ISSN 1041-9489

SAFETY BRIEF

September 1992 | Volume 8, No. 1

Triodyne Inc.
Consulting Engineers and Scientists
5950 West Touhy Avenue Niles, IL 60714-4610 (708) 677-4730
FAX: (708) 647-2047

The Doctrine of Manifest Danger

and Its Relationship to Reliability, Preventive Maintenance and Fail-Safe Design

by Ralph L. Barnett*

Abstract

"Dust thou art, and unto dust shalt thou return."[1] *Man has made no observations that would challenge this notion from the Bible and certainly safeguarding systems fall into lockstep. Safety technology has responded to the reality of eventual degradation using four general approaches: reliability design, preventive maintenance, fail-safe design and danger manifestation. The optimum implementation of these approaches will still not eliminate accidents; indeed, no work of man or nature is or can be danger free. Nevertheless, these sophisticated approaches are capable of producing ever-increasing levels of safety, albeit, with attendant ever-increasing cost. It is at once unfortunate and unacceptable that common law*[2] *is not equally sophisticated in dealing with the inevitable failure of safeguarding systems over time.*

This paper introduces The Doctrine of Manifest Danger which is defined as a design concept using direct cues or indicator devices to communicate to the community of users that the safety of a system has been compromised before injuries occur. Furthermore, the paper addresses a related legal issue by distinguishing between ***proximate cause*** *and* ***cause of action.***

---

* Professor, Mechanical and Aerospace Engineering, Illinois Institute of Technology, Chicago, IL.

[1] Genesis 3:19.

[2] Common Law: As distinguished from statutory law created by the enactment of legislatures, that body of legal concepts established in English courts throughout English history; it is composed of judge-made decisions used as precedent by subsequent courts. The cornerstone of the common law is the doctrine of *stare decisis* which literally means "to abide by decided cases." "Under doctrine a deliberate or solemn decision of court made after argument on question of law fairly arising in the case, and necessary to its determination, is an authority, or binding precedent in the same court, or in other courts of equal or lower rank in subsequent cases where the very point is again in controversy. *State v. Mellenberger*, 163 0r.233, 95 P.2d 709, 719, 720; 128 A.L.R. 1506."

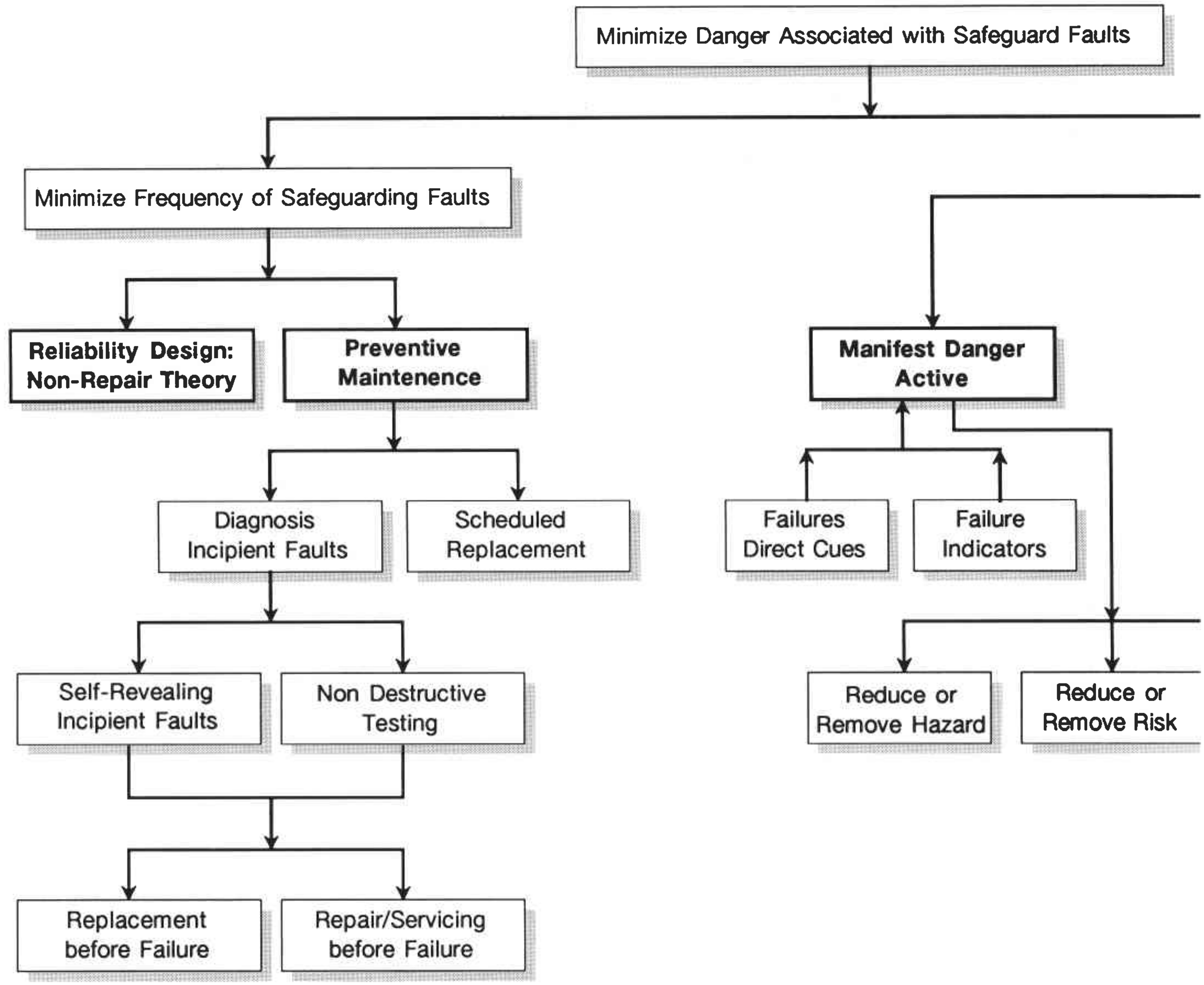
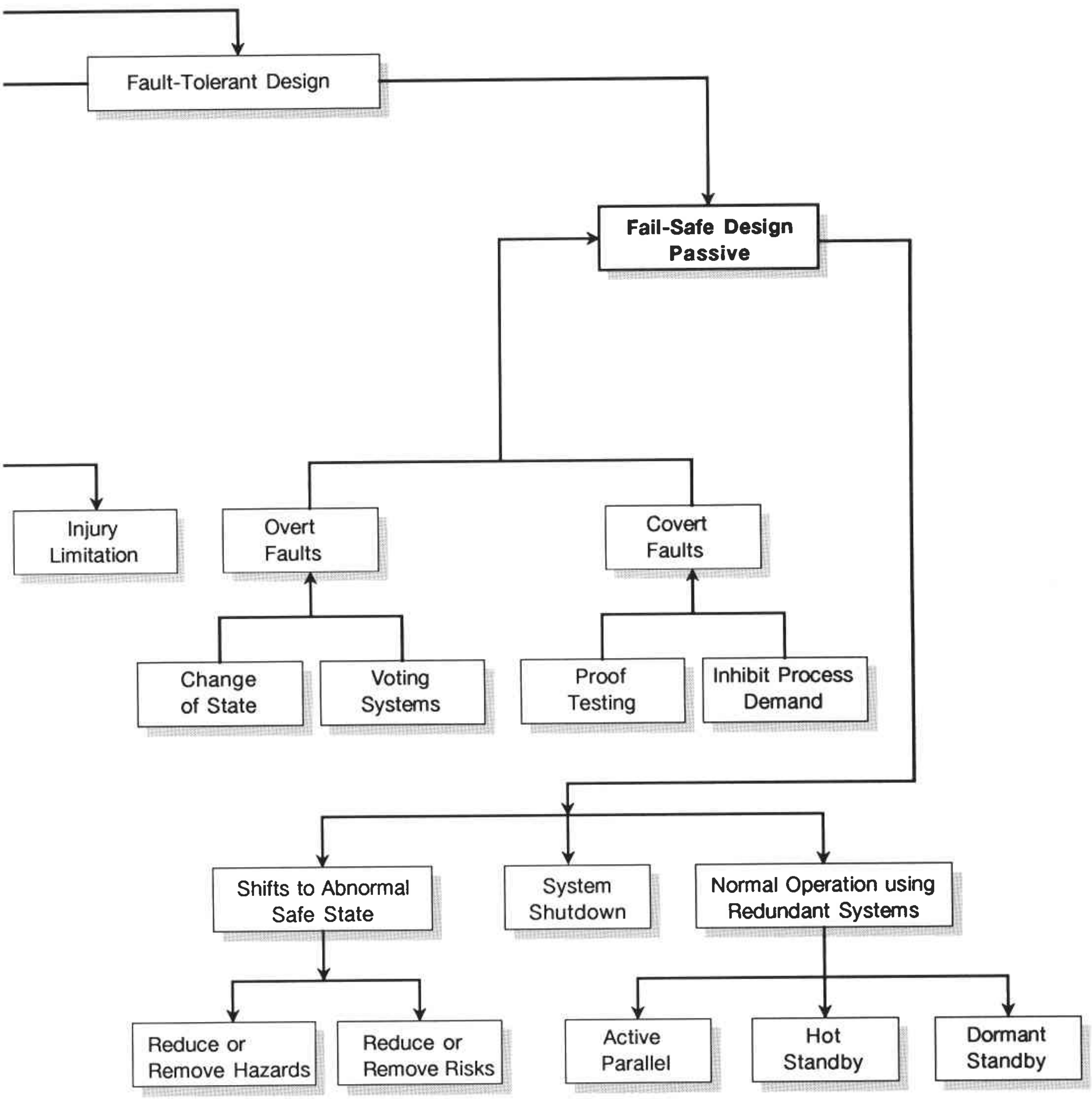


FIG. 1 – RELATIONSHIPS AMONG SAFEGUARDING DESIGN PHILOSOPHIES


Fault-Tolerant Design
Fail-Safe Design
Passive
Injury
Limitation
Overt
Faults
Covert
Faults
Change
of State
Voting
Systems
Proof
Testing
Inhibit Process
Demand
Shifts to Abnormal
Safe State
System
Shutdown
Normal Operation using
Redundant Systems
Reduce or
Remove Hazards
Reduce or
Remove Risks
Active
Parallel
Hot
Standby
Dormant
Standby

I. INTRODUCTION

It is axiomatic in Safety Engineering that every safety device or system will eventually degrade. Within reasonable constraints on cost and utility, the engineering codes of ethics require that the danger associated with safeguard failures be minimized. Currently, there are four tools available to accomplish this: reliability design, preventive maintenance, fail-safe design and manifest danger. The relationship among them is portrayed in Figure 1 where we observe that minimum danger is accomplished by reducing the number of safeguard functional failures and/or by making designs more forgiving or fault tolerant. The techniques of reliability design and preventive maintenance may be used to reduce the frequency of functional faults; fault tolerance is achieved passively by fail-safe concepts and actively by the Doctrine of Manifest Danger, which is the subject of this paper.

An overview of reliability design as it applies to safety devices and systems has been highlighted in Table I, Reliability Design–Safety Systems. That portion of reliability design that is used to minimize the number of safeguard faults does not include diagnostic and corrective maintenance capability which is treated in general reliability theory. The theory of preventive maintenance is summarized in Table II where corrective maintenance is absolutely excluded from the discipline. Elements of fail-safe design are described in Table III, but the most important caveat doesn't appear –there is no such thing as a fail-safe design; there are only modes of failure that can be made fail-safe.

The Doctrine of Manifest Danger is that protocol advocated by designers for causing a machine or system to communicate to users that its safety has been compromised before an injury occurs. Here, the word "danger" is used to characterize how badly something can hurt you (hazard severity) and how often it will hurt you (frequency or risk). The ordinary definition of manifest is adopted, as follows: "capable of being readily and instantly perceived by the senses; not hidden or concealed; capable of being easily understood or recognized at once; evident, obvious, apparent, plain, clear, conspicuous or open."

Structural integrity is often reduced by fatigue cracks which cannot be detected during ordinary field inspections. The cracks do not manifest themselves without special equipment and skills. On the other hand, colored threads or signatures are often molded into tires in such a way that their eventual appearance indicates sufficient tread wear to warrant tire replacement. This is an example of the Doctrine of Manifest Danger.

The body of this paper begins with a technical discussion of the Doctrine. Then, three case studies are explored to illustrate the technical and legal implications of the concept. A reasonable amount of legal detail is included so that engineers may understand how the judicial value system approaches the ideas of proximate cause and cause of action.

II. THE DOCTRINE OF MANIFEST DANGER

It is implicit in fault-tolerant design that safety devices or systems will eventually fail. To control the consequences of these failures in a way that will minimize human injury, the process must begin with information on the change in state of the failed safety components. There is nothing to reinvent; we adopt the classic three-step drill:

1. Detection/Perception/Sensing
2. Information processing/Interpretation
3. Action/Control execution

Steps one and two are central topics in information ergonomics and in psychology. Fail-safe design performs all three passively by machine. Under the Doctrine of Manifest Danger, all three may be undertaken by man; however, detection and information processing are often accomplished technically.

A. DEFINITION: DOCTRINE OF MANIFEST DANGER

A design concept using direct cues or indicator devices to communicate to the community of users that the safety of a system has been compromised before injuries occur.

B. DETECTION

Manifest danger is an active safety doctrine in which the sudden or gradual degradation of safeguards is detected directly through sensory perception of cues or by indirect feedback of their changed or changing status.

1. Direct Cues

a. *Visual Feedback:* Frayed cables on pull-outs attached to wristlets or frayed hoist ropes provide information on the decreased safety factor of these members.
b. *Audible Feedback:* Screeching of brake drums or disks signify critical brake pad wear.
c. *Tactile Feedback:* Dramatically increased steering effort is associated with the failure of power-assisted steering mechanisms.
d. *Olfactory Feedback:* The stench related to the leakage of toxic sulfur dioxide (rotten egg smell) provides a natural warning.
e. *Gustatory Feedback:* The added taste sensations (bitter, sweet, sour, and salty) associated with spoiled food provide information on the status of refrigeration equipment.
f. *Equilibrium:* A seat-of-the-pants sensation gives a crane operator a cue of incipient overturn. It may reflect a failure of the outriggers.

2. Fault Indicators

a. *Indicator lights:* Automobile dashboards and aircraft cockpit panels display component temperatures, lubrication status, electrical output and the adequacy of landing gear deployment. Lights are used on industrial equipment to indicate ground faults in their safety circuits.
b. *Odorants:* Mercaptan compounds are usually added to odorless natural gas so that leaks can be quickly detected by the resulting characteristic odor. The state of lubrication of railroad journal bearings on older boxcars was manifest by adding a temperature-sensitive, odor-producing substance that was triggered when low oil levels allowed the bearings to heat up. The trainmen riding in the caboose were immediately notified of a "hot box" by

the smell emanating from the leading cars; alas, on occasion the smell was so offensive that the caboose had to be abandoned.

c. *Control Forces:* When the movable hook block on a crane is hoisted too close to the stationary sheave block, this "two-blocking" condition is detected by a limit switch which sends a signal to a hydraulic system which in turn may cause certain control levers to be wrested from the operator and returned to neutral. Any electrical short in the wiring has the effect of a "two-blocking" signal. Here, the moving control levers communicate mischief to the crane operators.
d. *Horns, Whistles, Sirens, Bells and Buzzers:* Trucks and construction equipment that employ air brakes often use buzzers to indicate a low air pressure condition. Similarly, the smoke alarm notifies users of its battery status by a siren triggered by low voltage.
e. *Verbalizer:* Some automobiles make verbal statements relative to safety status, e.g., "Door Ajar." Unmanned trains enunciate when safety systems breakdown.
f. *Analogs:* Pointers on pressure gages may go into a red zone when relief systems fail to control pressure.
g. *Monitors:* Written and graphical messages appear on screens to communicate the status of power generation safety devices.
h. *Buddy System:* A team member acts as a sentinel to protect workers entering confined spaces against safety equipment failures.
i. *Digital Displays:* Radiation counters and infrared indicators to detect hot spots or flames are used to signal the breakdown of safety control devices.

C. INFORMATION PROCESSING

The notification of safeguard faults is only the first part of the Doctrine of Manifest Danger. The second involves the interpretation of the feedback, which, in turn, is dependent on the community of users and their cognitive capabilities. The onset of a dangerous situation may be recognizable to a maintenance technician but not to an operator or to a bystander. The effectiveness of the Doctrine is clearly affected by the background, training, education and experience of the users.

D. INJURY CONTROL AFTER SAFEGUARD FAILURE

Following detection and interpretation, the Doctrine calls for injury intervention. The control methods follow the classic profile:

1. Eliminate Risk
   a. Put on a gas mask
   b. Escape or Rescue
2. Reduce Risk
   a. Enter bomb shelters
   b. Jettison a fighter aircraft
3. Remove Hazards
   a. Shut down machines
   b. Put out fires
   c. Pray
4. Reduce Hazard Severity
   a. Slow down after a tire blowout
   b. Fail-Active: A destruct system on an air-to-air misssile is a fail-active device that an operator can activate if the missile misses its target and does not detonate within a set time. The destruct system blows the missile apart to halt its flight and limit the damage that an armed warhead or entire missile could cause by hitting the ground.
5. Injury Limitation
   a. Flood eyes with water after acid splash
   b. Take antidotes
   c. First aid

E. TIMELINESS

The final consideration in the application of the Doctrine of Manifest Danger is timing. The effects of faulty safety systems must be neutralized *before* an injury occurs. Harm cannot be averted if the process of sensing, interpreting and intervention takes too long. There are certainly excursions that are so rapid that the Doctrine will prove ineffective.

III. LEGAL DEFINITIONS AND CONCEPTS

The concepts, proximate cause, cause of action, strict liability and assumption of risk are defined in this section primarily by the fourth and sixth editions of *Black's Law Dictionary.*[3,4] Two different editions, indeed! Can you imagine another intellectual discipline with such fluid foundations that even fundamental definitions do not survive? To understand the judicial value system is not unlike measuring the world with a rubber ruler; but, understand it we must. The work of Safety Engineering is dominated by the field of product liability which is three orders of magnitude larger in dollar volume. Less cosmic, the four definitions are essential to an understanding of the case studies which follow.

1. *Proximate Cause.* That which, in a natural and continuous sequence, unbroken by any efficient intervening cause, produces injury, and without which the result would not have occurred. *Wisniewski v. Great Atlantic & Pac. Tea Co.*, 226 Pa.Super. 574, 323 A.2d 744, 748. That which is nearest in the order of responsible causation. That which stands next in causation to the effect, not necessarily in time or space, but in causal relation. The proximate cause of an injury is the primary or moving cause, or that which, in a natural and continuous sequence, unbroken by any efficient intervening cause, produces the injury and without which the accident could not have happened, if the injury be one which might be reasonably anticipated or foreseen as a natural consequence of the wrongful act. An injury or damage is proximately caused by an act, or a failure to act, whenever it appears from the evidence in the case, that the act or omission played a substantial part in bringing about or actually causing the injury or damage; and that the injury or damage was either a direct result or a reasonably probable consequence of the act or omission.

The last negligent act contributory to an injury, without which such injury would not have resulted. The dominant, moving or producing cause. The efficient cause; the one that necessarily sets the other causes in operation. The causes that are merely incidental or instruments of a superior or controlling agency are not the proximate causes and the responsible ones, though they may be nearer in time to the result. It is only when the causes are independent of each other that the nearest is, of course, to be charged with the disaster. Act or omission immediately causing or failing to prevent injury; act or omission occurring or concurring with another, which, had it not happened, injury would not have been inflicted. *Herron v. Smith Bros.* 116 Cal.App. 518,2 P.2d 1012, 1013.[3] There may be two or more proximate causes.

2. ***Cause of Action.*** The fact or facts which give a person a right to judicial redress or relief against another. The legal effect of an occurrence in terms of redress to a party to the occurrence. A situation or state of facts which would entitle party to sustain action and give him right to seek a judicial remedy in his behalf. *Thompson v. Zurich Ins. Co.*, D.C.Minn., 309 F.Supp. 1178, 1181. Fact, or a state of facts, to which law sought to be enforced against a person or thing applies. Facts which give rise to one or more relations of right-duty between two or more persons. Failure to perform legal obligation to do, or refrain from performance of, some act. Matter for which action may be maintained. Unlawful violation or invasion of right. The right which a party has to institute a judicial proceeding.[4]

3. ***Strict Liability*** (Restatement 2nd, Torts, § 402A). A supplier of a product is subject to liability in damages for harm to a person or to property if: (a) the supplier is engaged in the business of manufacturing, assembling, selling, leasing or otherwise distributing such product; (b) the product was supplied by him in a defective condition which rendered it unreasonably dangerous; it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold; and (c) the defective condition was a proximate cause of the harm to person or property."[5] This rule applies although (a) the seller has exercised all possible care in the preparation and sale of his product, and (b) the user or consumer has not bought the product from or entered into any contractual relation with the seller.

   A product is in a defective condition unreasonably dangerous to the user when it has a propensity for causing physical harm beyond that which would be contemplated by the ordinary user or consumer who purchases it, with the ordinary knowledge common to the foreseeable class of users as to its characteristics. A product is not defective or unreasonably dangerous merely because it is possible to be injured while using it. *Moomey v. Massey-Ferguson, Inc.*, C.A.N.M. 429 F.2d 1184.

4. ***Assumption of Risk.*** The doctrine of assumption of risk, also known as *volenti non fit injuria*, means legally that a plaintiff may not recover for an injury to which he assents, i.e., that a person may not recover for an injury received when he voluntarily exposes himself to a known and appreciated danger. The requirements for the defense of *volenti non fit injuria* are that: (1) the plaintiff has knowledge of facts constituting a dangerous condition, (2) he knows the condition is dangerous, (3) he appreciates the nature or extent of the danger, and (4) he voluntarily exposes himself to the danger. An exception may be applicable even though the above factors have entered into a plaintiff's conduct if his actions come within the rescue or humanitarian doctrine. *Clarke v. Brockway Motor Trucks*, D.C.Pa., 372 F.Supp. 1342, 1347.

   A defense to action of negligence which consists of showing that the plaintiff, knowing the dangers and risk involved, chose to act as he did. An affirmative defense which the defendant in a negligence action must plead and prove. *Fed. R. Civil P.8 (c).*

   In some jurisdictions, doctrine confined to master and servant relation. *Dowse v. Maine Cent. R.R.*, 91 N.H. 419, 20 A.2d 629, 631; *Packer v. Grand Trunk Western R. Co.*, 261 Mich. 293, 246 N.W. 125, 126; *West Texas Utilities Co. v. Reuner, Tex.*, 32 S.W.2d 264, 270. A term or condition in a contract of employment, either express or implied from the circumstances of the employment, by which the employee agrees that dangers of injury ordinarily or obviously incident to the discharge of his duty in the particular employment shall be at his own risk. *Parker v. City of Wichita*, 150 Kan. 249, 92 P.2d 86, 89; *Wisconsin & Arkansas Lumber Co. v. Otts*, 178 Ark. 283, 10 S.W.2d 364, 365; *Southern Pac. Co. v. McCready*, C.C.A.Cal., 47 F.2d 673, 675. It has reference to dangers that are normally and necessarily incident to the occupation, which are deemed to be assumed by workmen of mature years, whether they are actually aware of them or not. *Chesapeake & O. Ry. Co. v. Cochran*, C.C.A.W.Va., 22 F.2d 22, 25.

IV. CASE STUDIES

Case 1: Electric Furnace

A simple hydraulic jack was used to tilt an electric furnace so that its molten contents could be poured. A small pipe fitting in the jacking system was observed by the maintenance foreman to be leaking. He declared that he would replace the fitting in the near future and personally attempted this maintenance task about six weeks later. He jacked up or tilted the furnace and blocked it up with wooden 2x4's. He then loosened the leaking fitting with a wrench which eliminated the load-carrying capability of the jack and caused the entire weight of the furnace to rest on the 2x4's. These collapsed and the foreman was killed.

A strict liability action was filed against the manufacturer of the plumbing fitting which was one of two alleged proximate causes of the accident; the other was the inadequate blocking system. The focus of the suit was the alleged defective design of the fitting; there was no cause of action arising from the inadequate blocking supplied by the deceased or his company because by statute, the sole remedy available from an employer is worker's compensation.

Let us suppose that an electric furnace operator rather than the maintenance foreman was injured during the normal course of his duties by a defective fitting. Here, the facts clearly give rise to a cause of action under strict liability. On the other hand, the maintenance foreman was not injured *by* the defective fitting; at best one could argue but for the defective fitting, he would not have undertaken its repair and therefore would not have exposed himself to a hazardous maintenance environment. The elements relating to the maintenance foreman are quite different from those of our hypothetical furnace operator:

1. The danger associated with the fitting manifested itself to the deceased by leaking before causing an accident.
2. He was a member of a community of users who would appreciate the significance of a leaking fitting.
3. He observed the leak and understood its consequences relative to electric furnace safety.
4. One of his jobs was the repair of defective fittings.
5. He had the skill and experience to

Table 1: RELIABILITY DESIGN - SAFETY SYSTEMS

Objective of Reliability Design-Safety Systems: To control the probability of system failure.

Important Definitions

Failure: The termination of the ability of an item to perform a required function.

Reliability (Definition 1): The ability of an item to perform a required function under stated conditions for a stated period of time.

Reliability (Definition 2): The probability that an item will perform a required function without failure under stated conditions for a stated period of time (non-repaired items).

Covert Faults: A hidden or latent failure of an item that can only be revealed by inhibiting a process demand or by proof testing. These fail-danger faults may inhibit safe action.

Overt Faults: Failures of items that are self-revealing.

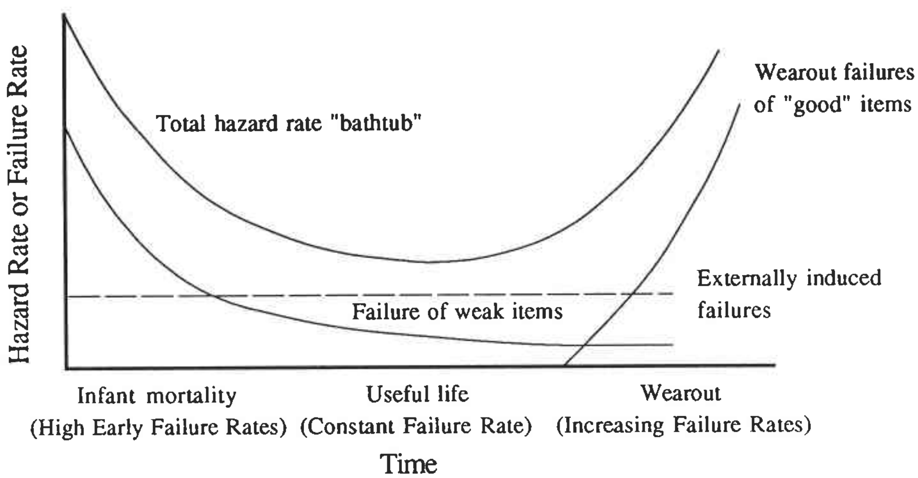
Mean Time to Failure (MTTF): Average time to failure of a non-repairable product or the average time to first failure of a repairable product.

Mean Time between Failures (MTBF): Average time between successive failures of a repairable product.

Hazard Rate: For a group of similar items, the hazard rate at any given time is the percentage of first failures per unit time.

Failure Rate: For a group of similar items that are repaired each time they fail, the failure rate is the percentage of all failures per unit time.

Bathtub Curve: A bathtub-shaped curve resulting from the plotting of Hazard or Failure Rate against the time period over which equipment is used:



Typical Reliability Tools

Safety Factor: An experience-driven multiplier which ensures that the generalized loads do not exceed the generalized resistance of items.

Quality Control: Ensuring conformance to specifications and tolerances.

Burn-In: Operation of parts under failure-provoking conditions for a time before delivery. The idea is to eliminate items in the range of infant mortality on the "bathtub" curve.

Proof Loading: Subjecting items to a single failure-provoking load condition after manufacture to eliminate any "weak sisters" from the product stream. For example, grinding wheels are operated at 150% of rated speed before shipping.

Redundancy: The existence of more than one means for accomplishing a given function. The various means need not be identical.

Derating: Use of derated parts to assure that the stresses applied are lower than the stresses the parts can normally withstand.

Environmental Control: Protect safety devices from the operating environment. For example, potting electronic components to protect them against climate and shock.

Proven Technology: Use of standard safety devices whose reliability has been established by actual field use.

repair defective fittings.

6. His use of blocking or cribbing indicated that he appreciated the danger posed by the repair task and adopted the correct method for controlling it. His only mistake was the choice of wooden 2x4's.
7. He encountered no unanticipated dangers that were outside his purview.

These facts would seem to preclude a cause of action under strict liability for the following reasons:

a. Because the danger of the fitting was manifest, there was no condition not contemplated by the ultimate user.
b. Because the danger of the leaking fitting was manifest, the deceased was able to plan and execute a maintenance task and in so doing he assumed the normal risk associated therewith.
c. The fitting did not reach the ultimate user in the condition distributed by the supplier.
d. The fitting itself did not cause the injury since it was removed just before the accident.

Nevertheless, the case was tried in strict liability with the attorneys for the fitting manufacturer pleading *assumption of risk* as an affirmative defense.

Case 2: The Fireman's Rule

There is a clear parallel between maintenance personnel undertaking the repair of manifestly defective machines and firefighting activities which by their nature manifest danger. Because the fireman's problem has been thoroughly studied in the law, engineers can gain some insight by examining the "Fireman's Rule:"

> "Where the defendant's negligence, whether active or passive, creates an apparent risk, which is of the type usually dealt with by firemen, and which is the cause of the fireman's presence and which is the direct cause of the fireman's injury, the defendant is not liable to the fireman." [6]

The phrase *apparent risk* is equivalent to manifest danger. Where danger is manifest, we propose extending the Fireman's Rule to include maintenance personnel, accident investigators, expert witnesses and the like.

Several court decisions have been selected from Scheafer[7] to illustrate how the common law supports the Fireman's Rule:

A. In *Baxley v. William's Construction Co.* (1958) 98 Ga.App. 662, 106 S.E.2d 799, the court denied a petition by a fireman for personal injuries, including a broken back, suffered when he fell into an unlighted excavation at a construction project at which a fire had broken out, because the fireman had the status of a licensee,[a] to whom the defendants, who were the general contractor and two other corporations engaged in the construction work, were not liable for anything but affirmative acts amounting to willfulness, and toward whom they owed no duty to keep the premises safe, except from "pitfalls, mantraps and things of that kind."[b] The court said that the rule that a fireman is a licensee "is based on sound public policy" because a fireman's right to go upon premises to extinguish a fire is based upon the permission of the law rather than the invitation of the owner or occupier, "even if the owner or occupier turns in the alarm," that the owner or occupier may not deny a fireman permission to enter upon premises to extinguish a fire thereon, and that "the basic reason for the rule" is that it is impossible to foresee the precise place where the fireman's duties may call him, and to require an owner or occupier to exercise at all times the high degree of care owed to an invitee[c] would be an intolerable burden which it is not in the best interest of society to impose.

B. In *Walsh v. Madison Park Properties, Ltd.* (1968)102 NJ Super. 134, 245 A.2d 512, the court stated that the status of firemen engaged in fire inspection was more closely akin to that of a building inspector and as such they were business invitees to whom the obligation of reasonable care was owing. The firemen were injured when a fire escape which they were inspecting malfunctioned. The court commented that while the fireman's presence on the premises did not depend upon the permission or express invitation of the owner, the latter, by operating his premises in a manner which called for this service, impliedly invited the firemen upon his premises for the purpose of performing their duty. The court further stated that the defendant's duty to exercise reasonable care did not encompass an obligation to affirmatively guard against defects in an apparatus which the plaintiffs were in the process of inspecting pursuant to the duty which brought them to the premises. The court explained that the need for the services of persons occupying the status of building or safety inspectors was premised upon the possibility that violations of safety or building codes could reasonably be expected to be encountered. It was the possibility of such violations that created the need for the inspector's services, declared the court. Thus, the court concluded, it could see no reason in logic to distinguish between one who came upon the premises to make repairs and the one who, as here, came there for the purposes of making an inspection to determine what repairs, if any, might be necessary.

C. Noting that nonliability of the owner or occupant of premises frequently had been placed on the theory that the fireman was but a licensee, the court, in *Buren v. Midwest Industries, Inc.* (1964, Ky) 380 S.W.2d 96, stated that justice was not aided by appending an inappropriate label and the visiting consequences which flowed from a status

---

[a] Definition: A licensee is usually described as one who comes upon the land with the landowner's consent, but for his own purposes. The landowner owes the licensee a duty to refrain from willfully or intentionally injuring him. See, e.g., W. Prosser, The Law of Torts, 4th ed (1971) 376.

[b] "Pitfalls, mantraps and things of that kind" are not dangers that are manifest.

[c] Definition: An invitee has been described as one who is invited upon the land for the landowner's purposes and to whom the landowner owes a duty of reasonable care to make the premises safe. See, e.g., W. Prosser, The Law of Torts, 4th ed (1971) 385-86.

Table II: PREVENTIVE MAINTENANCE PM

Objective of PM: To retain a system in an operational or available state by preventing failure from occurring.

Important Definitions

Maintainability: The ability of an item, under stated conditions of use, to be retained in, or restored to, a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources.

Mean Time to Repair (MTTR): The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

Maintenance, preventive: The actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure by repairing or replacing it. This concept must be contrasted with corrective maintenance which restores an item to a specified condition after it has failed.

Reliability Centered Maintenance (RCM): A systematic approach to maintenance planning which takes reliability aspects into consideration.

Typical Preventive Maintenance

1. Scheduled Replacement

a. Definition: The replacement of parts before failure at predetermined times.

b. Note: When the onset of failure of an item cannot be determined, scheduled replacement is the only PM strategy available.

c. Note: Reliability analysis techniques are required to develop replacement schedules (maintenance intervals) that will minimize the number of items which fail.

d. Note: All effective replacement strategies using new parts are applied in the "wear out" or increasing hazard rate range. Unfortunately, there are cases where no new part replacement schedule can be found that will decrease the failure probability.

e. Note: If a failure-free life exists for an item, it may always be replaced within this lifespan before failure occurs. This makes the failure probability zero.

2. Diagnosis

a. Definition: Those maintenance strategies which reveal incipient failure of items such as safety devices.

b. Inspection: Detection of self-revealing deteriorating conditions of items such as safety devices and systems.

c. Nondestructive Testing (NDT): A body of testing techniques and methods which will not compromise the item tested. This includes regular manual testing (e.g., X-ray) and automatic monitoring (e.g., light curtain circuit checking at the end of each cycle). The NDT determines whether the behavior of safety devices falls outside of performance and tolerance limits.

3. Servicing Strategy

a. Definition: Scheduled servicing (not part replacement) to prevent safety device and system failure.

b. Types of Servicing

- Cleaning
- Lubrication
- Calibration
- Adjustment
- Repair (not replacement)

artificially imputed, and, therefore held that a fireman was neither a licensee nor an invitee, but occupied *a status sui generis.*[d] The court reasoned that it was the fireman's business to deal with that very hazard and hence, perhaps by analogy to the contractor engaged as an expert to remedy dangerous situations, he could not complain of negligence in the creation of the very occasion for his engagement, the precise risk which the public paid him to undertake.

D. The court in *Horcher v. Guerin* (1968) 94 Ill.App.2d 244, 236 N.E.2d 576, expressly rejected the proposition that a landowner could be held liable to a fireman for negligence in causing a fire which brought the fireman to the premises. The court explained that it was the fireman's business to deal with this particular hazard. Noting that undoubtedly most fires could be attributed to negligence of some nature, the court stated that public policy dictated that a landowner would not owe a duty to a fireman, upon which liability could be predicated, to exercise care that a fire did not occur on his premises. The court opined that the exposure to liability which would result from such a rule would impose an unreasonable burden upon a person who owned or occupied improved land.

E. In an action for personal injuries suffered by a volunteer fireman when he responded to a call to the scene of a collision between two motor vehicles, the court, in *Buchanan v. Prickett & Son, Inc.* (1979) 203 Neb 684, 279 N.W.2d 855, held that the fireman's rule negated liability to a fireman by one whose negligence caused or contributed to a fire which in turn caused the injury or death of a fireman. The court said the underlying basis of the fireman's rule was that the ordinary risk which a fireman encountered in the performance of his duty in fighting fires and protecting life and property were those which he had assumed a duty to perform and to which he had assumed the risk in a "primary" sense. The court stated that in the absence of any statute or ordinance prescribing a duty on the part of the owner or possessor of the property to members of a public fire department, the owner was not liable for such injuries to the fireman except those proximately resulting from willful or wanton negligence or a designed injury, excepting cases where there might be the duty to warn of a hidden danger[e] or peril known to the owner or occupant but unknown to, or unobservable by, the fireman in the exercise of ordinary care.

Case 3: Steel Rule Die Press

A mechanical steel rule die power press was employed to cut out cardboard puzzles using a steel rule die (cookie cutter). The press is characterized by the special feature that the bottom platen moves upward toward a stationary upper platen upon which the die is mounted. Unlike ordinary punch presses which bring a ram down upon a stationary lower platen or bolster, an operator with hands in the die space is immediately notified by tactile feedback when the bottom platen begins to move. Because the platen movement is relatively slow with a long stroke and a dwell at the top and bottom of the stroke, the press will warn operators under normal circumstances of an unintended stroke in sufficient time to withdraw their hands from the point of operation or die space. This is an example of the Doctrine of Manifest Danger.

The press was activated and protected by a two-hand control which required both hands to depress two buttons and hold them throughout the first half of the cycle where the danger of crushing occurs. Removal of either hand during the upward movement of the ram results in an immediate freezing of the ram motion. The press was equipped with a single stroke or antirepeat feature that required both hands be removed from the two control buttons and then reapplied to obtain a second stroke. In other words, the press was operated with a standard two-hand hostage control which is a recognized and popular power press safety device. In addition, a classical pull-out device was used.

A senior operator experienced a press malfunction by multistroking and demanded reassignment to another machine. Her replacement also escaped injury when the press repeated. The new operator immediately notified management and two repairmen were assigned to the press. They were unable to find the cause of the repeating cycle, but nevertheless returned the press to service after proclaiming it was repaired. They remained with the press while the new operator continued to use it and were witnesses to another repeat which amputated her hand.

Re-examination of the press revealed that a single limit switch in the antirepeat circuit had worn out and allowed the press to recycle. Furthermore, the pull-out device was completely out of adjustment and failed to withdraw the operator's hand during the repeated stroke. A strict liability attack was launched against the press, limit switch and pull-out manufacturers. The injured lady did not have a cause of action against the two repair men who where fellow employees protected by the worker's compensation statute in her state.

The design of the steel rule die press incorporated the timely self-revealing features of the Doctrine of Manifest Danger. Its effectiveness may be judged from the following elements:

1. The machine warned the original and the replacement operators that a dangerous repetitive stroking condition had developed in the press.
2. The press system allowed them to escape injury.
3. Both women understood the warning and informed management of the malfunction.
4. Management reacted to their complaint and assigned two maintenance men to correct the problem.
5. The maintenance men undertook the repair task.

With respect to the pull-outs, a preventive maintenance program would have demanded that they be used and inspected for proper adjustment at the start of each shift, die set-up and change of operator. A

---

[d] Definition: *Sui generis,* Latin. Of its own kind or class, i.e., the only one of its kind; peculiar.

[e] Hidden dangers are not maniest. Manifest dangers may be those dangers observable by a given community of users or in the exercise of ordinary care should be observable.

PM procedure would have prevented the subject accident.

The primary defect alleged in this case was the lack of a second or backup limit switch in the anti-repeat circuit. If such redundancy were incorporated, the same accident might as easily have awaited the eventual failure of the second limit switch. On the other hand, fail-safe concepts might also be adopted to cause the press to shutdown after the first limit switch failure. Of course, the same maintenance crew would be called upon to repair a more sophisticated system. We have merely used different means of fault detection and in the end the maintenance men must correctly restore the system.

Assume, for argument, that the original maintenance crew worked for an outside contractor called in specifically to repair the press. Without the umbrella of the worker's compensation statute, would this crew not be the sole proximate cause of the injury?

V. OBSERVATIONS

A. No known method or combination of design philosophies can completely eliminate accidents caused by the inevitable degradation of safety devices and systems.

B. RELIABILITY DESIGN – SAFETY SYSTEMS

1. It is fundamental to reliability design that a certain percentage of safety systems will fail. The input to the theory is field and laboratory data and observations of real products. Negligence theory examines whether the failure percentages are reasonable, based on objective criteria. Strict liability theory makes every attempt to exclude negligence concepts and their associated "reasonableness" standards. The basic strict liability approach is simplistic; you made it, it caused the injury and it is unreasonably dangerous and not reasonably safe for safeguard systems to fail in normal use. The architecture of strict liability precludes the reality of general safeguard failure. It leaves us with absolute liability.
2. As time increases, the bathtub curve (hazard rate vs. time) eventually reaches a hazard rate of 100% failures per unit time. This is consistent with the fundamental safety axiom.
3. For systems where there exists a one-to-one relationship between injury and safeguard failure, there is a confluence of fundamental definitions from the fields of safety and reliability:

   Risk = 1 - Reliability

   Here, risk is the probability of encountering a hazard and reliability is the survival probability of the safeguards.

C. PREVENTIVE MAINTENANCE

1. PM has achieved remarkable success in the aircraft industry where its application is enforced and thoroughly monitored by a bureaucratic system which has no industrial equivalent.
2. To schedule PM properly, it is necessary to know the life of safety devices, which unfortunately, can only be characterized statistically. This implies that a statistically significant number of failures will still occur in spite of any PM strategy.
3. PM strategy is the exact oppposite of a very widespread maintenance philosophy: "If it ain't broke, don't fix it!"
4. Most manufacturers perform their own in-house PM. Injuries to their staff arising from faulty PM never become lawsuits; the sole remedy available is worker's compensation.

D. FAIL-SAFE DESIGN

1. It is not possible to design a system that is fail-safe against every contingency; nevertheless, this is a misconception that is being promulgated for unsavory reasons. Only modes of failure can be designed to be fail-safe.
2. Redundancy without Tears: Individual failures of safety devices are masked by pure parallel redundancy. To solve this problem, it is necessary that redundant designs give notice of component failure.
3. Most operating fail-safe designs address only single component failures.
4. This is the only one of the four design philosophies that produces nuisance shutdowns due to faulty safety devices. These disruptions in operation often lead to circumvention of the safety devices (See Compatibility Hypothesis).[8]

E. DOCTRINE OF MANIFEST DANGER

1. Reliability design, PM and Fail-Safe design all transfer the entire safety function to designers, manufacturers and maintenance crews who have a professional but not personal interest in safety. The Doctrine relies heavily on personal vigilance with the attendant self motivation to keep safe.
2. The discussions of the Doctrine have addressed the question, "Can it prevent injury?" and not, "Will it prevent injury?" Risk taking,indicator reliability and maintenance, motivation and the like all play a role in the effectiveness of the concept.
3. Intrinsic indicators leading to direct fault cues cannot be removed from machines and do not require maintenance and protection against bypassing.
4. It is easier to find legal criticisms of vigilance intensive systems. Decisions dealing with a manufacturer's non-delegable duty to install safety devices[9] will be easy to evoke even where the Doctrine is most effective.

Table III: FAIL-SAFE DESIGN

Objective of Fail-Safe Design: To design systems that set up safe conditions when a fault occurs.

Important Definitions

Fail-Safe Designs: No single failure should result in a potential for injury or disaster.

Redundancy, active: The redundancy wherein all redundant items are operating simultaneously rather than being switched on when needed.

Redundancy, dormant/standby: That redundancy wherein the alternative means of performing the function is inoperative until needed and is switched on upon failure of the primary means of performing the function.

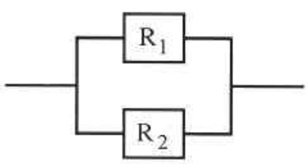
Redundancy, hot standby: Here, the redundant system operates offline while waiting to be called upon.

Series Configuration:

$$R_S = R_1 R_2$$

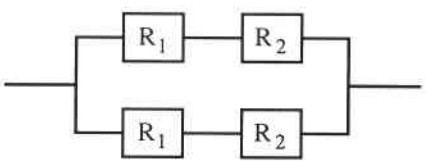
where R_1 and R_2 are the respective subsystem reliabilities and R_S is the system reliability

Parallel Redundancy:



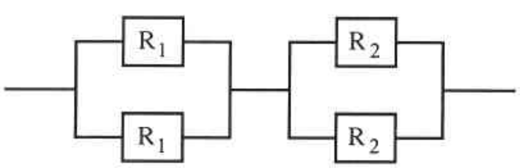
$$R_S = 1 - (1 - R_1)(1 - R_2)$$

Series - Parallel Redundancy:



$$R_S = 1 - (1 - R_1 R_2)^2$$

Parallel - Series Redundancy:



$$R_S = [1 - (1-R_1)^2]\ [1 - (1 - R_2)^2]$$

Common Mode Faults: These occur when two or more independent items fail due to a common cause such as failure of a single power supply.

Diversity: Principal requiring the use of functionally different types of safety devices for a wider spectrum of coverage.

Robustness: Usually applied to software, the term describes the capability of a program to withstand error conditions without serious effect such as becoming locked in a loop or "crashing." A program should be able to find its way gracefully out of a fault condition and indicate the source. This can be achieved by programming internal tests, or checks of cycle time, with a reset and fault indication if the set conditions are not met.

In statistics and process control theory, robustness means insensitivity to small departures from idealized states. For example, the selection of control parameter settings that reduce the sensitivity of a process to manufacturing variation. [11, 13]

Typical Fail- Safe Procedures:

Proof Testing: Scheduled exercise of normally quiescent items to reveal covert faults. For example, the proof testing of a pressure relief valve that may fail to open when the pressure exceeds its set point.

Inspection: Scheduled examination of items to reveal overt faults.

Testing: Those diagnostic techniques for revealing failed safety devices or systems.

Fail-Passive Designs:

A fuse or circuit breaker which opens under excessive current conditions and deenergizes an electrical system.

A brake monitor can shut down a system if a limit switch indicates too much coasting distance.

A barrier interlock limit switch of the normally open (off) held closed (on) type will shut down a machine if it loosens and falls from the machine.

Fail-Operational:

A process controller could be programmed to set up known safe conditions and indicate a problem, if no output is generated in two successive program cycle times or if the output valve changes by more than a predetermined amount.

Failure of a thermostat to switch off a heating supply can be protected against by ensuring that the supply will not remain on for more than a set period, regardless of the thermostat output.

Dual limit switches used in safety circuits may be configured to provide active parallel redundancy which will allow the safety system to function even if one of the limit switches fails.

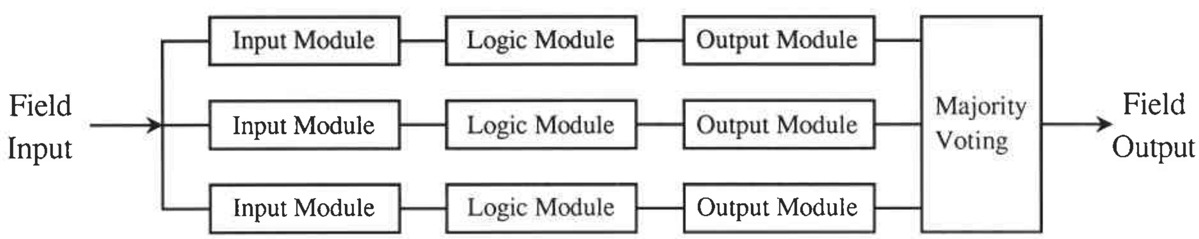
System Configuration: Safeguard systems utilizing either programmable logic controllers (PLC) or microprocessor-based technology are used to monitor fire, explosion and toxic gas release hazards. These systems contain components which may fail in ways where vital safety information is not picked up, and, consequently, the system is not shifted into a safety profile. Further, messages to shut down may be inhibited by covert faults or false information may be provided leading to nuisance shutdowns.

Dual Active Parallel Redundancy: If two duplicate operating PLC's are configured in parallel redundancy, a choice is required on how the final outputs will be voted when a conflict exists between the parallel channel states.

1oo2 Voting: A one-out-of-two (1oo2) votes means that either channel can shut down the process immediately. A single fail-safe (overt) fault in either channel will cause a spurious shutdown; a single fail-danger (covert) fault will not inhibit safe shutdown on demand.

2oo2 Voting: With this configuration, two-out-of-two channels are required to shut down the system. Here, a single fail-safe fault will not cause a spurious shutdown; but, there is now twice the probability that a fail-danger fault will inhibit safe shutdown.

Triple Redundant Systems:



This configuration has three active parallel channels with two-out-of-three (2oo3) output majority voting. A single fail-safe fault will not cause a spurious shutdown and a single fail-danger fault will not inhibit safe shutdown.

REFERENCES

1. *Genesis* 3:19.
2. *State v. Mellenberger,* 163 Or.233, 95 P.2d 709, 719, 720; 128 A.L.R. 1506.
3. Black, Henry Campbell, *Black's Law Dictionary*, 4th ed. St. Paul, MN, West Publishing Co., 1951, pp. 157-8, 279-80, 1391.
4. Black, Henry Campbell, *Black's Law Dictionary*, 6th ed. St. Paul, MN, West Publishing Co., 1990, pp. 123, 221, 1225-26.
5. *Arkansas Statute Annotated* § 85- 2-318.2.
6. *Scott v. E.L. Yeager Construction Co.* 12 Ca.App. 3d 1190, 1199; 91 Cal.Rptr. 232, 238 (4th Dist. 1970).
7. Scheafer, Larry D., "Annotation: Liability of Owner or Occupant of Premises to Firemen Coming Thereon in Discharge of His Duty," 11 *A.L.R. 4th 597*.
8. Barnett, Ralph L. and William G. Switalski, "Principles of Human Safety," *Forensic Engineering* v. 1 #3 (1988): 153-173.
9. *Bexiga vs. Havir Mfg. Co.* N.J.Super.Ct. App.Div. No. 834-69, April 26,1971.
10. Balls, Basil W., *Instrumentation for Safety,* presented at the Eighth Annual Convention and Conference of the Society of Piping Engineers and Designers, Houston, TX, January 26-7, 1989.
11. Huber, P.J., *Robust Statistics.* New York, John Wiley & Sons, 1981.
12. Juran, J.M. and F. M. Gryna, *Juran's Quality Control Handbook.* 4th ed. New York, McGraw-Hill, 1988.
13. Kackar, R.N. and A.C. Shoemaker, "Robust Design: A Cost-effective Method for Improving Manufacturing Processes," *AT&T Technical Journal* v. 65 #2 (March-April 1986): 39-50.
14. "Landowners' Liability to Injured Firefighters in Illinois - Washington v. Atlantic Richfield," *27 DePaul L. Rev. 137-154 (Fall 1977).*
15. O'Connor, Patrick D.T., *Practical Reliability Engineering*, 2nd ed. New York, Wiley, 1991, pp. 214-217.
16. Prosser, W., *The Law of Torts*, 4th ed. St. Paul, MN, West Publishing Co., 1971, pp. 376, 385-86.

SELECTED TRIODYNE STAFF PUBLICATIONS

AGRICULTURAL SAFETY

"Safety and Product Liability Considerations in Farm Machinery Equipment," *Triodyne Safety Brief* v. 2 #2 (August 1983).

"On Rubber Augers - Failure Modes and Effects," by Dennis B. Brickman and Ralph L. Barnett. *Triodyne Safety Brief* v. 4 #2 (June 1986).

"Small Agricultural Tractor ROPS - New Operator Protective Zone," by Edward A. Fritz and William G. Switalski. *Triodyne Safety Brief* v. 7 #4 (August 1992).

"Deadman Controls on Lawn Mowers and Snowblowers," by Ralph L. Barnett and Dennis B. Brickman. *Triodyne Safety Brief* v. 5 #2 (July 1988).

Brickman, Dennis B. and Ralph L. Barnett, "Auger Elevator - Failure Modes and Effects Case Study," *Reliability Stress Analysis and Failure Prevention - 1991.* New York, American Society of Mechanical Engineers, 1991, pp. 95-102.

ENVIRONMENTAL ENGINEERING AND INDUSTRIAL HYGIENE

Schumacher, J.S., G.D. Hanson, Richard Gullickson, et al., "Moisture Requirements to Control Dust in Foundry Sands," *AFS Transactions* v.80 (1973): 566-70.

Gullickson, R. and J.E. Doninger, "Industrial Hygiene Aspects of Olivine Sand Use in Foundries," *AFS Transactions* v.88 (1980): 623-30.

Hutter, Gary M., "Low-Concentration Air Contaminants and Modeling of the Near Environment," *Proceedings of the ASHRAE Conferences, LAQ '86, Atlanta, GA, April 20-23, 1986*, pp. 264-280.

Hutter, Gary M., "The Role of Epidemiological Studies in Evaluating Health Risks from Hazardous Materials," *Proceedings of the Hazardous Waste Symposium, American Institute of Chemical Engineers, New Orleans, March 9, 1988,* Abstract #76-B.

Hutter, Gary M., "New Proposed OSHA Confined Space Standard," *National Safety Council Power Press and Forging Newsletter* (March/April 1990): 2-3.

Hutter, Gary M. and G.R. Brenniman, "In-Soil Diffusion Coefficient Measurement of Trichloroethylene and n-Butane," *U.S.E.P.A. Advanced Monitoring System Division, Project No. OV-0379,* April 1990.

Hutter, Gary M., "In-Soil Diffusion Coefficient Measurements of Triochloroethylene and n-Butane," *Ph.D. Dissertation, October 12,1990 University of Illinois.* Ann Arbor, University Microfilms, 1990.

Hutter, Gary M., "What EPA Requires for Underground Storage Tanks," *National Safety Council Power Press and Forging Newsletter* (March/April 1991): 2.

"Airborne Contaminants in the Machine Tool Industry," by Gary M. Hutter. *Triodyne Safety Brief* v. 7 #1 (August 1991).

Hutter, Gary M., "Airborne Comtaminants in the Machine Tool Industry: excerpt," *IITRI/IIT Manufacturing Competitiveness Frontiers* v. 15 #16 (October 1991): 17.

Hutter, Gary M., G.R. Brenniman and R.J. Anderson, "Measurement of the Apparent Diffusion Coefficient of Trichloroethylene in Soil," *Water Environment Research* v. 64 #1 (Jan/Feb 1992): 69-77.

Hutter, Gary M., "Case Study of a Confined Space Entry Accident," *Water Environment Federation Safety and Health Bulletin* v. 1 #1 (Summer 1992): 6-7.

Moshman, Diane, "Phase I Environmental Property Audits Still a Good Idea?" *Northern Illinois Real Estate Magazine* (August 1992): 10.

Hutter, Gary M. "Confined Space Entry and the New Proposed OSHA Regulation - A Consultant's Perspective," *Pre-Conference of the Water Environment Federation, New Orleans, LA, September 20, 1992.*

FIRE SAFETY

Campbell, John A., "Hazards of Friction Spark Ignition of Aircraft Crash Fires," *NACA TN-4024.* Washington, National Advisory Committee for Aeronautics, May 1957.

Waterman, T.E., J.G. Degenkolb and C.W. Stickney, "A Study - Early Warning Fire Detection Performance in the Hospital Patient Room," *Fire Technology* v. 10 #4 (November 1974): 287-303.

Hirano, T., S. Noreikis and T.E. Waterman, "Postulations of Flame Spread Mechanisms," *Combustion and Flame* v. 22 (1974): 83-96.

Campbell, John A., "Fire Tests in Nursing Home Patient Rooms," *Journal of American Health Care Association* v. 1 #1 (July 1975): 51-6.

Waterman, Thomas E., "Heat Penetration to Protected Areas from Fires in Adjacent Spaces," *ASHIAE Transactions* v. 81, Part 1 (1975): 581-89.

Kuhn, R.L., W.J. Potts, and T. E. Waterman, "A Study of the Inhalation Toxicity of Smoke Produced upon Pyrolysis and Combustion of Polyethylene Foams. Part II. Full-Scale Fire Studies," *Journal of Combustion Toxicity* v. 5 #4 (November 1978): 434-64.

Waterman, T.E., "Use of Automatic Door Closers Improves Fire Safety," *Journal of Clinical Engineering* v. 4 #3 (July-Sept 1979): 260-64.

Pape, R. and T.E. Waterman, "Understanding and Modelling Preflashover Compartment Fires," *ASTM STP68S*, Design of Buildings for Fire Safety. Philadelphia, American Society for Testing and Materials, 1979, pp. 106-138.

Campbell, John A., "Expanding Fire Safety Management Systems in High-Rise Buildings," Boston, *Society of Fire Protection Engineers Technical Report* 82-5,1983.

Waterman, T.E., "Fire Venting of Sprinklered Buildings," *Fire Journal* v. 78 #2 (March 1984): 30-32, 34, 36-39, 86.

Varley, Reed B., "Designing Reliability and Safety into Smoke Control Systems," Chicago, *Society of Fire Protection Engineers Technology Report* 85-2, 1985.

"Fire and Explosion Investigations - A Historical and Hysterical Perspective," by John A Campbell and Kim R. Mniszewski. *Triodyne Safety Brief* v. 7 #2 (1991).

FORENSIC ENGINEERING

"The Changing World of Products Liability Law," by Kenneth W. Clarkson and Francisco O. Loriga. *Triodyne Safety Brief* v. 6 #1 (March 1990).

Defect-Definitions-by-State Series:

"What is a Defect? Alabama," by Gary and Paula Ruben. *Triodyne Safety Brief* v. 1 #1 (April 1981): 2.

"What is a Defect? Alaska?." by Gary and Paula Ruben. *Triodyne Safety Brief* v. 1 #1 (April 1981): 4.

"What is a Defect? Arizona." by Gary and Paula Ruben. *Triodyne Safety Brief* v. 1 #2 (Sept. 1981): 4.

"What is a Defect: Arkansas." by Gary and Paula Ruben. *Triodyne Safety Brief* v. 1 #2 (Sept. 1981) L: 4.

"What is a Defect? California." by Gary and Paula Ruben. *Triodyne Safety Brief* v. 1 #2 (Sept. 1981): 4-5.

"What is a Defect? Colorado," selected by Robert A. Zupkus, White & Steele, Denver Co. *Triodyne Safety Brief* v. 2 #1 (July 1983): 4-5.

"What is a Defect? Connecticut." selected by John Bradley, Great American Insurance Company, Hartford, CT. *Triodyne Safety Brief* v. 2 #1 (July 1983): 5.

"What is a Defect? Delaware." selected by Robert A Kosseff, Howard M. Berg & Associates, Wilmington, DE. *Triodyne Safety Brief* v. 3 #2 (June 1985): 7.

"What is a Defect? District of Columbia," selected by Joel M. Savits, Carr, Jordan, Coyne and Savits, Washington, DC. *Triodyne Safety Brief* v. 3 #2 (June 1985): 7-8.

"What is a Defect? Florida," selected by Fred Mattlin, Siemon, Larsen & Mattlin, Boca Raton, FL. *Triodyne Safety Brief* v. 3 #4 (Sept. 1985): 7.

"What is a Defect? Georgia," selected by Paul W. Painter, Karsman, Brooks & Painter, Savannah, GA. *Triodyne Safety Brief* v. 3 #4 (Sept. 1985): 7-8.

"What is a Defect? Idaho," selected by Oar Hackney, Lynn, Scott and Hackney, Boise, ID. *Triodyne Safety Brief* v. 4 #1 (April 1986): 22.

"What is a Defect? Illinois (Part I)," selected by James T.J. Keating, Law Office of James T.J. Keating, Chicago, IL. *Triodyne Safety Brief* v. 4 #1 (April 1986): 22-24.

"What is a Defect? Illinois (Part 2)," selected by James T.J. Keating, Law Office of James T.J. Keating, *Triodyne Safety Brief* v. 4 #2 (June 1986): 8-10.

"What is a Defect? Illinois (Part 3)," selected by James T.J. Keating, Law Office of James T.J. Keating, *Triodyne Safety Brief* v. 4 #3 (November 1986): 6- 8.

"Whats is a Defect? Indiana," selected by Thomas H. Bryan, Fine and Hatfield, Evansville, IN. *Triodyne Safety Brief* v. 4 #4 (December 1986): 11.

"What is a Defect? Iowa," selected by John Werner and Daniel J. Hanson, Grefe & Sidney, Des Moines, IA. *Triodyne Safety Brief* v. 5 #2 (July 1988): 16.

"What is a Defect? Kansas," selected by Jon Blongewicz, Boddington & Brown, Kansas City, KS. *Triodyne Safety Brief* v. 5 #2 (July 1988): 16.

"What is a Defect? Hawaii," selected by Calvin E. Young, Libkuman, Ventura, Ayabe, Chong and Nishimoto, Honolulu, HA. *Triodyne Safety Brief* v. 5 #3 (October 1989): 7-8.

"What is a Defect? Kentucky," selected by Edward H. Stopher, Boehl, Stopher, Graves and Deindoerfer, Louisville, KY. *Triodyne Safety Brief* v. 5 #3 (October 1989): 8-9.

"What is a Defect? Louisiana," selected by John Swanner, Seale, Smith, Zuber & Barnette, Baton Rouge, LA. *Triodyne Safety Brief* v. 6 #4 (May 1991): 19-20.

"What is a Defect? Maine," selected by Frederick F. Costlow, Richardson & Badger, Bangor, ME. *Triodyne Safety Brief* v. 6 #2 (June 1990): 16.

"What is a Defect? Maryland," selected by Francis X. Quinn, Anderson & Quinn, Rockville, MD. *Triodyne Safety Brief* v. 6 #2 (June 1990): 16.

"What is a Defect? Massachusetts," selected by Patrick T. Jones, Cooley, Manion, Moore & Jones, Boston, MA. *Triodyne Safety Brief* v. 6 #3 (March 1991): 6-7.

"What is a Defect? Michigan," selected by Allen S. Bush and Wesley A. Butch, Butch, Quinn, Rosemurgy, Jardis, Bush, Burkhart & Strom, Escanaba, MI. *Triodyne Safety Brief* v. 6 #3 (March 1991): 7-8.

"What is a Defect? Mississippi," selected by Vincent J. Castigliola, Brynam, Nelson, Allen, and Schroeder, Pasacagoula, MS. *Triodyne Safety Brief* v. 7 #1 (August 1991): 14.

"What is a Defect? Missouri," selected by Micahel W. Manners, Law Firm of Welch, Martin & Albano, Independence, MO. *Triodyne Safety Brief* v. 7 #2 (December 1991): 18.

"What is a Defect? Montana," selected by Steve Reida, Law Firm of Landoe, Brown, Planalp & Braaksma, Boze-man, MT. *Triodyne Safety Brief* v. 7 #2 (December 1991): 19.

"What is a Defect? Nebraska," selected by Melinda G. Hess, Melinda G. Hess Law Office, Omaha, NB. *Triodyne Safety Brief* v. 7 #4 (August 1992): 18-9.

"What is a Defect: New Mexico," selected by Jeffrey D. Tatum, Atwood, Malone, Mann & Turner, Roswell, NM. *Triodyne Safety Brief* v. 7 #4 (August 1992): 19-20.

HUMAN FACTORS

"The Dependency Hypothesis (Part I)," by Ralph L. Barnett, Gene Litwin and Peter Barroso, Jr. *Triodyne Safety Brief* v. 2 #3 (November 1983).

"The Dependency Hypothesis Part II): Expected Use," by Ralph L. Barnett, Gene D. Litwin and Peter Barroso, Jr. *Triodyne Safety Brief* v. 3 #1 (December 1984).

"The Meat Grinder Safety Throat," by Ralph L. Barnett, Gene Litwin and Gary M. Hutter. *Triodyne Safety Brief* v. 3 #4 (Sept. 1985).

"Principles of Human Safety," by Ralph L. Barnett and William G. Switalski. *Triodyne Safety Brief* v. 5 #1(1987).

"Ergonomic Studies in Grip Strength - Literature Review," by Dennis B. Brickman. *Triodyne Safety Brief* v. 6 #2 (June 1990).

Hutter, Gary M., "OSHA's Draft of Ergonomic Guidelines," *National Safety Council Power Press and Forging Newsletter* (March/April 1990): 4.

LIBRARY AND INFORMATION SERVICES

Hamilton, Beth A., "Reinventing the Wheel: Information Services in Forensic Engineering," in *Issues and Involvement: Alberta E. Brown Lectures in Special Librarianship 1978-1980.* New York, Special Libraries Association 1983, pp. 39-48.

Hamilton, Beth A., "Online Access to Chemical Standards Information," *Chemical Engineering Progress* v. 82 #1 (January 1986): 7-11.

"AIDS and Hepatitis B in the Workplace," Bibliography (1113) compiled by Meredith L. Hamilton under OSHA Contract, Niles, IL, Triodyne Inc., 1988, $660.00.

"Manual Lifting and Workplace Back Injuries," Bibliography (63) compiled by Beth A. Hamilton under OSHA Contract, Niles, IL, Triodyne Inc., 1987 & 1991, $1200.00

"AIDS and Other Bloodborne Diseases Transmitted to Health Care Personnel by Accidental Needlestick," Bibliography (1140) compiled and paper presented to CDC-Atlanta Conference by Beth A. Hamilton under NIOSH Contract, Niles, IL, Triodyne Inc., 1989, $880.00.

"Safety Registry: 1000," by Safety Information Center Staff. $7.00, includes both editions. Niles, IL, Triodyne Inc., 1987, 2nd 1990.

"Carpal Tunnel and Other Compression Syndromes Bibliographic Database," by Meredith L. Hamilton. Niles, IL, Triodyne Inc., *PC and Macintosh Disk Editions,* $60.00 (March 1992).

MECHANICAL SAFETY

"Power Press Brake Safety Package," by Mary A. Misiewicz. *Safety Posters*, $10.00 (1980).

"Power Punch Press Safety Package," by Mary A. Misiewicz. *Safety Posters*, $20.00 (1980).

"Drill Press Guards," by William G. Switalski and Ralph L. Barnett. *Triodyne Safety Brief* v. 2 #4 (Sept. 1984).

Barnett, Ralph L., "A Pressure Vessel Hatch Cover Failure - A Design Analysis," *Case Histories Involving Fatigue and Fracture Mechanics. ASTM (PCM) 04-918000-30.* Philadelphia, American Society for Testing and Materials, 1986.

"Mechanical Power Press Safety Bibliography," by Beth A Hamilton, Joyce E. Courtois and Cheryl A Hansen. *Triodyne Safety Brief* v. 4 #1 (April 1986).

Dilich, Michael A. "Force Distribution Bottom Guard for Vertically-Closing Door," *U.S. 4,771,505,* assigned to Triodyne Inc., patented Sept. 30,1988.

Dilich, Michael, "Safety Mechanism for Vertical Closure," *U.S. 4,813,305,* assigned to Triodyne Inc., patented March 21,1989.

"Part I: Introduction to Fracture Mechanics," by E. J. Ripling. *Triodyne Safety Brief* v. 6 #3 (March 1991).

MEDICAL EQUIPMENT SAFETY AND STUDIES

Khan, M.A.Q. and J.P. Bederka, eds. *Survival in Toxic Environments.* New York, Academic Press, 1974.

Odenbro, A, J.P. Bederka et al., "Behavioral and Intellectual Consequences of Early Childhood Lead Poisoning," *Ambio* v. 12 #1(1983): 40-44.

"Reliability and Safety of Medical Devices: Introduction," by James R. Wingfield. *Triodyne Safety Brief* v. 5 #3 (Oct. 1986).

"Status of Standards of Practice in Pharmacy," by James T. O'Donnell. *Triodyne Safety Brief* v. 5 #4 (June 1990).

"Ergonomic Studies in Grip Strength - Literature Review," by Dennis Brickman. *Triodyne Safety Brief* v. 6 #2 (June 1990).

Barnett, Ralph L., Steven R. Schmid, and Robert Kaplan, "Minimum Energy Curb Negotiating Wheelchair," *U.S. 4,962,942,* assigned to Triodyne Inc., patented October 16, 1990.

"Carpal Tunnel and Other Compression Syndromes Bibliographic Database," by Meredith L. Hamilton. Niles, IL, Triodyne Inc., *PC and Macintosh Disk Editions,* $60.00 (March 1992).

SAFETY PHILOSOPHY

"On Classification of Safeguard Devices (Part I): Intrinsic Classification of Safeguarding Systems," by Ralph L. Barnett and Peter Barroso, Jr. *Triodyne Safety Brief* v. 1 #1 (April 1981).

"On Classification of Safeguard Devices (Part 11): Functional Hierarchy of Safeguarding Systems," by Ralph L. Barnett and Peter Barroso, Jr. *Triodyne Safety Brief* v. 1 #1 (Sept. 1981).

"Philosphical Aspects of Dangerous Safety Systems," by Ralph L. Barnett and Beth A. Hamilton. *Triodyne Safety Brief* v. 1 #4 (Dec. 1982).

"On Safety Codes and Standards," by Ralph L. Barnett. *Triodyne Safety Brief* v. 2 #1 (July 1983).

"Safety Hierarchy," by Ralph L. Barnett and Dennis B. Brickman. *Triodyne Safety Brief* v. 3 #2 (June 1985).

Hutter, Gary M., "Active versus Retroactive Regulations: Criteria for Implementing a Safety Regulation," *Standards Engineering* v. 37 #6 (Nov/Dec 1985): 127-9.

Hutter, Gary M., "Antitrust, Unfair Trade Practices and Safety," *Professional Safety* v. 31 #5 (May 1986): 13-16.

"A Proposed National Strategy for the Prevention of Severe Occupational Traumatic Injuries," *Triodyne Safety Brief* v. 4 #4 (December 1986).

"Principles of Human Safety," by Ralph L. Barnett and William G. Switalski. *Triodyne Safety Brief* v. 5 #1 (February 1988).

Barnett, Ralph L., Peter Barroso, Jr., Beth A. Hamilton and Gene D. Litwin, "Selected Principles of Human Safety in the Workplace," International Journal of Materials and *Product Technology* v. 4 #2(1989): 125-44.

"Safety Interlocks - The Dark Side," by Frank B. Hall. *Triodyne Safety Brief* v. 7 #3 (June 1992).

"The Doctrine of Manifest Danger and Its Relationship to Reliability, Preventive Maintenance and Fail-Safe Design," by Ralph L. Barnett. *Triodyne Safety Brief* v. 8 #1 (Sept. 1992).

VEHICLE SAFETY

Uzgiris, S.C. and Paul Torda, "The Blue Flame," *Mechanical Engineering* v. 92 #7 (July 1970): 9-18.

"Zero Obstruction Repair Overpass," by Ralph L. Barnett. *Triodyne Safety Brief* v. 1 #3 (1982).

"On the Safety of Motorcycle Side Stands," by Dror Kopernik. *SAE Technical Paper No.840905* and *Triodyne Safety Brief* v. 2 #4 (September 1984).

"Trailer Hitches and Towbars," by William G. Switalski and Ralph L. Barnett. *Triodyne Safety Brief* v. 3 #3 (July 1985).

Kopernik, Dror, "The Side Stand Problem," *United Motorcyclists of Illinois Newsletter* (August 1985 and January 1986).

Dilich, Michael A., S.C. Uzgiris, D.F. Rudny, and Dror Kopernik, "Truck Speed Control in Curves and Exit/Entrance Ramps," Washington, *National Highway Traffic Safety Administration Report, Contract No. DTNH 22-85-D- 47259, Task 1,* April 2,1986.

Dilich, Michael A., S.C. Uzgiris, D.F. Rudny and Dror Kopernik, "Analysis of Accident Case Histories," *National Highway Traffic Safety Administration Report, Contract No. DTNH 22-85-D-47259, Task 2,* May 2,1986.

"Mandatory Seat-Belt Usage Laws: Exemptions to the Rule," by Gary M. Hutter and Cheryl A. Hansen. *Triodyne Safety Brief* v. 4 #3 (November 1986).

Hutter, Gary M. and Cheryl A. Hansen, "With State Belt Use Laws, Exemptions Are the Rule," *Traffic Safety* v. 87 #2 (March/April 1987): 10-13, 26-28.

Uzgiris, S.C. and J.J. Hebert, "Defining Safety," *AFS Transactions* v.96 (1988): 505-508.

Dilich, Michael A., "Force Distribution Bottom Guard for Vertically-Closing Door," *U.S. 4,771,505,* assigned to Triodyne Inc., patented Sept. 30, 1988.

Dilich, Michael, "Safety Mechanism for Vertical Closure," *U.S. 4,813,305,* assigned to Triodyne Inc., patented March 21,1989.

Dilich, Michael A. and Donald F. Rudny, "Compliance with Safety Standards: A Necessary but Not Sufficient Condition," *ASME Technical Paper 89-DE-1.* New York, American Society of Mechanical Engineers, April 24-27, 1989.

Hansen, Cheryl A., Joel J. Hebert, and Michael A. Dilich, "Standards Identification and Retrieval for the Design Engineer," *ASME Technical Paper 89-DE-2.* New York, American Society of Mechanical Engineers, April 24-27, 1989.

"Photographic Documentation and Analysis in Vehicle Accident

Reconstruction," by Dror Kopernik and Crispin Hales. *Triodyne Safety Brief* v. 6 #4 (May 1991).

Dilich, Michael and Gene Litwin, "Automatic Garage Door Child Entrapment Hazards," *ASME Technical Paper 91-WA-DE-12.* New York, American Society of Mechanical Engineers, Dec. 1-6, 1991.

Commercial Vehicle Preventable Accident Manual: A Guide to Countermeasures developed under Federal Highway Administration contract by S. C. Uzgiris, Michael A. Dilich and Crispin Hales. $15.00 (April 1992).

Editor: Beth A. Hamilton
Illustrated and produced by Triodyne Graphic Communications Group.