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Selecting Safety Standards for Machine Safeguarding Requirements

Part 1 of 5 in a series addressing the primary milestones to a safe machine

Introduction

When embarking on a path to implement machine safeguarding (protective) measures, one cannot dismiss the influence and importance of documented safety requirements – whether they are mandatory versus voluntary; normative opposed to informative; and regardless of their designation as a law, directive, regulation, harmonized standard, consensus standard, technical guideline, or merely best practice [herein referred to simply as 'safety standards'].

"Safety standards" are requirements designed to ensure the safety of people around products, activities, or processes. They may be advisory or compulsory and are typically laid down by either a voluntary or statutory body that may be advisory or regulatory.

When it comes to safety standards, there is no shortage of documentation outlining specific requirements. Before defaulting to a laundry list of requirements that your organization has bought into for guidance, it is important to first understand why referencing specific sources is important to an organization.

Why Reference Standards?

Generally speaking, we reference documented material as a measurement we can compare to. In terms of machine safety, this is a sort of litmus test; selecting appropriate standards will clearly define the minimum allowable requirements, specifications and expectations for comparison, which in turn will ease the burden of determining if those goals have been achieved – either by internal team members retrofitting equipment or external suppliers contracted to provide equipment with appropriate safeguards.

Identifying EH&S Goals

Before we can get into which safety standards are 'right' for an organization, we must also address what the goals of the organization are. There are many different factors that influence the needs and desires to provide a safe workplace (which we won't address here), but understanding the intentions will provide guidance throughout the process.

One of the major factors to consider is if the organization is striving for compliance, safety, or a combination of the two. While at first glance these aspects may appear to be one and the same, they are in fact very distinctive. 'Compliance' is the practice of adhering strictly to published standards and could be viewed as a reactive or defensive approach to safety, in that the primary purpose is to evade prosecution – either in a court of law or in the court of public opinion. 'Safety,' on the other hand, is viewed as a proactive approach to provide protection from danger or to achieve a condition with as little risk as possible, or as low as reasonably practical (ALARP).

It is important to recognize that ‘compliant’ equipment is not always ‘safe’ and that ‘safe’ equipment is not always ‘compliant’, leading many of us to desire BOTH ‘safety’ and ‘compliance.’ While it could be argued that as long as the true goal of providing a safe workplace is maintained, compliance may not truly matter. For many, however, compliance is extremely relevant because it provides a decisive result regarding how safe is ‘safe enough’ while also protecting organizations from further liability. Clearly understanding your organization’s view on this issue will provide great assistance with this endeavor.

Types of Standards

The primary purpose of most safety standards is to provide the audience (readers) with an overall framework and guidance for decisions during the entire lifecycle of machinery to enable them to maintain machines that are safe for their intended use. Many standards developing organizations (SDOs) use the following structure (also see Figure 1):

- **Type-A standards** (basic safety standards) giving basic concepts, principles for design and general aspects that can be applied to machinery;
- **Type-B standards** (generic safety standards) dealing with one safety aspect or one type of safeguard that can be used across a wide range of machinery:
    - **Type-B1 standards** on particular safety aspects (e.g., safety distances, surface temperature, noise);
    - **Type-B2 standards** on safeguarding device (e.g., two-hand controls, interlocking devices, pressure-sensitive devices, guards);
- **Type-C standards** (machine safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

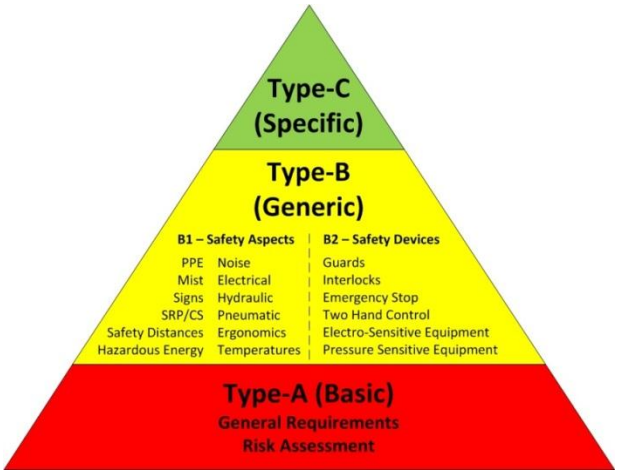

Figure 1: Structural Organization of Standards

Often, safety professionals either focus on one of two ends of the spectrum. Some will gravitate toward the type-A and -B standards (often referred to as ‘horizontal standards’ because of their broad application across industries and machine types), assuming general requirements applicable to all machines will address most concerns. Others will focus only on the type-C standards (sometimes labeled as ‘vertical standards’ due to their depth of focus on a specific topic), in hopes that the panel of experts who created the standard addressed all possible scenarios and provided clear direction regarding how to abate any resulting risks.

In reality, however, it is imperative to use all applicable standards together – both horizontal and vertical – to ensure the most thorough approach to risk identification and mitigation in order to achieve the safest equipment and workplace attainable. As shown in Figure 2, type-A standards provide a general overview of hazard identification and type-B standards provide typical requirements addressing conventional application of safety aspects or devices, while type-C standards probe deeper into the respective details as they apply to a specific industry or machine group. It is important to note that when a type-C standard deviates from one or more technical stipulations addressed by a type-B standard, the type-C standard takes precedence. Additionally, there may be instances where type-C standards do not exist within a region for specific equipment, in which case the type-A and -B standards become even more significant.

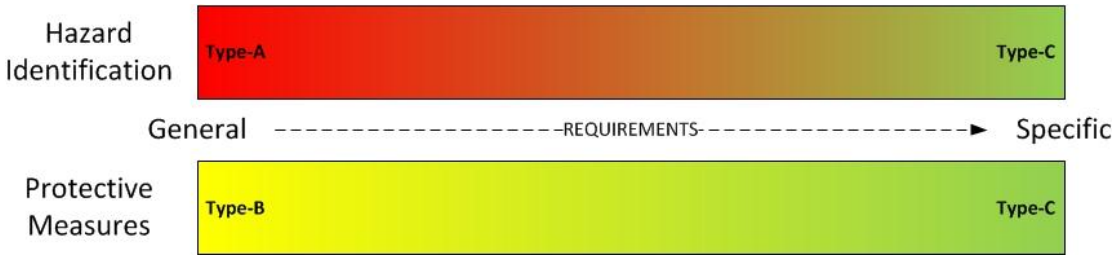

Figure 2: Coordinated Application of Standards

Regulatory Requirements

When determining which standards to apply, the organization must consider a number of factors. First, there are local regulatory (legal) requirements which are mandatory and must be met. For organizations that operate only in a specific country or region of the world, the list of possible standards to choose from is somewhat more limited. If your organization operates internationally, the catalog of potential standards is extensive in comparison.

Regardless of the function of your organization – either as a machine builder (OEM), integrator, or end-user – it is important to understand the governing obligations that apply. For global organizations, it is worth mentioning the Agreement on Technical Barriers to Trade (TBT) developed by the World Trade Organization (WTO). This agreement strives to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles, while also providing member countries with the right to implement measures to achieve legitimate policy objectives, such as the protection of human health and safety, or the environment.

The CE Mark

Even with a global initiative toward harmonization, however, various regions still stipulate additional requirements that exceed expectations of other regions. For instance, one of the most well known regional requirements is the CE mark, which includes mandatory conformity marking for certain products sold within the European Economic Area (EEA). The CE mark on a product or machine confirms compliance with the valid European regulations in order to achieve free movement and sale of the product throughout the EEA. The most straightforward method for OEMs to meet the essential health and safety requirements of the Machinery Directive involves manufacturing the equipment in conformity with harmonized standards, as published in the *Official Journal of the European Union*, to achieve a presumption of conformity. For machine builders and rebuilders (including end-users who modify their own equipment), it is important to know these requirements when moving machinery into and within the EEA.

Inspection Requirements in the Americas

Examples of additional requirements include the obligation for a Pre-Start Health & Safety Review (PSR) in the Canadian province of Ontario in accordance with Section 7 of the Regulation for Industrial Establishments, and the responsibility to provide a Technical Responsibility Annotation (ART) for equipment in Brazil as a function of the Regional Council of Engineering and Architecture (CREA). In both instances, the requirements apply to new equipment, as well as when there is substantial transformation of the operating system of a machine – including retrofitting. Furthermore, the review and documentation can only be performed by a legally qualified professional – a Professional Engineer (PE) licensed in the applicable region. In these instances, it is in the best

interest of both the machine manufacturer / rebuilder / modifier and the end user (employer) to work together to ensure the statutory requirements are managed.

OSHA and ANSI

In many regions of the world, there are also expectations placed on the employer. In the United States, the Occupation Safety & Health Administration (OSHA) places the legal burden for safety on the employer. The Occupation Safety and Health (OSH) Act of 1970 includes the General Duty Clause, which states, in Section 5(a)(1):

> Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.

Furthermore, it is also important to note that 27 states and jurisdictions have approved State Plans as encouraged by Section 18 of the OHS Act of 1970 (see Table 1). Under the Act, jurisdictions which create State Plans must set job safety and health standards that are "at least as effective as" comparable federal standards. Most states adopt standards identical to federal ones, but they also have the option to advocate standards covering hazards not addressed by federal standards.

Alaska	Indiana	Nevada	Oregon	Vermont
Arizona	Iowa	New Jersey *	Puerto Rico	Virgin Islands *
California	Kentucky	New Mexico	South Carolina	Virginia
Connecticut *	Maryland	New York *	Tennessee	Washington
Hawaii	Michigan	North Carolina	Utah	Wyoming
Illinois *	Minnesota	* State plans cover public sector (state & local government) employees only		

Table 1: States and Jurisdictions with State OSHA Plans

To confuse the issue further within the United States, it is not sufficient to simply read all of the OSHA regulations, standards, and state laws. To determine the legal obligations, employers must also account for the technical safety standards published by organizations such as the American National Standards Institute (ANSI). While OSHA laws typically set out only a general framework, procedure or set of standards to guard against a hazard, many ANSI standards go much further toward protecting workers, taking into account current state of the art practices and technologies. Additionally, they provide the technical details regarding performance requirements that OSHA typically omits.

In order to stay current with best practices used within industry, ANSI requires that each ANS shall be revised, reaffirmed, or withdrawn after a five year period, unless an extension has been granted. While this ongoing maintenance of ANSI standards ensures that commonly used and time-tested approaches to achieving safety are included and shared with the public, it also adds a level of uncertainty because the requirements of the standards selected by an organization could change from one revision to the next.

While some ANSI standards have been directly adopted into the Code of Federal Regulations (CFR) as OSHA standards (and therefore legally mandatory as law), some can be 'incorporated by reference,' meaning they have been sited within an OSHA regulation and are therefore enforceable by OSHA. All other ANSI standards are generally considered voluntary – but even this is misleading. OSHA standards typically establish the general expectations each employer must meet and gives the employer discretion to decide how best to achieve the stated goals. Employers are expected to use this latitude to consider any existing consensus standards, including non-legislative standards adopted by industry and other non-governmental organizations. Even though these standards are not legally enforceable as part of an OSHA inspection, they represent a consensus on what experts consider safe. In the event that an incident were to occur, OSHA might (and often does) regard an

employer's failure to adopt a voluntary standard relating to an OSHA requirement as evidence that it did not take reasonable actions to comply with expectations of the General Duty Clause.

To make matters even more complicated, ANSI is not actually responsible for the content of each individual American National Standard (ANS); rather, they are a private non-profit organization which coordinates, facilitates, and promotes the development of voluntary consensus standards through its accreditation of the procedures of participating SDOs. With nearly 220 SDOs and approximately 10,000 ANS, ANSI Essential Requirements expect a "good faith effort to resolve potential conflicts between and among existing and candidate American National Standards." In reality, this means that each SDO is somewhat responsible for self-governance, sometimes resulting in possible overlap with the scope of other standards, causing confusion. Two examples where multiple documents address the same core topic are risk assessment and robot safety, as shown on the next page in Table 2.

RISK ASSESSMENT

Standard	Title	Scope
ANSI B11.0	Safety of Machinery – General Requirements and Risk Assessment	Power driven machines, not portable by hand, used to shape and/or form metal or other materials by cutting, impact, pressure, electrical or other processing techniques, or a combination of these processes.
ANSI/ISO 12100	Safety of machinery – General principles for design – Risk assessment and risk reduction	Machines assembled, fitted with or intended to be fitted with a drive system consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application. This also covers an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole.
ANSI/PMMI B155.1	Safety Requirements for Packaging Machinery and Packaging Related Machinery	Packaging, processing and packaging-related converting machinery.
ANSI/AIHA/ASSE Z10	American National Standard for Occupational Health & Safety Management Systems	Policy, organization, planning & implementation, evaluation, and action for improvement of employee health and safety.
ANSI/ASSE Z590.3	Prevention through Design: Guidelines for Addressing Occupational Hazards & Risks in Design & Redesign Processes	Design / redesign of work premises, tools, equipment, machinery, substances and work processes.
AWS D16.3M/D16.3	Risk Assessment Guide for Robotic Arc Welding	Arc welding robot systems.
SEMI S10 *	Safety Guideline for Risk Assessment and Risk Evaluation Process	Micro- and nano-electronics industries, including: • semiconductors; • photovoltaics (PV); • high-brightness LED; • flat panel display (FPD); • micro-electromechanical systems (MEMS); • printed and flexible electronics; • related micro- and nano-electronics.

ROBOT SAFETY

Standard	Title	Scope
ANSI/RIA R15.06	Safety Requirement for Industrial Robots and Robot Systems	Automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.
ANSI/RIA/ISO 10218-1 **	Robots for industrial environments – Safety requirements – Part 1: Robot	Manufacture of automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.
ANSI/SPI B151.27	Safety Requirements for the Integration of Robots with Injection Molding Machines	Plastics machinery.
ANSI/UL 1740	Standard for Safety – Robots and Robotic Equipment	Robotic equipment and systems intended for indoor and outdoor use in applications including: • parts assembly; • parts transfer; • automated material handling; • inspection; • loading; • diecasting; • deburring; • welding; • paint spraying; • clinical/diagnostic systems; • pharmaceutical applications; • commercial food processing; • automated vehicle refueling systems; • library book handling/sorting; • clean room applications; • medical use for surgery; • mobile robots; • automated guided vehicles; • automated storage/retrieval systems.
AWS D16.1M/D16.1	Specification for Robotic Arc Welding Safety	Arc welding robot systems and ancillary equipment.

NOTES

*	SEMI is not an ANSI accredited SDO.
**	To be withdrawn in December 2014.
	Information listed is believed to be accurate at time of publication; subject to change at any time. Check with appropriate SDO for additional information regarding scope and content of standards listed.

Table 2: Examples of American Standards with Possible Overlap in Scope

Use of Work Equipment Directive

In Europe, the Use of Work Equipment Directive (UWED) is aimed at users of machinery (employers) and is in addition to the Machinery Directive, which is directed toward suppliers. The UWED covers all industrial sectors and places general duties on employers along with minimum requirements for the safety of work equipment. All European Union countries enact their own form of legislation to implement this Directive. For organizations that operate as users of equipment in the Europe Union, it is important to be aware of the local legislation intended to meet this requirement, understanding that each country has developed their own requirements.

Expectations in Asia

Conversely, many Asian countries apply expectations of safety to the employee, either through documented standards or cultural expectations. Some Asian countries – including Japan, China and Korea – continue to develop or adopt standards related to safety of machinery. However, adherence to and enforcement of these standards is still somewhat arbitrary at this time.

Global Approach

Understanding the legal ramifications of local laws and customs is essential to making an educated decision regarding which standards to select for your organization. Although many companies do not operate globally, there is a strong case to be made to implement a combined approach, establishing a holistic policy to share the responsibilities surrounding safety with all stakeholders. Many proactive companies – especially end users – are applying this approach by establishing clear requirements for the acquisition of new equipment (affecting suppliers), for upgrading and maintaining existing equipment (affecting plant level management), and setting expectations of their employees. Manufacturers and suppliers who wish to transact with forward looking companies should read the writing on the wall and make efforts to stay relevant and competitive in the market place by applying best practices from all world regions, as shown in Table 3.

Region / Function	Europe	North America	Asia	GLOBAL
Manufacturer / Supplier	☑	☐	☐	☑
End User / Employer	☑	☑	☐	☑
Employee	☐	☑	☑	☑

Table 3: Comparison of Primary Obligations by Region

Relevancy of Standards

In addition to the regulatory requirements of each region, organizations should also consider the expectations of the consumers and the local market. No entity wishes to be perceived as one with little or no regard for the local population and environment; this is one reason why so many companies today make great efforts to give back through charitable and philanthropic activities in their communities. Equal attention and investment should be made internally to ensure that the safety and welfare of the employees are adequately addressed and maintained. In the global marketplace that exists today, any competitive advantage is considered a leg up. While cost is always important, forward thinking companies look beyond the initial cost of acquisition and consider the total cost of ownership – including legal liability, public perception, and future costs (both direct and indirect) which would come into play if an incident were to occur. For progressive organizations, the value of human life is equal in all parts of the world, regardless of legal requirements.

Differences between Standards

Aside from the obvious differences stated above regarding which entities are held responsible by various standards, there are also technical differences that exist within various industries and regions. For instance, when applying electro-sensitive protective equipment (ESPE) such as light curtains to protect people from identified hazards, their effectiveness relies upon the device being located (mounted) at an appropriate distance from the hazard such that the hazardous motion or situation is prevented, completed or stopped before the individual can be harmed. In order to determine the minimum safe distance, a formula must be applied. As shown in Table 4, the theory behind the formula is exactly the same in Europe and North America; only the identifiers for the variables are different. For applications with the device used in a vertical orientation (or the detection zone orthogonal to the direction of approach) the respective formulae are:

	Europe (ISO 13855)	**United States** (ANSI B11.19)
Formula	**$S = (K * T) + C$**	**$D_S = (K * T) + D_{pf}$**
With the following variables:		
Minimum Distance	S	D_S
Approach Speed	K	K
Total Stopping Time	T	T
Intrusion Distance / Depth of Penetration	C	D_{pf}

Table 4: Minimum Distance Formulae for Vertical ESPE

A cursory examination would lead to the conclusion that there is global harmonization with respect to minimum safe distance calculations for safeguarding devices – and in fact there is, but only in the theoretical approach. When deeper investigation is performed, however, safety professionals see that the values and rules applied to the formula result in different final values, as shown in Figure 3.

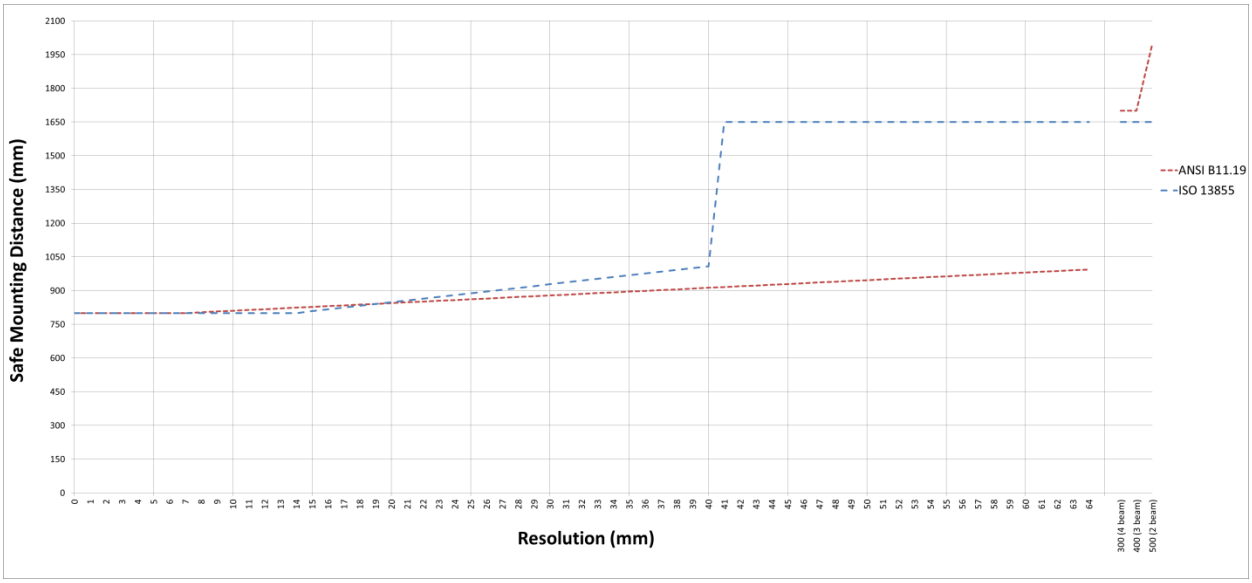

Figure 3: Comparison of Minimum Distance Calculations for Vertical ESPE Based on Device Resolution [T = 500 ms]

It is difficult to claim that one formula is 'safer' than the other when both regions have thousands – if not millions – of compliant installations where personnel have been effectively protected from harm. A brand new machine installed in North America with a CE Mark can be considered safe when used within the appropriate parameters, and it carries with it a declaration of conformity and compliance with the Machinery Directive through the application of harmonized standards, including ISO 13855 for calculating minimum safe distances. Once installed, though, the local requirements should also be considered, such as ANSI B11.19 for determining the safe mounting distance of safeguarding devices. So even with a CE Mark and a declaration of conformity, a new machine may still not be compliant with local requirements. We can clearly see in this example that 'compliance' and 'safety' are two separate concerns.

For organizations operating globally, which standard should be selected? It is clear that one standard cannot be selected as the most conservative, because both standards require a greater distance at different intervals. One could create an internal requirement that the most conservative value always be applied, thus ensuring ease of use in terms of auditing to a consistent standard and providing for the possibility of global relocation of equipment. However, this approach may cause undue restrictions in various world regions, including use of extra floor space that would not otherwise be required.

Selecting Standards

The balance between ease of use and cost of implementation is ultimately what must be determined for each organization. While establishing a list of requirements to be used globally may have select benefits, so does the regionalized management of local requirements.

Regional Requirements (when available)	**Global Standards** (when established)
Expectation to meet compliance with local regulatory requirements	Expectation to meet (or exceed) local regulatory requirements
Requires monitoring of changes to local regulatory requirements	Requires monitoring of changes to global regulatory requirements
Prevents over-designed solutions compared to local expectations	Easy training, rollout and auditing for entire organization
Costs controlled through adherence to local requirements only	Consistent global expectations and value for safety of employees
Limited modifications to established requirements	Stable interpretation of ALARP

Table 5: Comparison of Benefits between Local and Global Standards

When determining which standards to apply in a given industry or application, it is important to circle back to the types of standards discussed above and not discount their significance. While type-A and -B standards from various regions can often be boiled down and combined into best practices, type-C standards still address the specific concerns of the application. In some instances, there may simply be no type-C standards in existence for the equipment in question, especially when the machinery is custom built for a very unique process. Sometimes, type-C standards may not exist in the local environment, but do in external regions. In these circumstances, the organization should consider whether or not to apply non-legislative requirements as a best practice approach to reducing risk. In other instances, there may be multiple requirements within a region or across regions. In these scenarios, the organization is most likely best off addressing each situation on a case-by-case basis. Table 6 below includes an abbreviated list of possible standards which could be selected / applied to two common types of machines; power presses and industrial robots. In the United States, we see that there is more than one standard for robots which could be applied, including industry specific requirements for the welding and plastics industries, as outlined earlier in Table 2.

Region / Standards		EUROPE	AMERICAS				ASIA PACIFIC			
		European Union	USA	Canada	Mexico	Brazil	Australia	China	Korea	Japan
C-Type (examples)	Power Press	EN 692 EN 693 EN 13736 (ISO 16092)	OSHA 1910.217 ANSI B11.1 ANSI B11.2	CSA Z142		NR-12 NT-16 PPRPS EN 693 NBR 13930	AS 4024.3001 AS 4024.3002	GB 11291		JIS B 8433
	Industrial Robot	ISO 10218 (ISO TS 15066)	ANSI/RIA R15.06 UL 1740 AWS D16.1 ANSI/SPI B151.27	CSA Z434			AS 4024.3301	GB 4584		JIS B 6410
B-Type (not all inclusive)		IEC 60204 ISO 4413 ISO 4414 ISO 13849 ISO 13854 ISO 13857 ISO 13855 ISO 14118 ISO 14120 ISO 14119 ISO 13856 IEC 61496 ISO 13851 IEC TS 60246 IEC 61508	ANSI B11.19 ANSI/ASSE Z244.1 OSHA 1910.147 OSHA 1910.219 NFPA 79 ISO 4413 ISO 4414	CSA Z432 CSA Z460	NOM-004-STPS	NR-12 NR-10 EN 60204 NBR 14153 NBR 14154 NBR NM-ISO 13854 NBR NM-ISO 13852 NBR NM-ISO 13853 ISO 13855 NBR 13759 NBR NM 273 NBR NM 272 NBR 14152	AS 4024.1401 AS 4024.1501 AS 4024.1502 AS 4024.1601 AS 4024.1602 AS 4024.1603 AS 4024.1604 AS 4024.1701 AS 4024.1702 AS 4024.1703 AS 4024.1704 AS 4024.1801 AS 4024.1802 AS 4024.1803	GB/T 16855 GB 23821 GB/T 19876 GB 12265 GB/T 8196 GB/T 18831 GB/T 17454 GB/T 19436 GB/T 19671 GB 16754 GB/T 19670 GB 5226	KSC IEC 60204 KSB ISO 13849 KSC IEC 61508 KSC IEC 61496 KSB ISO 13850 KSB ISO 13854 KSB ISO 13852 KSB ISO 13853	JIS B 9703 JIS B 9704 JIS B 9705 JIS B 9710 JIS B 9711 JIS B 9712 JIS B 9714 JIS B 9715 JIS B 9716 JIS B 9717 JIS B 9718 JIS B 9960 JIS B 9961 TR B 025
A-Type		ISO 12100	OSHA 1910.212 ANSI/ISO 12100 ANSI B11.0	CSA Z432	DOF 21.10.1997	NBR NM 213 NBR 14009 NR-12	AS 4024.1101 AS 4024.1201 AS 4024.1202 AS 4024.1301 AS 4024.1302	GB/T 15706 GB/T 16856	KSB ISO 12100 KSB ISO 14121	JIS B 9700

Table 6: Example of Type-A, -B, and -C standards by Country / Region
Information listed is believed to be accurate at time of publication; subject to change at any time.
Check with appropriate SDO for additional information regarding scope and content of standards listed.

Conclusion

As we can see from this discussion, there is no one 'right' choice for every organization when selecting standards to follow for implementing safeguarding measures. There are, however, choices which are clearly wrong – such as not doing anything. If the process appears daunting and overwhelming, do not hesitate to request assistance from outside sources, preferably sources with direct and extensive experience in a wide range of industries and world regions.

This white paper is meant as a guideline only and is accurate as of the time of publication. When implementing any safety measures, we recommend consulting with a safety professional.

For more information about safety standards and regulations, contact SICK Safety Application Specialist Chris Soranno at chris.soranno@sick.com, or visit our web site at www.sickusa.com.