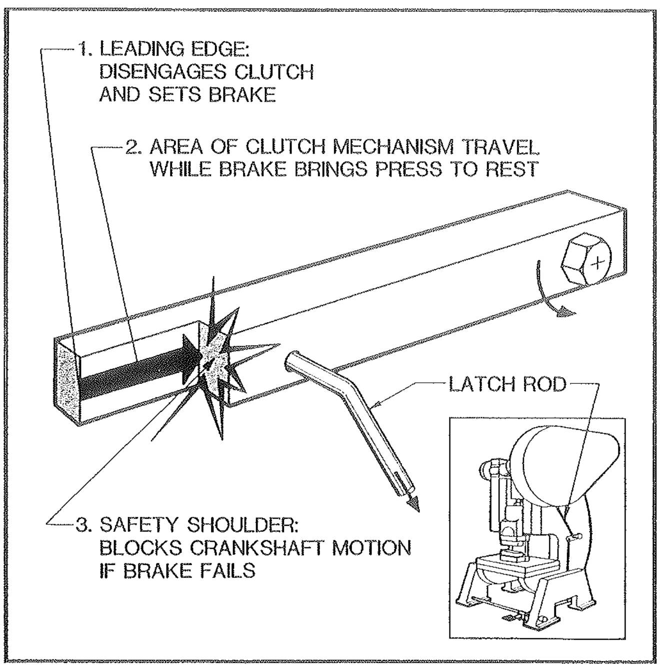

Fig. 4. Safety Shoulder/Full Revolution Punch Press

5. Crane Hook Safety Latches In order to prevent slack rigging from escaping the throat of a crane hook, a safety latch, safety finger, or mousing is used to bridge the hook opening. The anticipated use of safety latches does not subject them to significant forces since they act only to restrain slack rigging. However, the presence of the safety latches enables operators to fill the hook with more shackles and cables than the hook could accommodate without the safety latches. Overloaded, the latches are subjected to very large forces as the rigging tries to escape from the normal contours of the hook during lifting. Many safety fingers fail under such circumstances and the loads are dropped.

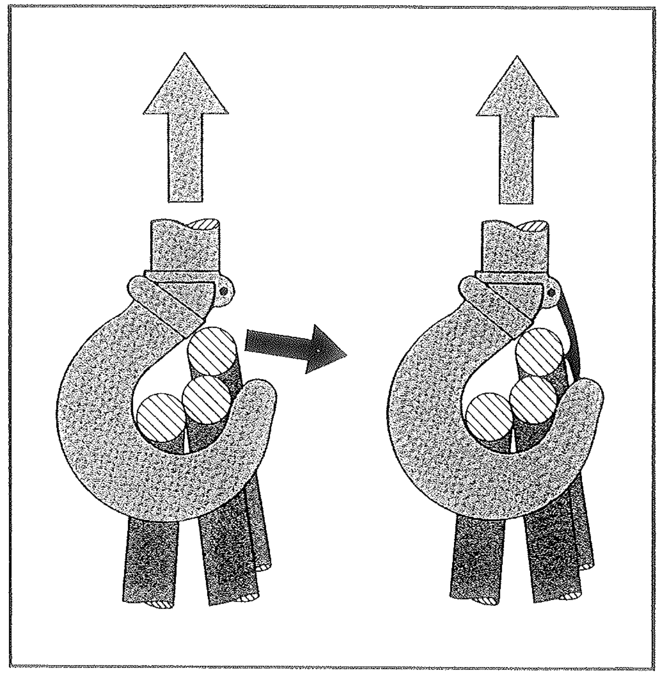

Fig. 5. Safety Latch Problem

6. Barrier Guards Fenders, transmission guards and footswitch covers are misused regularly to support various parts of the anatomy during casual or non-operational circumstances. People sit on automobile fenders, lean up against transmission guards, or use footswitch covers as footrests. These postures would not be attempted if these barrier guards were not present.

IV. Misuses in Magnitude

To provide structural integrity, engineers incorporate "safety factors" or "factors of ignorance" into their designs to account for uncertainties in the assumed loading, shortcomings in workmanship, approximations in their design methodology, variability in material properties and the effects of time, wear and alterations. The use of safety factors almost always leads to designs which are stronger than required by the functional specifications of the problem. Safety factors invariably increase the cost of the final design and very often increase the size and weight. These effects are endured, indeed are demanded, by society as a guarantee that the final design will perform at least as well as expected. Unfortunately, users come to depend on the *extra capacity* built into devices, and compromise their reliability by pushing them beyond their rated performance levels. Some classic examples follow.

Power Press Ejection Methods

is one of a series of safety posters available from our graphics division. The posters depict the areas where each of the classical safety devices is inapplicable and the circumstances where it is unsafe.

Note: controls and guards removed for clarity.

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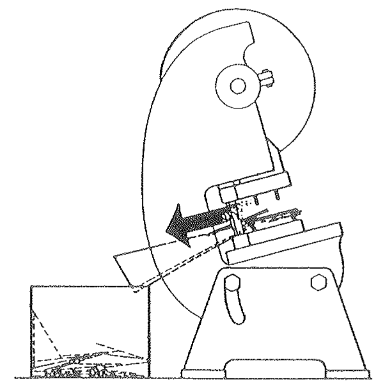
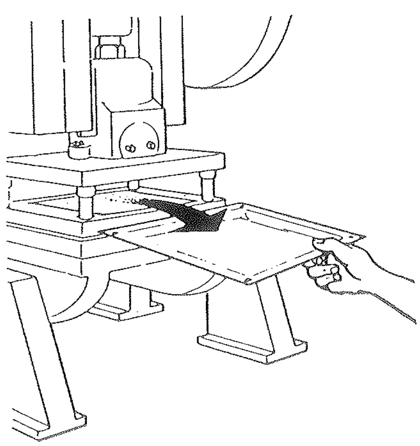
GRAVITY EJECTION



HAND



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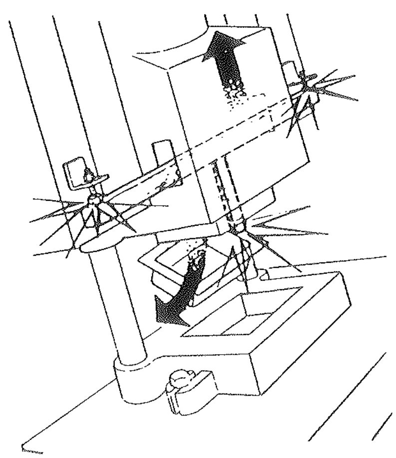
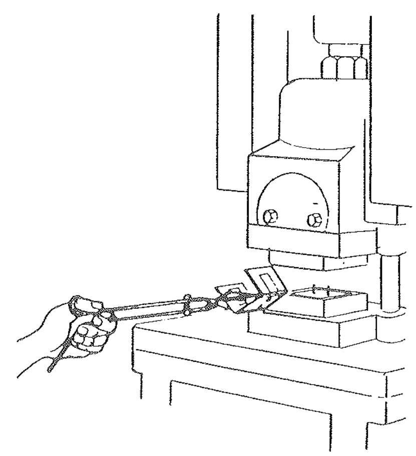


HAND TOOL



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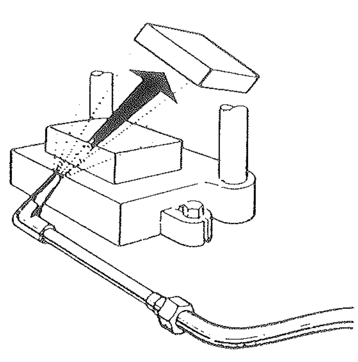
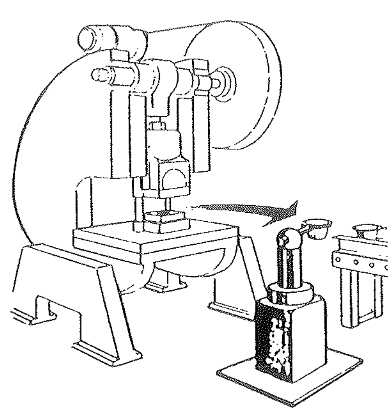


ROBOT



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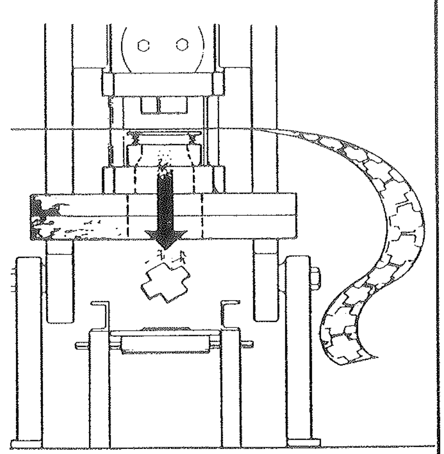

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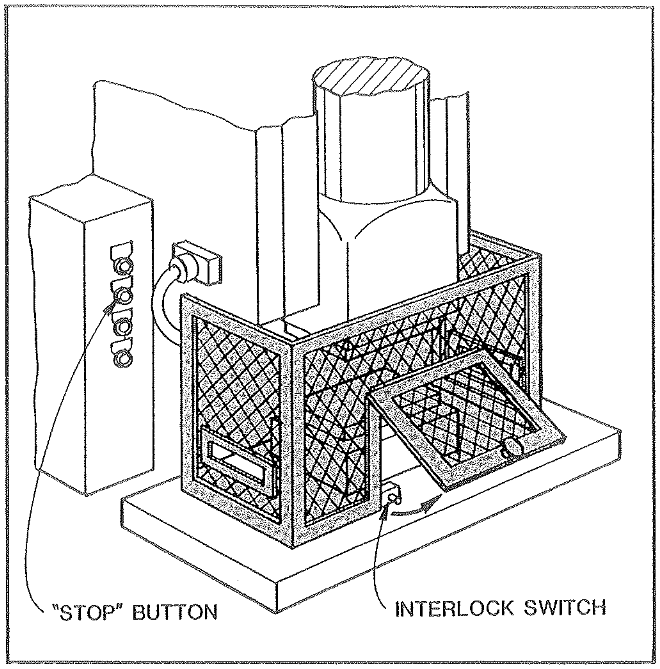

Fig. 2. Interlocked Barrier Guard

4. Light Curtains: A Standardization Dilemma An extension of the classical "electric eye," a light curtain acts as a sentinel in front of a point of operation. Penetration of the curtain signals the machine to stop so that no harm will befall the operator. The systematic misuse of the curtain to interrupt the cycle to reposition parts, clean off debris or perform routine maintenance has led to an even higher form of control. In England (not as yet in the United States), light curtains may now be used to prevent movement of a punch press ram during loading and to commence operation when the user removes his hands from the point-of-operation. These control functions supplement the curtain's traditional role of cycle interruption during inadvertent acts.

The light curtain gives rise to a special type of misadventure involving standardization. The misuse of the curtain as an *emergency stop control* becomes habitual. When operators are transferred to machines not equipped with light curtains, their automatic emergency response is to *reach into the machine*! This is analogous to the habit of using one's foot to catch small parts that have dropped. This useful predilection fails decisively when the foot automatically catches a heavy die or crankshaft.

III. Misuses In Kind

Designers are variously shocked, amused, bewildered and relieved at the alternative and additional uses which are suffered by safety devices. The following misuses in kind may seriously compromise the well-being of the users/innovators.

1. Football Helmets The defensive characteristics of the modern football helmet are often turned into offensive weapons. The use of helmets for spearing was not originally anticipated by the helmet designers and will cause wearers neck injuries culminating in paraplegia and quadroplegia. Football helmets are not designed to protect the neck; they are designed to protect the head.

2. Portable Saw and Grinder Guards Hand held grinding machines incorporate guards which function principally to deflect the swarf, or broken grinding wheel fragments, away from the operator. Hand held electric circular saws utilize leaf guards to enclose the lower portion of the sawblade whenever the saw is not cutting. The guard was intended to prevent bodily contact with the sawblade. Unfortunately, both saws and grinders can be set down and supported on their guards while their blades or grinding wheels are in motion. The ability to use these guards as supports enables the operators to engage in the unsafe practice of releasing their hand tools before their motion has stopped.

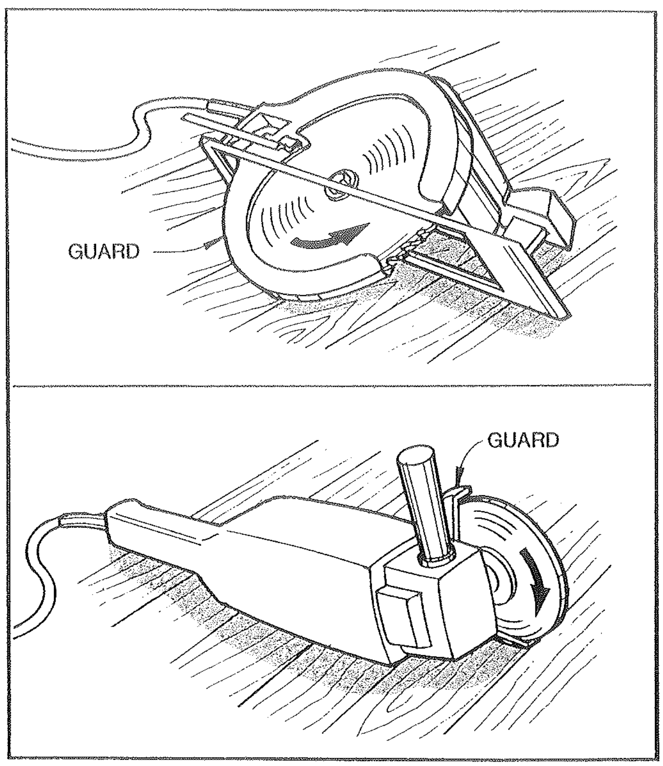

Fig. 3. Portable Saw and Grinder Guards

1. The Hoisting Problem A one-ton crane hook is proportioned to achieve a five ton ultimate capacity. This corresponds to a safety factor of five (5). As they use the hooks, many users will divine their excess capacity and take advantage of it. When such misuse results in tragedy, the adversary system will suggest that the misuse was reasonably foreseeable and that the safety factor of five (5) is too low, in spite of the fact that it meets professional safety code specifications for crane hooks. Such arguments, when abetted by the natural compassion of juries, will frequently lead to verdicts against hook manufacturers. Repeated punishment by the courts will eventually compel manufacturers to make their products "liability proof" by adopting higher and higher safety factors. Thus, a one-ton hook may achieve an ultimate capacity of ten (10) tons, i.e. a safety factor of ten (10). Unfortunately, users will continue to depend on the ever increasing excess capacity of the hooks, accidents will result, suits will be filed and the process will continue without end.

2. The Axle Problem It is a rule of thumb in the trucking industry that no part will be disposed of until its repair cost exceeds its replacement cost. Consider the design of a truck axle bracket. When vehicles were designed for fifty (50) thousand miles, their axle brackets were developed to provide an average fatigue life of two hundred and fifty thousand miles, that is, with a fatigue safety factor of five (5). If the vehicle was retired before the axle bracket was broken, however, the truck owner insisted on using the axle bracket to repair another truck. This process would continue, not only until the bracket fractured but, until the cost of re-welding the fractures exceeded the cost of replacement with a new bracket.

Unfortunately, the fracture of an axle bracket on the road may lead to the most tragic consequences. This prospect horrified bracket manufacturers and they responded by increasing the axle bracket life first to five hundred thousand miles and now to one million miles. But, the truck owner's rule of thumb did not change. Users just use these "safer" brackets longer. One or more bracket fractures are still obligatory in a bracket's history.

It should be noted that the foregoing scenario cannot take place in the aircraft industry where regulations demand that components be monitored and replaced according to scientifically determined *schedules*. Here, the users are not allowed to depend on the safety factors built into the designs.

3. The Grinding Wheel Problem Most grinding wheels are proof tested by overspeeding them by 50 percent at the time of manufacture. This safety system removes all the weak sisters from the statistical population of wheels and assures that the survivors have a strength level at least fifty percent greater than the wheel rating.

The faster the grinding wheel, the faster material is removed. This motivates users to overspeed them in spite of maximum speed instructions marked on the wheels. These users depend on the built in fifty percent overspeed capability.

END OF PART I

SAFETY BRIEF

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