

Safe Motion Technologies

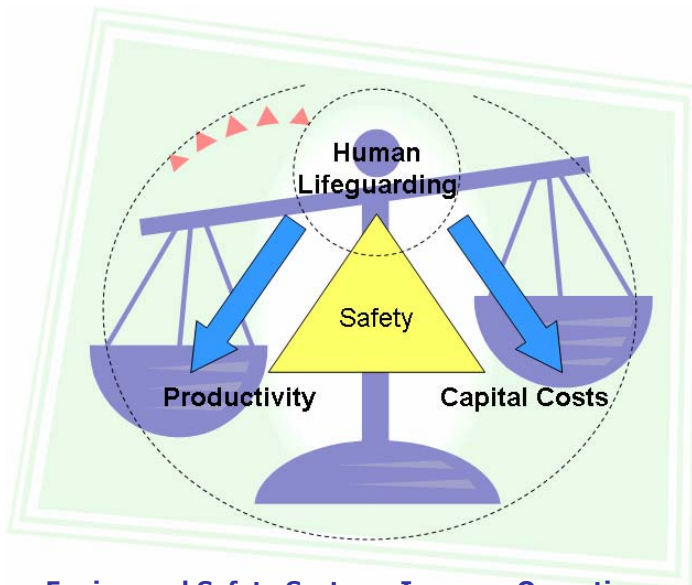
Competitive Advantages for Early Adopters

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Competitive Advantages of Modern Safety Solutions

Manufacturing organizations today are learning to justify improvements in factory safety systems by using operational and business metrics, rather than viewing them simply as a cost burden. To this end, many companies are changing the way they evaluate and deploy safeguarding systems. The modern approach is to perform a task and associated hazard analysis, which forms the basis of a safeguarding strategy. As a result, modern safety systems now contributor to - rather than detract from - productivity on the factory floor.



Engineered Safety Systems Improve Operations

Task-based safety is far more effective in reducing the residual risk of injury to the operator. The result is a quiet revolution in manufacturing and associated safety policies. Business and plant managers are actively seeking a well thought out, intelligent safety strategy that not only protects humans, machines and the environment, but also supports business benefits such as increased productivity, improved machine efficiency and increased uptime. Manufacturers are taking into account these business factors in the planning stages when considering new automation upgrades and installations. In effect, the industry has elevated safety to a business strategy in contrast to simply

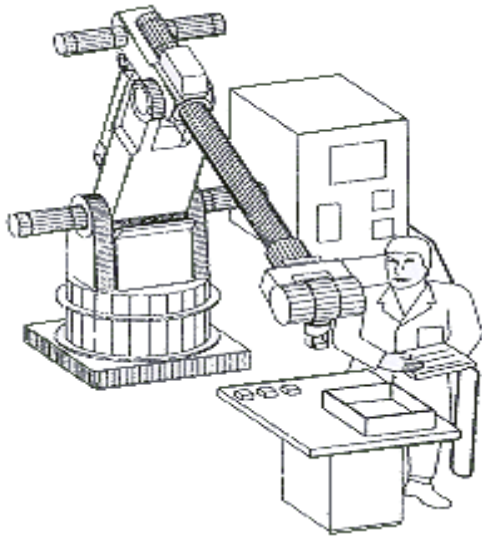
being a cost burden and regulatory requirement. As a result, automation suppliers are offering a new generation of safety solutions designed to be more effective in preventing accidents, less costly to implement, easier to adapt, and more reliable than existing hard wired systems.

Coherent Safety Strategy Improves Business Metrics

Safety, in terms of human and machine “health” and environmental protection, has moved to the forefront of critical topics for manufacturers due to an increased awareness of its strategic value. Machine safety in the traditional sense refers to add-on electrical and mechanical components that protect personnel from injury or death while working in or near industrial machinery. Thus, it is the internal engineering organizations that are being directed to

change the way safety systems are specified and designed because the business goals can be aligned.

Manufacturers are seeking upgrades of safety solutions for existing assets and select new capital equipment expenditures that improve utilization, minimize unscheduled downtime, and allow operators to work efficiently. Historically, conventional safeguarding systems emphasized absolute operator safety at the expense of productivity. From the perspective of local health and safety authorities, union representatives, and insurance providers, absolute operator safety is the right approach. However, despite the efforts to make equipment “absolutely safe”, highly motivated operators seeking productivity improvements may override a conventional safety system, often



A Task Oriented Approach to Safeguarding Allows Operators and Machinery to Work Productively

resulting in an accident. For this reason, even rigid safety solutions can't guarantee absolute safety. Also, when servicing a conventional safety system or investigating a nuisance trip, the combination of hard-wired discrete components makes it difficult to diagnose faults due to a lack of common diagnostic tools.

A more modern, effective safeguarding strategy is one that evaluates the use of equipment from a task oriented perspective (i.e. how does the operator have to interact with the machinery?). This task-oriented approach lends itself to the use of an integrated system solution that relies on intelligent automation components. This minimizes the risk of operator injury to a tolerable level in specific operational modes of the machine while allowing the operator to work efficiently compared to absolute safety measures such as physical guards and interlocks. For example, modern safety systems allow operators and maintenance personnel to gain access to machine safety zones by setting programmable limits on actuator speeds, forces, and torques to mitigate the risk of injury from these devices.

Further justification of this modern approach to safety can be found in studies in Sweden and Japan regarding robotic accidents. The studies concluded that many robot accidents do not occur under normal operating conditions, but rather during programming, maintenance, repair, testing, setup, or ad-

justment. In most instances, work procedures required the operator or maintenance worker to temporarily enter the robot's working envelope where unintended operations could result in injuries. Perimeter guarding or light curtains are temporarily overridden, thereby allowing the operator to enter the work zone while the machine is still operational. In contrast, a modern safety approach respects the behavior of factory personnel and implements safety solutions that allow access to work zones. This approach to safety is allowing significant improvements in manufacturing productivity.

Manufacturing engineering organizations recognize that the deployment of intelligent safety systems can lead to increased machine utilization, which directly bolsters the business bottom line. Many manufacturers have come to view an intelligent safety strategy as a competitive advantage rather than a cost burden. In addition, ensuring worker safety directly supports manufacturers' initiatives to limit liability exposure and to improve their public image. From ARC's perspective, modern, intelligent safety systems can directly improve the bottom line.

Safe Drives Achieve the Highest Productivity Improvements

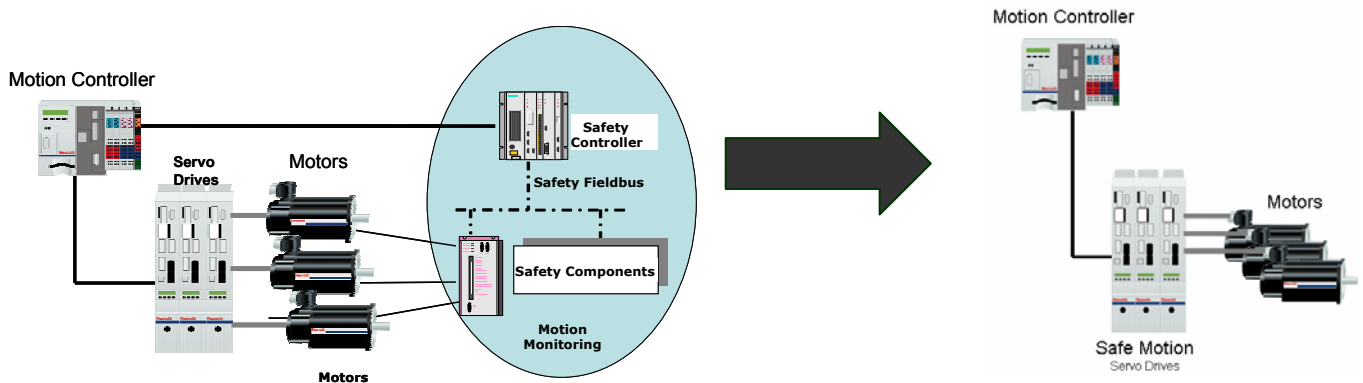
Modern, intelligent safety solutions are usually associated with safety PLCs that replace conventional hard-wired safety relays. However, far more important to productivity improvements are the avoidance of unintended axis movement and „safe motion“ that reduce the risk of injury to operators by allowing continued but limited axis movement. In addition, the use of freely programmable safety logic greatly increases the flexibility of a safety system. Thanks to these benefits, safety PLCs and safe motion have become a permanent part of modern safety concepts.

Product Segment	Description
Safety PLC	Safety-rated Programmable Logic Controllers rated for up to SIL 3 Level applications
Safe Drives	Servo drives and AC drives providing motion related safety functions.
Safety Relays	Safety relays and contactors designed to interface to safety devices such as e-stops, safety gates, light curtains, and safety mats

Range of Safe Guarding Solutions Expands Beyond Safety Relays

Safe Motion Embedded in Digital Servo Drives

Integrated safety in motion actuation devices, known as “Safe Motion”, supports a wide variety of safe drive functions without the use of external safety hardware. These functions can greatly increase machine productivity by allowing operators to perform tasks such as checking, cleaning, aligning and changing tools, which in the past could only be performed if power were completely removed from the drives. The benefits include faster restarts, no loss of accuracy due to repositioning, less brake wear, faster recovery from faults, and shorter downtime.



Safe Motion Reduces Complexity

Reusability has tremendous value in Safe Motion technology. Safety functionality is no longer an integral portion of the control system, but rather is embedded in the actuators that are distributed throughout the machinery. Safe Motion functionality has enabled machine builders to develop a flexible solution that can be employed in a wide range of applications to help lower the cost of design and installation. While cost and flexibility goals have generally competed against one another in machine design, Safe Motion has shattered this prevailing notion. This is a case where reductions are being made in component count, wiring and design time. This technology has allowed machine builders to leverage reuse of the safety solution from previous designs on each generation of machinery, as well as in a variety of machine product lines. This is where we see how the value of Safe Motion is making an impact on the machine building community.

A drive-based safety system has a distinct advantage over both an external safety monitoring system and a hardwired implementation because it fundamentally reduces the external component count and has a faster speed of response. In many cases, even the safety PLC can be eliminated.

Overall, the use of embedded intelligence is no longer novel in safety system components. These new generations of safety devices that use embedded intelligence are

subjected to same levels of validation and verification as more complex programmable devices. However, the approach taken by suppliers in the servo drive market is an interesting evolution for safety rated digital servo drives. The fact is, these solutions have significantly reduced the cost of software engineering and validation by incorporating a parameter configuration tool specifically for machine builders.

Safety on Board in Motion Control

As machinery employs more automated subsystems for either material handling or automated changeover, the trend in the market is towards safety solutions that allow operators to work better within the work envelope of the machine. Current safety standards allow the integration of configurable safety systems directly in servo drives. This embedded functionality in the

Stop Category 0	Uncontrolled stop. Immediately remove power to drives.
Stop Category 1	Controlled stop; Power is removed after the machine has come to a standstill.
Stop Category 2	Controlled stop; Power is still fed to the machine at standstill.

Stop Categories According to EN 60204-1

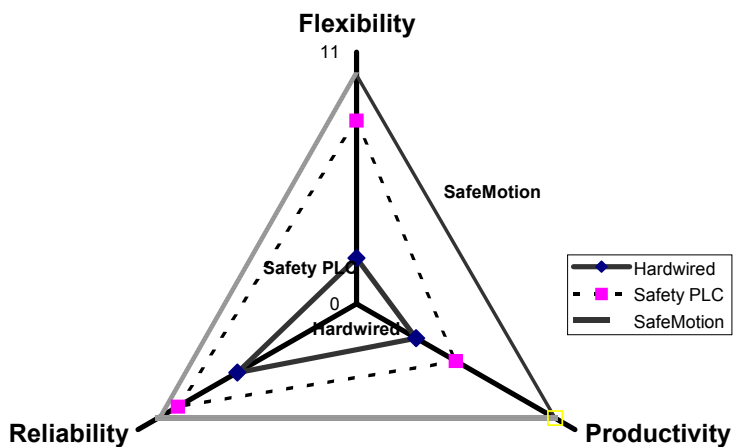
drives makes it possible for machine builders to incorporate safety strategies that improve the operator productivity. With safe drives, safety solutions are becoming less complex, with far fewer cables and connections, resulting in reduced design, commissioning and installation costs. Safe Drive functionality in a servo drive has two fundamental modes of operation: (1) Safe Stop in accordance with EN60204-1 and (2) Safe Motion.

Operational benefits of Drive-Integrated Safety

The ability to incorporate slow speed modes and higher speed response in the safety zone effectively obsoletes the use of multiple lock-out-tag-out requirements in powered machinery and work cells. While the external safety solution and the safety motion implementation have the same end result, the real difference is in performance. The safety motion in the drive provides the shortest possible reaction times in each axis drive of the machine. This is where drive based safety has a distinct advantage. Similar to a safety relay where a supplier integrates multiple relays wired in a safe fashion for fast and safe functioning, the drive with safety combines two channel functionality with a dual channel motor feedback device to provide a safe device. It can respond very fast to internal malfunction and connected device signals which is the benefit of distributed intelligence.

When designing a safety system, the maximum response time from pushbuttons and sensors to actuator is a critical design parameter. Realizing

the safe motion functionality in the motion controller or Safety PLC is an option, but either of these solutions have inherent performance disadvantages. The underlying issue is the time delay between the safety PLC or motion controller and associated feedback devices. A drive-based solution, on the other hand, has access to all the required signals, but benefits from the faster update time of the controller cycle time. From a performance perspective, an external solution forces the machine designer to incorporate greater margins of safety that reduce the operator's ability to work within the machine envelope. A side benefit of the drive-based



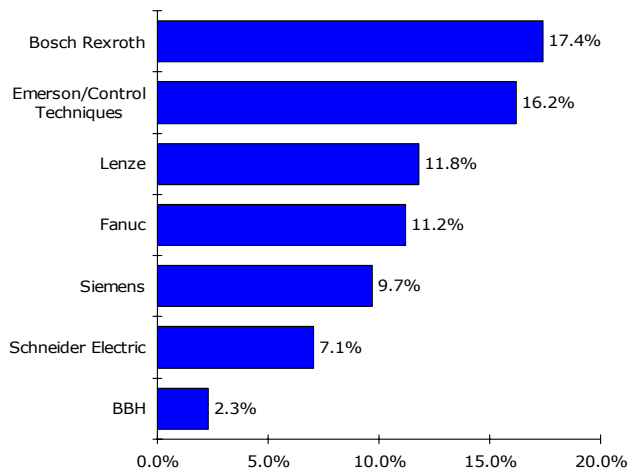
**Safe Motion In Drives Achieves Highest Levels
In all Performance Metrics**

approach is that, in many cases, the safety PLC can be completely eliminated by monitoring the safety zone from the drive.

Safe motion in a drive can simplify the overall safety design. By utilizing the limited I/O in a drive, the safety functionality can be incorporated where it is processed most efficiently and provides the fastest reaction time for handling a safeguarding event. The machine builder is now able to minimize safe stopping distances for the operator that is working withing the machine operating envelope. Secondly, a drive-based safety solution inherently lowers the overall component count of safety devices in the machine, which can have a significant cost advantage when factoring in costs of design, layout, programming and commissioning.

Bosch Rexroth's IndraDrive Boasts Leadership in Safe Motion

The machine safeguarding business has traditionally been a highly fragmented market dominated by a large number of privately held component suppliers of safety relays, safety interlocks, light guards, and other ancillary mechanical guarding solutions. However, as motion control suppliers gain a foothold in this business by offering integrated Safe Motion solutions, the balance of power is being upset. Bosch Rexroth has been actively involved



Bosch Rexroth Leads the Safe Motion Market

Motion into the market is having a greater impact on the Machine Safeguarding business than any other factor, even the venerable Safety PLC. Thus, a class of suppliers never before considered in the safeguarding business is emerging and is being led by Bosch Rexroth.

Bosch Rexroth's Safe Motion Strategy

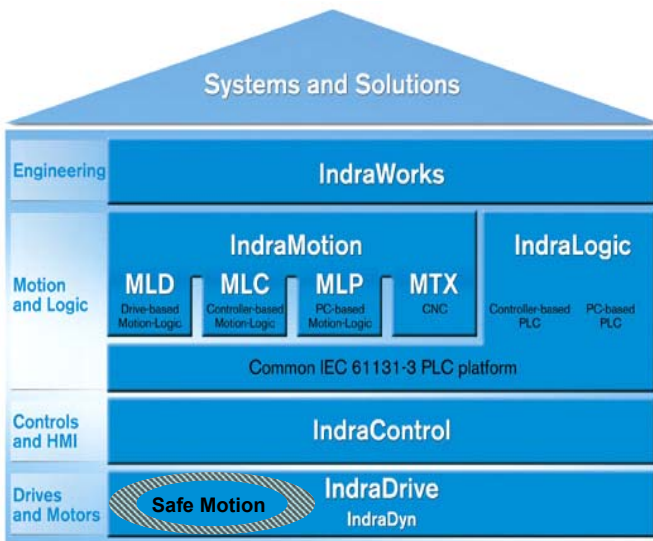
The manufacturing community seeks to maximize the utilization of equipment capital expenditures. By purchasing machinery that incorporates Safe Motion, manufacturers can enjoy immediate improvements in operator efficiency and overall machine utilization. Specifically, large efficiencies can be achieved in the areas of production changeover, production setup, and intelligent diagnostics for maintenance. Bosch Rexroth's IndraDrive's "Safety on Board" feature offers a reliable safety solution that incorporates the most advanced integrated safety functions that comply with the latest international standards for "safe stopping" and "safe motion". Equally important is that these capabilities are available on a common platform that functions as a servo-drive or frequency converter. Thus, a machine builder that uses both types of motor technologies (induction and brushless permanent magnet) is able to use a common drive platform along with a common safety controller system. Common controls lowers the overall cost of integration and deployment for the machine builder while the end user benefits from machinery that maximizes the advantage of the latest safe motion technology throughout the entire system.

with Safe Motion technology since 1996. Consequently, the company has a mature product line that has helped it gain a strong foothold in the Safe Motion business. In 2004, ARC ranked Bosch Rexroth as the leading supplier of Safe Motion solutions in a market research report. Bosch Rexroth's approach to Safe Motion was to challenge the traditional way of architecting a safe guarding solution by adding configurable intelligence that facilitates a more complex set of rules, enabling the operator to work more productively. The introduction of drive-based Safe

Reducing Automation Complexity

IndraDrive's Safety On Board safe motion technology is integrated directly in the drive. Consequently, vertical machinery applications can leverage these capabilities independently of the selected motion controller. Thus, motion controllers within the Indra family or even third party motion controllers are able to leverage Safe Motion technology integrated in the drive. Drive integrated safety from Bosch Rexroth has incorporated a revolutionary design such that production never needs to stop. The standard requires safety subsystems to perform a functional test at least every eight hours which effectively forces the machinery to shutdown. The IndraDrive has incorporated a unique feature keeps the machine running while performing an integrity check. Bosch Rexroth's Safety On Board provides programmable

wire pulse testing that functions continuously in the background alleviating a machine shutdown. This is important factor in making active safety transparent to the user.



Bosch Rexroth's Automation House

The IndraDrive generally has enough spare I/O directly on the drive that can be dedicated to handle the safeguarding logic needed to interface to safety gates, panel switches, and interlock switches. Thus, machine builders need to only learn one safety solution for an application, but have the freedom to deploy a varied number of motion controllers if requested. However, when the application demands more I/O

such as in small machines or modular machine designs, an optional drive-integrated, IEC 61131-3-compliant PLC is an option. The PLC incorporates motion function block programming for profiling, electronic gearing, CAM profiles and other widely used motion control functions. Overall, the inclusion of a PLC in the drive reduces the number components for the overall machine control, but does not impact the machine builder's ability to leverage built-in safety technology. The Safe Motion capabilities, while integrated in the form factor of the drive, are wholly independent of the drive-integrated PLC. Another benefit of the Safe Motion subsystem is the use of configuration rather than programming as a means to deploy the safety logic. In essence, Bosch Rexroth has taken the complexity of pro-

gramming out of the safety product, which can help facilitate the validation process of the safeguarding strategy.



A Wide Range Of Machinery Applications Are Able To Leverage Safe Motion Technology

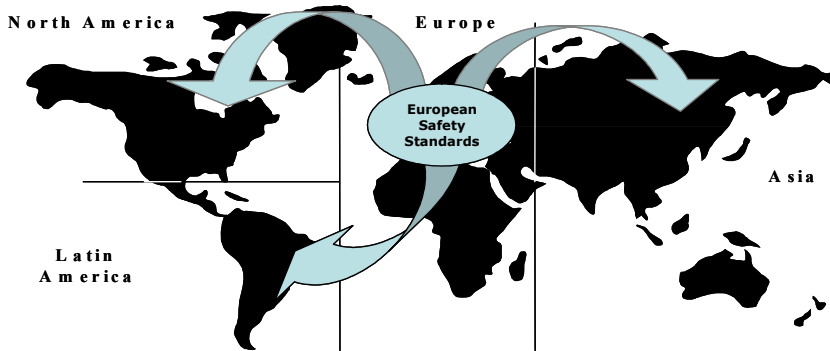
Bosch Rexroth has successfully taken Safe Motion technology into the high demand production arena of automotive manufacturing. Automotive end users recognize the company's deep domain expertise in both powertrain and body & assembly. To this end, machine building customers seek Bosch Rexroth's leadership in guiding them to the most appropriate technology and architecture for an application. The technology in the IndraDrive series has been developed with the business issues of both machine builders and end customer in mind. Consequently, the solution has been engineered in a collaborative fashion that acutely balances the needs of machine

builders and the functional requirements of end customers. The IndraDrive product line continues to be refined and improved across printing & converting, metalworking machine tools, packaging, and light assembly. Bosch Rexroth simply does not stand still, but continues to innovate with the latest technology while supporting these systems with skilled application expertise. IndraDrive "Safe Motion" has been deployed predominantly in the European machine building market since the regulatory environment has recognized the viability of control reliable safety solutions since the middle of the 1990s. However, the trend that started in Europe is rapidly disseminating to other regions of the world. Thus, machine builders need to look over the horizon in overall control and safety architecture when considering new machine designs or re-engineering existing systems in order to offer end users the advantages of Safe Motion technology.

European Union Influences Trends in Machine Safety

A machine safeguarding solution is an engineered system that reduces the risk of harm to people, equipment, or the environment that may arise from the operation of a piece of production equipment. In this regard, the standards or best practices for creating a safe environment when people are

involved with operating or maintaining machinery continue to evolve. The standards or best practices for creating a safe environment when people are involved with operating or maintaining machinery continue to evolve.



European Safety Standards are Permeating Worldwide

The European safety strategy has a dual purpose: to reduce the risk of injury to machine operators to an acceptable limit while increasing the availability of the production equipment. The European market has effectively demonstrated that machine utilization

does not have to be traded off for increased operator safety. The impact of EN safety standards has spread globally and is driving trends in configuration and deployment of safety components and solutions in machinery, production lines, and factories.

This renewed interest in manufacturing safety emanating from Europe is driven by the economic aspects of this region. Europe is the largest machine building community in the world when machinery for general production, plastics, metal working, printing and packaging is all combined. From the economic perspective of the machine builder, safety harmonization has had a benefit of simplifying machinery shipments between countries in the European Union by unifying the highly legal landscape. The other regions of the globe that are exporting machinery to the European Union are being impacted as well where European Norm standards such as EN 954-1, which defines the guidelines for safety-relevant parts of control systems, is garnering interest in Japan and North America.

North America Lags the Regional Trends

In the U.S., health and safety in the workplace has not always been a primary consideration in manufacturing environments as evidenced by the excerpt from a New York Times article published in 2003. Although it is not possible to put a value on an individual life or limb, the most disconcerting fact is that the article concluded that over a span of two decades, from 1982 to 2002, the U.S. Department of Labor Occupational Safety & Health Administration (OSHA) investigated 1,242 of these accidents and concluded that workers

“Every one of their deaths was a potential crime. Workers decapitated on assembly lines, shredded in machinery, burned beyond recognition, electrocuted, buried alive — all of them killed, investigators concluded, because their employers willfully violated workplace safety laws. These deaths (...) were not accidents. They happened because a boss removed a safety device to speed up production, or because a company ignored explicit safety warnings, or because a worker was denied proper protective gear.”

“When Workers Die: US Rarely Seeks Charges for Deaths in Workplace”, David Barstow, The New York Times, December 22, 2003

had died because of their employer's "willful" safety violations. While these tragic accidents continued to persist, OSHA declined to seek prosecution in 93 percent of those cases.

Since this period, OSHA has been making dramatic changes in order to reduce negligent safety. OSHA issued a 2003-2008 strategic plan with goal is to reduce workplace fatalities by 15 percent and workplace injuries and illnesses by 20 percent by 2008. Each year, OSHA will emphasize specific areas to achieve this broader goal; for example, in 2003-2004, OSHA's goal is a one percent drop in general industry fatalities, as well as a four percent drop in injuries and illnesses

in construction, general industry, and specific industries with high hazard rates. OSHA's legacy as an understaffed agency unable to adequately enforce safety policies is rapidly dissipating.

Trends in Asian Countries

In situations where regulations may be unclear or not yet harmonized, the risk exposure of not complying even with non-compulsory practices is still high, but companies can at least demonstrate their “best faith” by documenting compliance with all generally accepted industry practices. Such tactics can also be applied to safety strategies, especially for machine builders faced with differing safety regulations in foreign markets. While harmonization of standards is lessening the workload, the burden of proof of compliance still lies with both the OEM and the end user. In Asia, many countries such as Japan publish equivalency charts that associate local standards with internationally recognized standards (ISO and IEC), making it somewhat easier for OEMs to declare compliance by association.

Regional Influence of European Safety Standards

Overall, these advancements in the European safety standards and international norms have simplified the jungle of regulations that a machine OEM has to understand and comply with, but up until now this has strictly benefited European manufacturers. The regulatory environment continues to vary by country whereby the OEM and end use manufacturer still bear the

responsibility for ensuring compliance. In the United States, for example, OSHA's local safety authority needs to be convinced that a safety implementation is fulfilling the local standards. Thus, the burden of proof for a safety implementation often resides with the end user purchasing the equipment.

There is evidence that more control reliable safety solutions emanating from Europe are being accepted by a number of the local safety authorities in the US

There is evidence that more control reliable safety solutions emanating from Europe are being accepted by a number of the local safety authorities in the US. The first recognition of control reliable safety in the US was the NFPA-79 guidelines. NFPA-79 incorporated language in the guidelines that created an opportunity for machine builders to incorporate both programmable and electronically controlled machine stops that comply with EN954-1 up to Category 4 levels of safety. However, the guidelines continued to require electromechanical relays between the drives and motors when implementing a Category 0 stop. OSHA has not specifically incorporated the NFPA-79 guidelines by reference in their documents because they primarily rely upon the ANSI B11 standards to validate a safeguarding implementation for a specific machinery class. To this point, there has been considerable activity in the ANSI standards committee to incorporate language which has allowed machine builders to design in Safe Motion technology.

"During production runs, the safe guarding solution may use any control reliable means that is redundant and has in-line verification..."

GM's global manufacturing perspective has provided the impetus to pave the way for Safe Motion in North America. By adding this language to the ANSI Standards, North American safety solutions will approach European best practices.

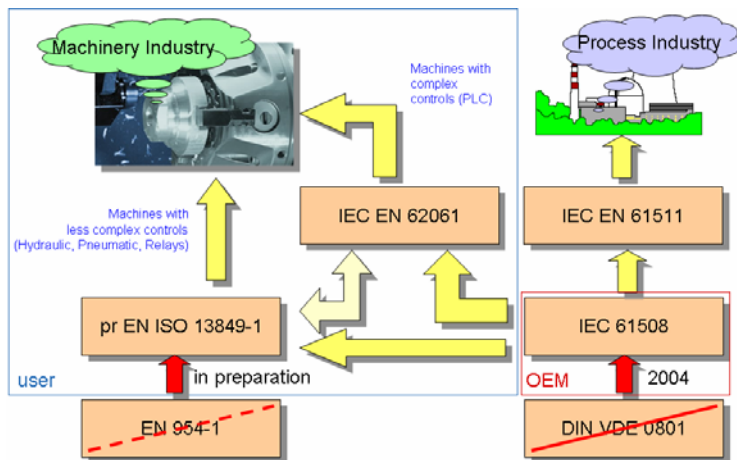
While this specific language has not been released into the ANSI standards, OSHA is recognizing the validity of this statement and has been allowing end users to purchase machinery with Safe Motion technology. Automotive OEMs for General Motors and Ford have been pushing for this technology. They see a tremendous productivity gains in work cells where operator can be within the work envelope to perform setup, changeover and some maintenance operations while the machine remains under control. Secondly, the use of control reliable safety solutions effectively obsoletes the use of multiple lock-out tag outs for a work cell. The manufactures are able to provide the production floor personnel with a single switch which places the machinery in a safe operational mode for the specific "task" being performed. To

this end, the US is adopting a risk assessment process in the ANSI B11.TR3 standards that is promotes a task – hazard pair analysis.

Thus, it is anticipated that the approach to safety employed in the European Union today will progressively be adopted in the US as part of a common recognized set of standards. The acceptance the European Union’s safety standards will move rapidly as evidence mounts that these innovative solutions can provide protection of both man and machine while increasing the Overall Equipment Effectiveness (OEE) of the production equipment.

Summary: Evolution of Safety Standards

The probability-based or risk based approach of new safety norms has created an opportunity for technology improvements to be employed that benefit users. The latest European Norms such as EN62061 and EN13849 consider the probability of failure of a safety function not just the individual components that are used to implement the safety function. Basically, safety functions are now being designed and implemented for which the probability of the failure of the safety function lies below a user’s tolerable level of



risk and the chance of discovering so-called „sleeping“ faults is high enough. Moreover, these norms support the notion that freely programmable systems have become a permanent part of modern safety solutions. In general, many of the causes of faults lie in the machine safety specification, which is why norms based on IEC 61508 place demands on the whole product lifecycle.

The Latest Standards Take into Account Safety Design

The risk based approach to safety will rapidly disseminate throughout the manufacturing community globally. Increasingly more companies are manufacturing are global in nature with numerous production facilities. Consequently, the benefits of the modern approach to safety is providing a manufacturing competitive advantage to European producers, as a result the demand for leading safety solutions definitively increase throughout all regions of the globe.

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Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Community/terms/terms.htm

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