PEMA

# Global Machine Safety Regulations and Standards for Port Equipment

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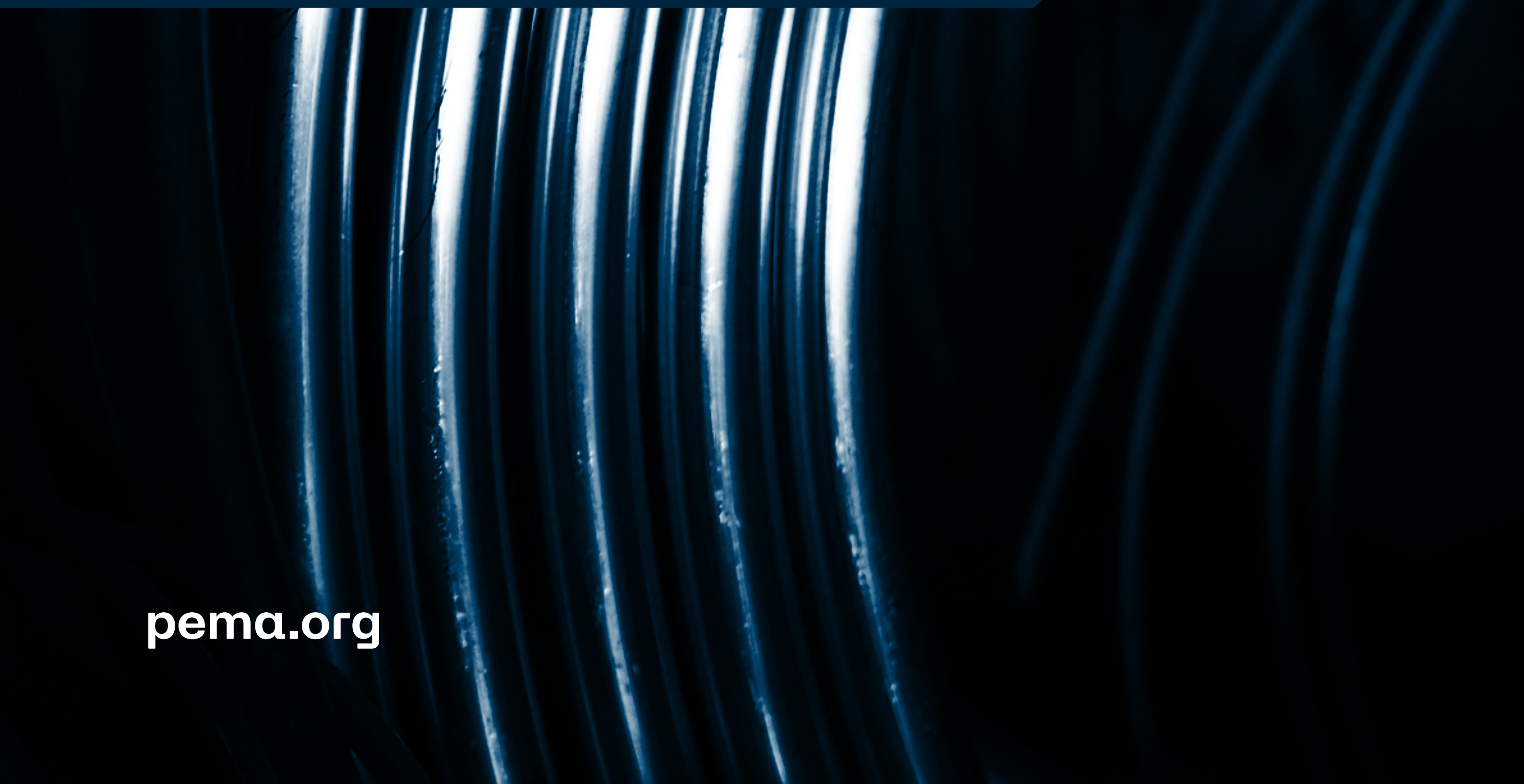

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# Contents

# 1.0 Abstract

Current crane tender specifications frequently list a wide range of electrical standards. These standards often are national standards that have evolved over time. When attempting to comply with all such standards, the user is confronted with overlapping and contradicting requirements. Equipment suppliers and electrical integrators struggle to decide which standard to consider and which to ignore.

The port industry has various very large machines operating in congested areas including equipment from outside the terminal such as on the seaside with ships and barges, and on the landside with trucks, rail, etc. As the shipping industry continues to increase ship sizes, larger and faster cargo handling equipment with automation is required to improve cargo movement efficiency. It becomes therefore even more important that the port industry follows a rigid risk analysis process and implements the appropriate safety equipment and controls of machines to mitigate the hazards and provide for the protection of personnel.

Since the industry is global it is important that port equipment manufacturers are aware of the various international regulations and standards and in particular be cognizant of the international standards which have to be followed to meet these global regulations. The purpose of this paper is to provide a guideline as to which safety standards are considered relevant when applied to container handling equipment. This paper primarily addresses these issues from an electrical perspective.

### 1.1 About this Document

# 2.0 Summary

General and crane specific approaches to standards in various regions of the world, Europe, United States, China, Canada, and Australia and New Zealand are presented, with a particular focus on electrical standards.

Specific requirements related to electrical crane design in various regions are presented. Examples of the differences in regional requirements for specific parts of crane safety design are presented for reference.

# 3.0 Background

Safety standards in tender specifications have to comprehensively cover hazards resulting from the operation of a wide range of container handling machine types in different container yard configurations. The following comparison and evaluation of different electrical safety standards is intended to be used as a reference for tenders for container ship-to-shore cranes, rail-mounted gantry cranes, rubber-tyred gantry cranes as well as straddle carriers.

The standards are equally relevant for manually operated or automated terminals. Application of the recommended standards will substantially reduce the risks arising from state-of-the-art remote-operated equipment where the ‘machine’ includes not only the moving crane itself but also the stationary remote operation station and the associated data communication.

# 4.0 Global Regulations and Standards

## 4.1 International Standards

The International Organization for Standardization (ISO) [1] began in 1926 as the International Federation of the National Standardizing Associations (ISA). It was disbanded in 1942 during the Second World War but was re-organized under the current name, ISO, in 1946. ISO is an independent, non-governmental global network of national standards bodies represented by 163 countries, one member per country.

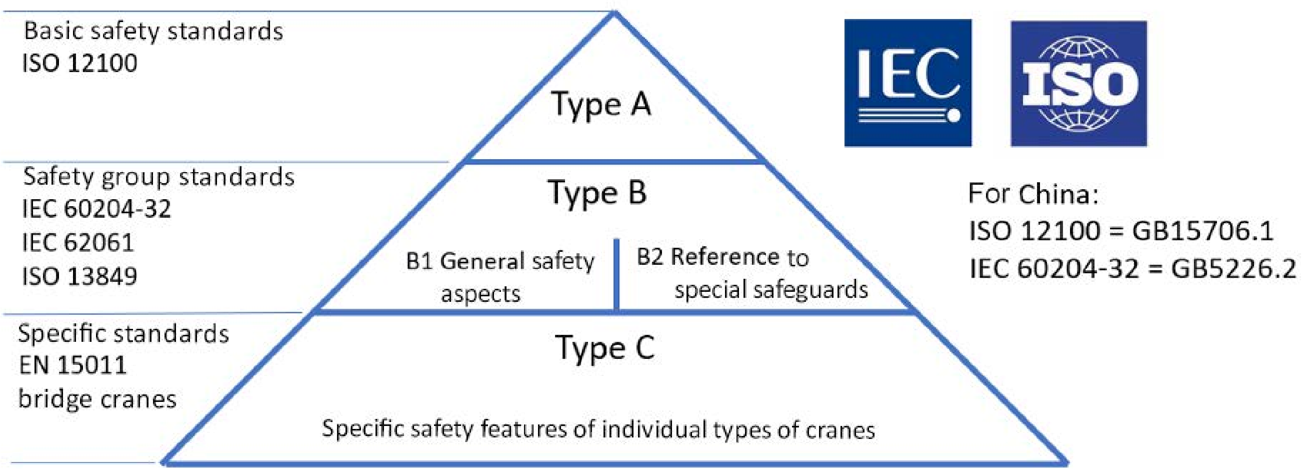
The International Electrotechnical Commission (IEC) [2] is the global organization formed for the preparation and publication of consensus International Standards for all electrical, electronic and related technologies known collectively as 'electro technology'. It was founded in 1906 and has ~82 members (60 full members), one per country.

ISO and IEC are known collectively as 'International Standards'. They are divided into three types:

- **Type A Standards**: Generally applicable to all types of machines.
- **Type B Standards**: Subdivided into two groups.
  - **Type B1 Standards**: particular safety and ergonomic aspects of machinery.
  - **Type B2 Standards**: safety components and protective devices.
- **Type C Standards**: specific types or groups of machines, i.e. EN 15011 (Cranes-bridge and gantry cranes)

The illustration below shows the hierarchy of the ISO/IEC standards.

The IEC and ISO are both independent, non-governmental, not-for-profit organizations that develop and publish consensus-based International Standards. International Standards from IEC and ISO have the advantage of having a broad geographical reach as the membership of these two organizations is made up of countries from all over the world, covering approx. 97 % of the world's population. The use of IEC and ISO International Standards is consistent with the obligations of countries that are members of the World Trade Organization in order to reduce technical barriers to trade. Many countries have adopted ISO/IEC standards or have incorporated them into their own standards.



## 4.2 ISO 12100 Risk Assessment and Risk Reduction

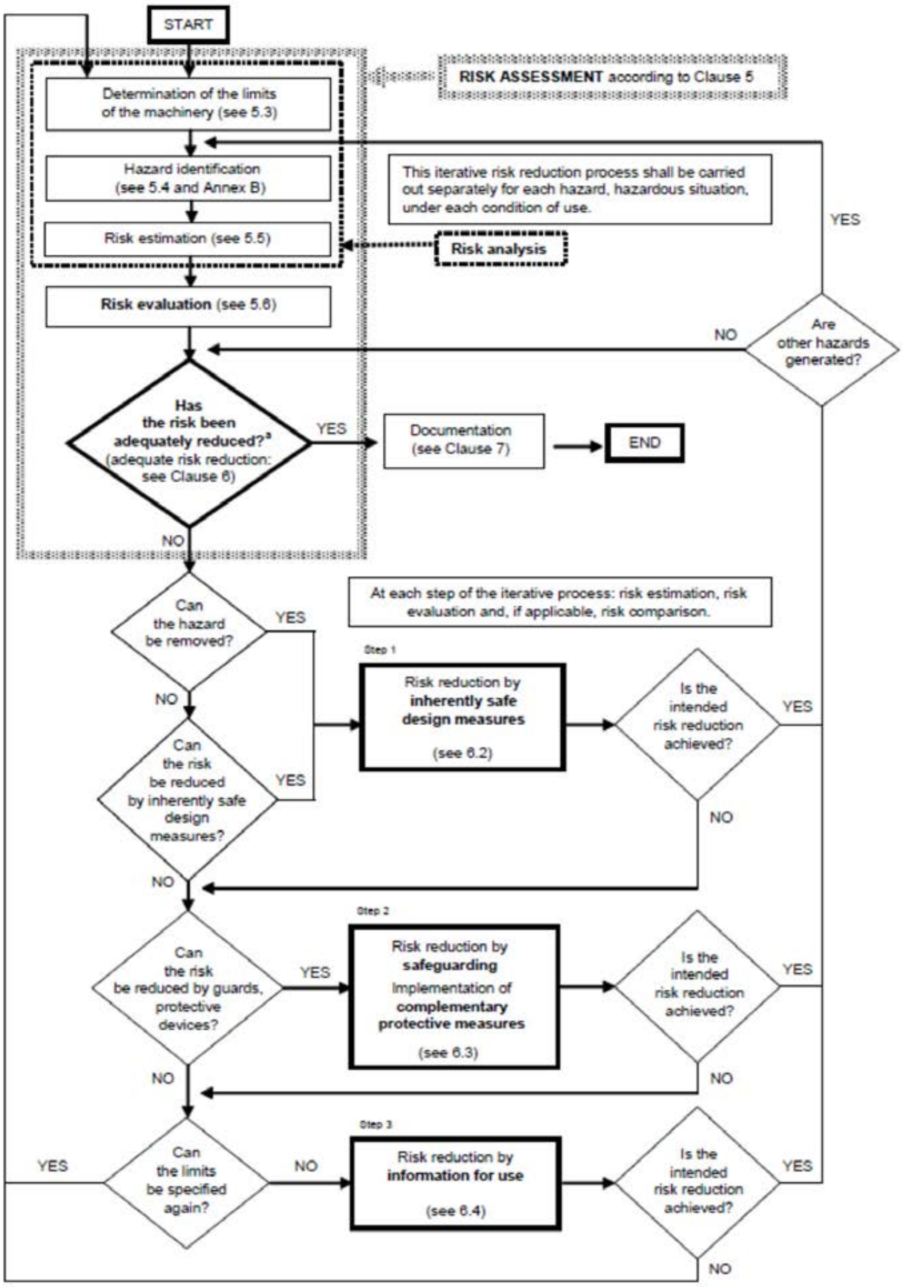
**Overview of ISO 12100 – Safety of Machinery – General principles for design – Risk assessment and risk reduction. Note ISO 12100 has replaced ISO 14121. The diagram below is an outline and summary of ISO 12100.**

Risk assessment is a series of logical steps to enable, in a systematic way, the analysis and evaluation of the risks associated with machinery. This is an iterative process through risk assessment and mitigation until the risk is minimized to an acceptable level.

The risk assessment and reduction strategy is defined in the following A-type standards:

- ISO 12100:2010 - Safety of machinery - General principles for design - Risk assessment and risk reduction
- ANSI B11.0-2010 - Safety of Machinery; General Requirements and Risk Assessment.

These standards provide a consensus standard for risk assessment and reduction. This paper will focus on ISO 12100 [21].




[a] The first time the question is asked, it is answered by the result of the initial risk assessment.

## Type B Standards

Type B standard IEC 60204-1 Safety of machinery – Electrical equipment of machines. Part 1: General requirements has global relevance.

**IEC 60402-11:** Requirements for HV Equipment for voltages above 1,000v AC or 1,500v DC and not exceeding 36Kv has relevance for the electrical safety of larger port machines.

**IEC 60402 Part 32:** Requirements for hoisting machines is a crane-specific adaptation of IEC 60204-1 ‘Safety of machinery – Electrical equipment of machines – Part 1: General requirements’.

IEC 60204-32 as a crane-specific section of IEC 60204-1 is focused on:

- Safety of persons and property
- Consistency of control response
- Ease of maintenance.

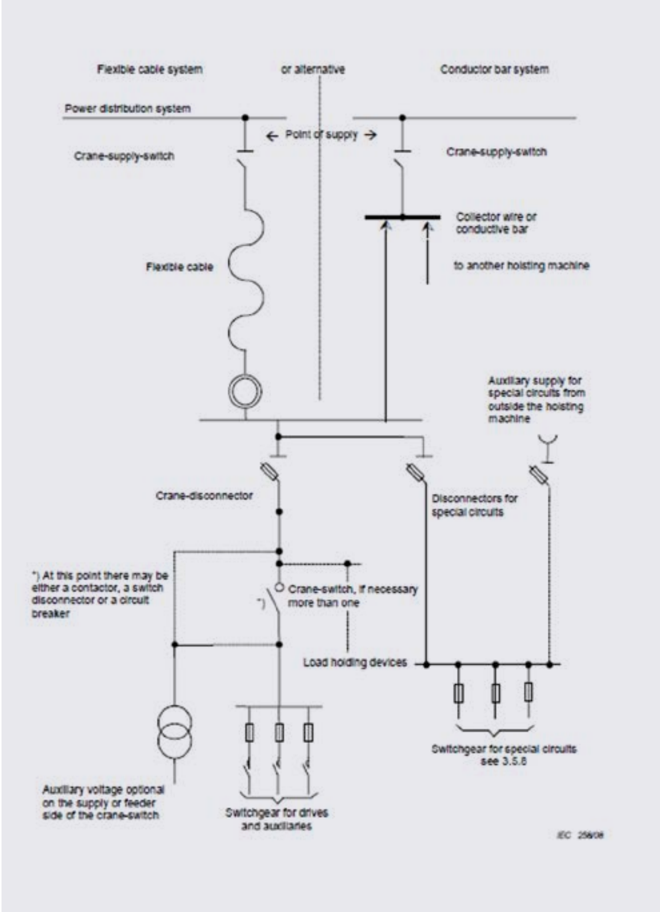
This crane-specific standard defines basic design requirements for crane control circuits such as:

- Safety circuits shall have an appropriate level of safety performance as per ISO 13849 or IEC 62061
- A risk analysis is required (9.4.1) as per ISO 12100
- Proven circuit techniques to be employed (9.4.2.1)

Key safety functions of the crane’s power supply system are defined in section 5 such as:

- crane disconnect switch(es) for disconnecting the crane’s power supplies
- a single crane supply switch for isolation of all electrical circuits during maintenance
- crane switch for de-energizing the motion drive system during an E-stop event.

*Fig. 1: Extract IEC 60204-32*
*Overview crane power supply structure*




- IEC 60364-4-43 ‘Low-voltage electrical installations - Part 4-43: Protection for safety - Protection against overcurrent’
- IEC 62271-105 ‘High-voltage switchgear and control gear - Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV’.

The standards ISO 13849 ‘Safety of machinery – safety-related parts of control systems’ and IEC 62061 ‘Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronics control systems’ for the design of the safety of the cranes control system are in use in the majority of countries.

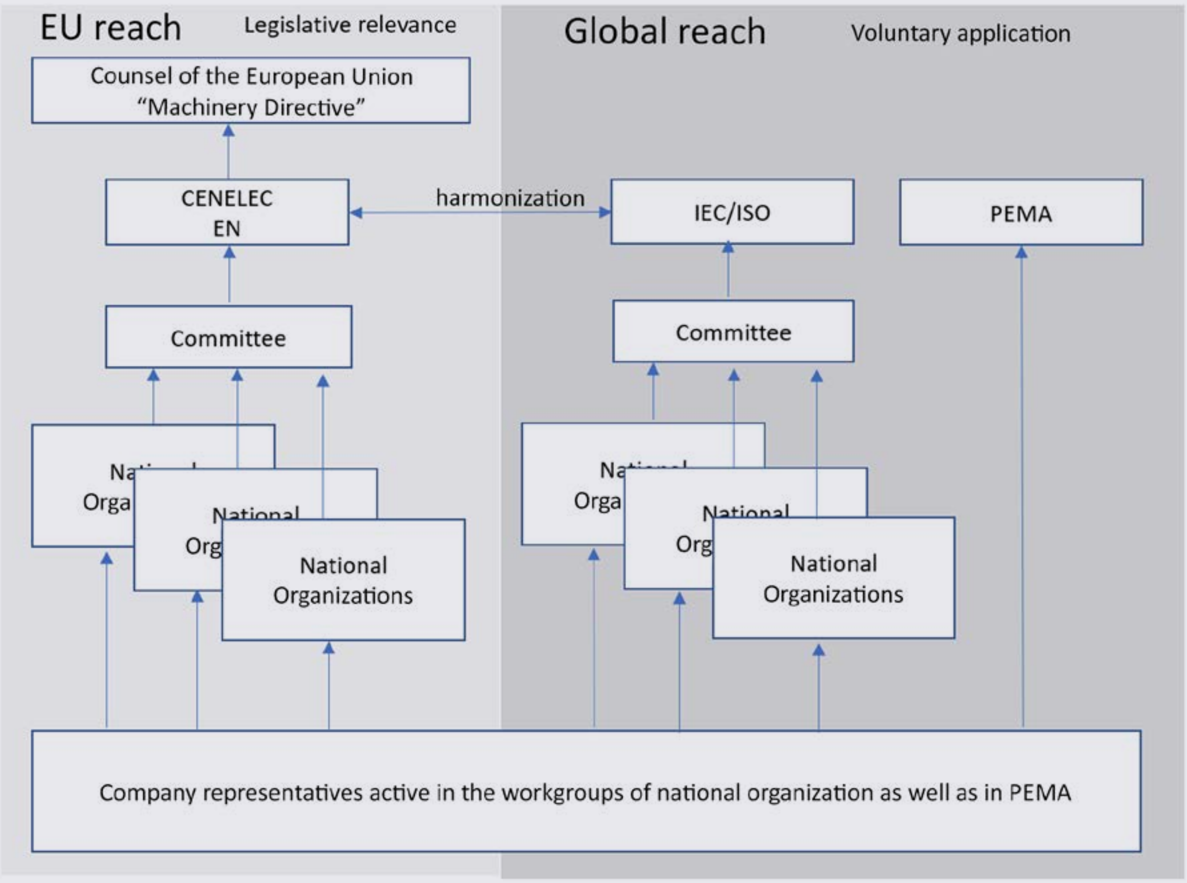
# 4.3 European Union

### 4.3.1 Legal Requirements and Regulations

The European Union places requirements and responsibilities on both the manufacturer of a plant or system as well as the plant operating company, which are regulated using the appropriate European Directives, Laws and Standards. The European Commission issues Directives which must be ratified as law by the Member States.

EU Directives including the Machinery Directive only contain general safety goals and define basic requirements. Standards Associations that have the appropriate mandate of the EU Commission (i.e. CEN, CENELEC) can define technical details. These standards are harmonized under a specific directive and become EN (European Norm) standards which are listed in the official EU Journal [3]. By affixing the CE mark on the crane the manufacturer declares that the machine design and build as having followed the required standards. Legislation does not dictate that specific standards have to be complied with, however, when specific standards are referenced then it can be 'assumed' that the associated safety goals of the EU directives have been complied with. Where a specific EN standard is referenced then it is assumed that all standards referenced under that standard are also applicable. This is the basis for the so-called 'presumption of conformity'. Only EN harmonized standards convey assumption of conformity. EU directives specify that Member States must mutually recognize national regulations. ***The Machinery Directive 2006/42/EC*** [4] provides the regulatory basis for the harmonization of the essential health and safety requirements for machinery at European Union level.

*Fig 2: Relevance of CENELEC and ISO with national committees to machinery directive and link to PEMA*



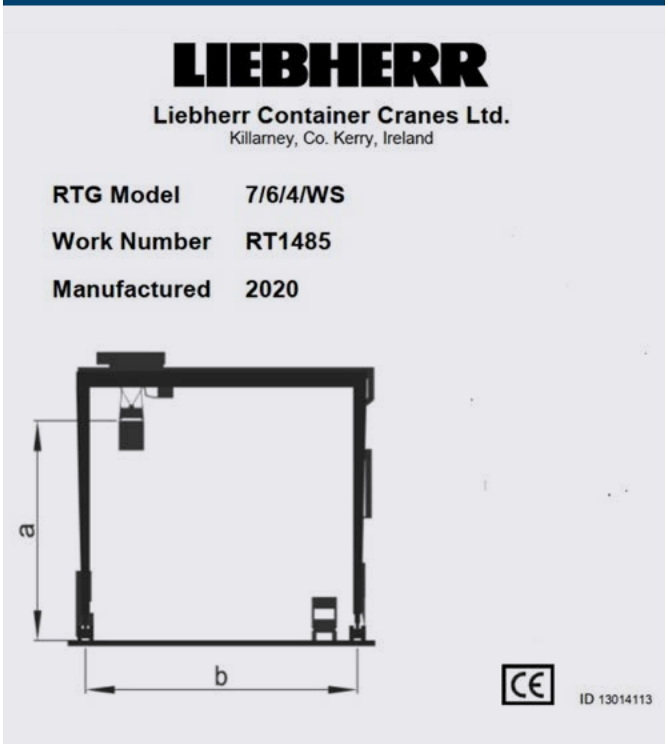
Guidance for ***Machinery Directive 2006/42/EC*** is published in the ‘***Guide to application of the Machinery Directive 2006/42/EC - Edition 2.1***’ [5].

Another useful guide for the application of the machinery directive and EN standards for cranes can be found in the bi-lingual publications of the Association of German Engineers (VDI).

The basis of the European approach is the self-certification process where the manufacturer applies the standards as deemed applicable and affixes a ‘CE’ mark to its machine accompanied by a certificate of conformity which lists the applicable standards considered. The correct application of the standards is left solely to the discretion of the manufacturer. Only in the case of an accident and during the subsequent legal proceedings is the relevant detailed support documentation required to be presented.

In the case where new technology is being applied the involvement of an independent inspection body is recommended in order to verify the correct application of the relevant standards which formed the basis for the presumption of conformity. Such an inspection body could be: TÜV in Germany, ABOMA-KEBOMA in the Netherlands or similar.

***Fig 3: Typical example of a ‘CE’ machine type plate***




The CE mark is a generic mark used in the European Union (EU) to indicate that a manufacturer has declared that the product meets regulatory requirements in the EU. It is unrelated to product safety outside the EU unless specifically requested as a procurement requirement.

### 4.3.2 Standards

EN Harmonized European Standards are common to all European Economic Area (EEA) countries and are produced by the European Standardization Organizations CEN and CENELEC:

- CEN (Comité Européen de Normalisation) [6]. CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries.
- CENELEC (Comité Européen de Normalisation Electrotechnique) [7]. CENELEC is the European Committee for Electrotechnical Standardization and is responsible for standardization in the electrotechnical engineering field.
- CEN-CENELEC Management Centre (CCMC) [8]. The close collaboration between CEN and CENELEC was consolidated at the start of 2010 by the creation of a common CEN-CENELEC Management Centre (CCMC) in Brussels.

CEN and CENELEC harmonize many ISO and IEC standards with the related directives which become EN (European Norm) standards. Summary list of titles and references of harmonized standards is published in the official European Journal under Directive 2006/42/EC for Machinery. [3]

# 4.4 United States

### 4.4.1 Legal Requirements and Regulations

US occupational safety and health law is governed by the OSH Act of 1970 as defined in the Code of Federal Regulations (CFR) - Title 29 - Subtitle B - Chapter XVII [9] which is administered by the Occupational Safety and Health Administration (OSHA).

OSHA law defines the requirement that an employer must guarantee a safe place of work. OSHA does not directly apply to equipment manufacturers but as a result of product liability laws, a manufacturer can be held liable for injury or damage caused by their product. Therefore machinery manufacturers are primarily driven by product liability laws. Invariably in the case of heavy machinery, the employer utilizing such equipment will require that OSHA has certified its suitability prior to putting it into service.

### 4.4.2 Standards

**OSHA – Occupational Safety and Health Administration [15]**

OSHA promulgates national consensus standards or established US federal standards (CFR) as safety standards. The mandatory provisions of the standards, incorporated by reference, have the same force and effects as the standards listed in 29 CFR Part 1910. For example, the national consensus standard NFPA 70 – National Electric Code (NEC) is listed as a reference document in Appendix A of Subpart S-Electrical of Part 1910 of 29 CFR. NFPA 70 is a voluntary standard, which was developed by the National Fire Protection Association (NFPA). By incorporation, all the mandatory requirements of the NEC are mandatory by OSHA.

**Applicable Standards for the enforcement of the OSHA laws:**

1. **Specific standards as defined in CFR 29**

2. **'Incorporation by Reference' Standards** are specifically listed by OSHA in 29 CFR 1910.6. More than 100 'incorporated by reference' consensus standards are listed.

3. **National consensus standards**. OSHA reserves the right to issue citations for violations under the ***General Duty Clause*** [12] and referencing consensus standards evidencing that certain hazard(s) are present and that there are various means available to mitigate those hazard(s).

4. **Nationally recognized testing laboratory (NRTL) standards.** OSHA's authority is limited to employers; therefore, OSHA does not generally require manufacturers or suppliers to have the products they manufacture or supply certified by a Nationally Recognized Testing Laboratory (NRTL). That said, it would be in the interest of manufacturers or suppliers to have products requiring approval under OSHA standards to be NRTL certified.

**Note:** OSHA requires specific types of equipment to have NRTL certification [14] under OSHA's NRTL requirements. Such products must have the mark of one of the NRTLs recognized bodies approved to test and certify this type of product.

Key clause of the **OSH Act of 1970 – is the General Duty Clause - 29 USC 654 - SEC. 5. Duties**

(a) Each employer -

> (1) 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;
>
> (2) shall comply with occupational safety and health standards promulgated under this Act.

(b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.

This clause is very important as many OSHA citations use this requirement where there are no specific requirements in OSHA standards, particularly if there is a voluntary consensus standard covering this situation.

**Sections of the CFR regulations that apply to the Marine Terminal industry are:**

- PART 1910 - Occupational Safety and Health Standards (General Industries) [10]
- PART 1917 - Marine Terminals [11]

*Part 1910.147 The control of hazardous energy (lockout/tagout) [13].*

*Part 1910.147 Subpart-O*
*- Machinery and Machine Guarding.*

*Types of guarding.*

*General requirements for machine guards.*

*Point of operation guarding.*

## ANSI – American National Standards Institute [16]

ANSI serves as the administrator and coordinator of the United States private sector voluntary standardization system. It is a private, non-profit, membership organization supported by a diverse constituency of private and public sector organizations. ANSI, itself, does not develop standards, it facilitates the development of standards by establishing consensus among qualified groups. ANSI also ensures that the guiding principles of consensus, due process and openness are followed by the qualified groups.

## NFPA – National Fire Protection Association [17]

The National Fire Protection Association (NFPA) was organized in 1896. Its mission is to reduce the burden of fire on the quality of life by advocating scientifically based consensus codes and standards, research and education for fire and related safety issues. The NFPA sponsors many standards to help accomplish its mission. Two very important standards related to industrial safety and safe-guarding are the NFPA 70 - National Electric Code (NEC) and NFPA 79 Electrical Standard for Industrial Machinery. Machines, which are not covered by specific OSHA standards, are required to be free of recognized hazards which may cause death or serious injuries. These machines must be designed and maintained to meet or exceed the requirements of applicable industry standards.

## NFPA70 (NEC) -The National Electrical Code

The National Electrical Code (NEC) is a set of regularly updated standards for the safe installation of electric wiring in the United States. First published in 1897, the NEC is updated once every three years. The National Electrical Code® (NEC) is approved by the American National Standards Institute (ANSI), and is the most complete set of electrical Code requirements that govern electrical installations in the interest of safety for persons and property. As a NFPA sponsored standard the National Electrical Code (NEC), sets the foundation for electrical safety. The NEC provides guidelines for electrical installation in order to prevent fires and other electrical accidents. The current edition is 2020.

Despite its authoritative positioning and national title, NEC standards are not federal law. Instead, NEC standards are either adopted by local governments or local governments create and enforce their own electric code. The differing codes in various states are therefore something to be aware of.

## UL – Underwriter's Laboratory [18]

UL stands for Underwriter Laboratories, a third-party certification company that was founded in 1894. They certify products with the aim to make the world a safer place for both workers and consumers. Besides testing, they set industry standards to be followed when innovating new products.

They continually check these products to ensure that they meet these standards. UL testing makes sure that wire sizes are correct or that devices can handle the amount of current they claim to be able to. They also ensure that products are constructed correctly for the highest safety.

There's no such thing as a general UL approval. Instead, it's broken down into several tiers. These tiers are UL listed, UL recognized, and UL classified.

### ASME – American Society for Mechanical Engineers

**ASME B30** is an ‘Incorporated by reference’ standard and as such must be respected.

Relevant subsections include:

**ASME B30.2** Overhead and gantry cranes

2.1- 13 Electrical equipment states requirements as to the wiring and refers to ANSI/NFPA 70.

2.1-13.5 Switches overlap/contradicts IEC 60204-32, clause 5 ‘crane supply switch’.

**ASME B30.24** Container cranes

24-1.11.1 Defines requirements as to the rating of hoist brakes (This clause overlaps with class C EN 15011 ‘bridge and gantry cranes’ which is more comprehensive in detailing requirements for all motions of the crane).

24-1.13.4 Details power supply requirements. ( This section overlaps/contradicts IEC 60204-32 E.g. E-stop pushbutton required specifically in the cabin whereas the IEC standard would require a risk assessment to decide in which location an E-stop push button is required).

### NEMA – The National Electrical Manufacturers Association

The National Electrical Manufacturers Association (NEMA) is the largest trade association of electrical equipment manufacturers in the United States. It advocates for the industry, and publishes standards for electrical products.

# 4.5 Canada

### 4.5.1 Regulations

Some workplaces in Canada fall under federal legislation, which is recognised by the Canadian Centre for Occupational Health and Safety (CCOHS). However, the majority are regulated through the province or via local regulations. The Standards Council of Canada is the coordinating body of the National Standards system. This is a federation of independent, autonomous organizations working towards the further development and improvement of voluntary standardization in the national interest.

### 4.5.2 Standards

*Canada Standards [19], [20]*

**CSA (Canadian Standards Association)**

Electrical standards in Canada are published by CSA. CSA Standards reflect a national consensus of producers and users – including manufacturers, consumers, retailers, unions and professional organizations, and government agencies.

CSA standards are often similar to US requirements. Some electrical CSA standards are based on IEC standards and adapted to Canadian needs, others have been developed in conjunction with UL or NFPA. Electrical safety is certified by laboratories, which are accredited by the SCC (Standards Council of Canada). These include CSA and UL for example, but also many more. CSA standards related to electrical safety are covered by standard numbers C22.1 and C22.2, and collectively constitute the Canadian Electrical Code Part I and Part II, respectively.

The standard CSA C22.2 No. 301, 'Industrial Electrical Machinery' is aimed at the same types of equipment covered by NFPA 79 and IEC 60204-1.

# 4.6 China

## Chinese Standards

The Chinese standards system is administered by the Standardization Administration of the People's Republic of China (SAC), a government organization under the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ). AQSIQ itself is a ministerial-level organization under the authority of the State Council of the People's Republic of China. The State Council tasks its administrative departments with managing the standardization work of their corresponding professional sectors. At the regional level (provinces, autonomous regions, and municipalities), the regional government is in charge of administering a uniform standardization regime for the region. At the local level (city or county), the local government administers the standardization regime as specified by the relevant regional government.

Chinese standards may be either mandatory or voluntary. Mandatory standards have the force of law as do other technical regulations in China. They are enforced by laws and administrative regulations and concern the protection of human health, personal property and safety. All standards that fall outside of these characteristics are considered voluntary standards.

There are four hierarchical levels of Chinese standards.

- **National Standards**
- **Professional Standards**
- **Local Standards**
- **Enterprise Standards**

National Standards or Guobiao standards or often referred to as 'GB standards'. They are consistent across all of China and are developed for technical requirements. As of 2006, there were a total of 21,410 Chinese national GB standards, among which approximately 15% were mandatory, and 85% voluntary. Chinese national GB standards can be identified as mandatory or voluntary by their prefix code, as indicated below:

| Code | Content |
|---|---|
| GB | **Mandatory National Standards** |
| GB/T | **Voluntary National Standards** |
| GB/Z | **National Guiding Technical Documents** |

Many Chinese national GB standards are adopted from ISO, IEC or other international standards developers. (As of 2006, nearly half of all Chinese national GB standards were adoptions of international standards and 'advanced foreign standards'.)

In the Standards Administration of China, National technical committee 227 is in charge of maintaining safety standards for cranes.

Chinese recommended standard GB/T 16855 is equivalent to ISO 13849. GB/T 28256 is equivalent to IEC62061.

GB/T 15706.1 is equivalent to ISO12100 and GB/T 16856.1 is equivalent to the former ISO14121.

GB5226.2 (2002) is equivalent to IEC60204-32 (1998)

### China National Standard-Cranes

-GB: Mandatory Standard
-GB/T: Recommended Standard

| Item No. | CN Standard No. | Standard Title in English | Adopted International Standard No. |
|---|---|---|---|
| 1 | GB/T 16855.1-2008 | Safety of machinery - safety-related parts of control systems - Part 1: General principles for | ISO 13849-1: 2006 |
| 2 | GB/T 16855.2-2015 | Safety of machinery - safety-related parts of control systems - Part 2: Validation | ISO 13849-2: 2012 |
| 3 | GB 28256-2012 | Electrical safety of machinery- Functional safety of safety-related electrical, electronic and programmable electronic control systems | IEC 62061: 2005 |
| 4 | GB/T 14405-2011 | Bridge crane for general purpose | |
| 5 | GB/T 27997-2011 | Shipbuilding gantry crane | |
| 6 | GB/T 5031-2008 | Tower crane | |
| 7 | GB/T 24817.1-2016 | Cranes - Control layout and characteristics - Part 1: General Principles | ISO 7752-1: 2010 |
| 8 | GB/T 23724.1-2016 | Cranes - Inspections - Part 1: General | ISO 9927-1: 2013 |
| 9 | GB/T 5905-2011 | Cranes - Test code and procedures | ISO 4310: 2009 |

# 4.6 Australia and New Zealand

### 4.6.1 Standards

AS4024.1502 is the applicable standard in Australia and New Zealand for Machine safety.

AS 4024.1502 (2006) 'safeguarding of machinery, part 1: General principles' has been prepared by the Standards Australia Committee SF-041. This Standard is technically equivalent to ISO 13849-2:2003, Safety of machinery – Safety related parts of control systems – Part 2: Validation.

The principal task of the 2014 revisions of several parts of the AS 4024.1 – 2006 series was to consider the latest international revisions to the Standards incorporated in the original 2006 Standards.

One of the core principles in the drafting of the 2006 Standards was to publish the standards as a series of small parts. This approach has the result that as new editions of relevant ISO, IEC or EN Standards become available, they can be adopted and published within the framework of AS 4024 with minimum delay, so ensuring continued international alignment.

### AS/NZS 62061:2006

This Standard is technically identical with, and has been reproduced from IEC 62061, Ed. 1.0 (2005), Safety of machinery—Functional safety of safety-related electrical, electronic and programmable electronic control systems.

Editorial variations to IEC 62061, Ed. 1.0 (2005) are indicated at the appropriate places throughout this standard. Strikethrough (example) identifies IEC text, tables and figures which, for the purposes of this Australian Standard, are deleted. Where text, tables or figures are added, each is set in its proper place and identified by shading (example). Added figures are not themselves shaded, but are identified by a shaded border.

### AS 1418.3

AS1418.3 (1997) 'Bridge, gantry, portal (including container cranes) and jib cranes' corresponding to EN15011 'bridge cranes'.

This edition of this Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME/5, Cranes, to supersede AS 1418.3 – 1990.

### AS/NZS 3000

AS/NZS 3000: 2007 Wiring Rules defines principles of safety and configuration of electrical circuits which are mandatory for installations in Australia and New Zealand. During preparation of this Standard, reference was made to IEC 60364, Electrical installations of buildings (all parts) although it is not identical.

Part 1 provides uniform essential elements that constitute the minimum regulatory requirements for a safe electrical installation. Part 2 provides installation practices that achieve certainty of compliance with the essential safety requirements of Part 1.

# 5.0 Evaluation of scope and compatibility of the different standards

The compatibility between standards is discussed using the topics raised in IEC 60204-32.

Since Chinese standards follow ISO and IEC standards, they do not need to be compared here. The focus of the comparison examples is therefore on IEC versus Australian/NZ and North American standards.

The evaluation is based on a sample of specific areas where a difference between the standards could be identified.

### 5.1 IEC and AS 1418 (Australia New Zealand)

One such area is the formulation of requirements of the method of switching to stop a crane's motion drive system in case of an emergency. The 'crane switch' in IEC60204-32 is identified as the means to disconnect the motion drive system in case of an emergency stop.

For Australia/New Zealand AS1418 in section 8.7 defines the same stop categories as IEC60204-32. Yet, section 8.10 in the power supply structure does not use the terms 'crane switch' and 'special circuits' which in IEC60204-32 are defined with function and related requirements.

### 5.2 IEC and ASME B30.2

North American standards do not formulate crane-specific requirements in respect of the crane power supply structure.

Some crane-specific requirements are integrated in standards issued by the American Society of Mechanical Engineers ASME. The difficulty with these crane-specific standards is their wide scope covering mechanical and electrical subjects.

**ASME B30.2** 'overhead and gantry cranes' in section 2.1-13 defines requirements for electrical equipment with sub-chapters and refers to ANSI/NFPA 70:

- general (13.1)
- equipment (13.2)
- controllers (13.3)
- resistors (13.4)
- switches (13.5)
- conductors (13.6)

**Section 2.1** – 13.4 defines requirements for runway conductors and in this respect overlaps with IEC 60024-32, clause 5 'crane supply switch'.

**Section 2.1** – 13.5 Switches overlaps/contradicts IEC 60204-32, clause 5 'crane supply switch'.

**ASME B30.24** 'Container cranes – safety for cableways, cranes,' is similar to B30.2 but adjusted to the requirements of container cranes.

**Clause 24** – 1.11.1 details requirements for the main hoist brake rating. The standard overlaps and/or contradicts requirements of the brake rating of EN class C standards e.g. EN 15011.

**Clause 24.1.13.4** defines requirements for the power supply. As such it details topics which are covered in IEC60204-32. E.g. an E-stop push button is definitely required to be installed in the operator cabin. The approach of IEC60204-32 in this respect is more general as it requires the designer to carry out a risk analysis and install E-stop pushbuttons wherever the risk analysis identifies. In this case IEC covers ASME requirements whereas ASME would not comply with IEC.

## 5.3 IEC and NEMA ICS8

**NEMA ICS8-1993** overlaps and contradicts **IEC60204-32** in sections 4.1.3 'protection' and 4.4 'control voltage'. Section 8 for example defines the ratings of VFD drives for hoist applications as 175% rating for 1 min. This is difficult to apply in a consistent manner for state-of-the-art variable speed drives.

Wiring in general is requested to comply with article 610 of ANSI 70 which may deviate relevantly from IEC standards.

In the case of ambiguity in each of the above examples the relevant general electrical standard of the country must be considered.

## 5.4 Specific detailed example relating to the protection of primary and secondary cables of MV Power transformers

**IEC and NEC**

The topic of the protection of the cables connected to a crane's medium voltage transformer's primary from the supply source as well as those LV cables connected from the secondary winding to the drive system panel in-feeder shows a critical and relevant difference between the IEC and the American standards.

**IEC 60354-4-43** in paragraph 434.3 details that overcurrent protection for installations at the point of connection to the supply grid can be omitted where the overcurrent protection is provided at the grid level and where the supply company agrees that this protection is sufficient. Such cables are to be laid in a manner that the risk of short circuit is reduced to a minimum and the cables are not laid in proximity to flammable material.

The conclusion therefore is that over current protection can be omitted if the upstream short circuit protection is found to be sufficient and if the party responsible for the supply network agrees to the omission.

The relevant North American standard NEC/NFPA70 article 240 in contrast leaves no room for interpretation in this respect.

**IEC60204-32, clause 7.2.7** 'Transformers' requires transformers to be protected against overcurrent and against excessive temperature rise in case of a short circuit of the secondary.

**IEC60204 Clause 7.2.8** 'location of overcurrent protection devices' requires protection devices e.g. fuses for cables connecting the transformer secondary with the drive in-feeder. Nevertheless, IEC-conforming installations often omit overcurrent protection device for these cables citing the permitted exceptions listed in section 7.2.8:

- current carrying capacity of conductor is at least equal to the requirement of the load
- conductor length is not more than 3 m
- conductor is protected by a duct or conduit.

*Fig. 4: Typical arrangement key electrical components in STS machinery house*

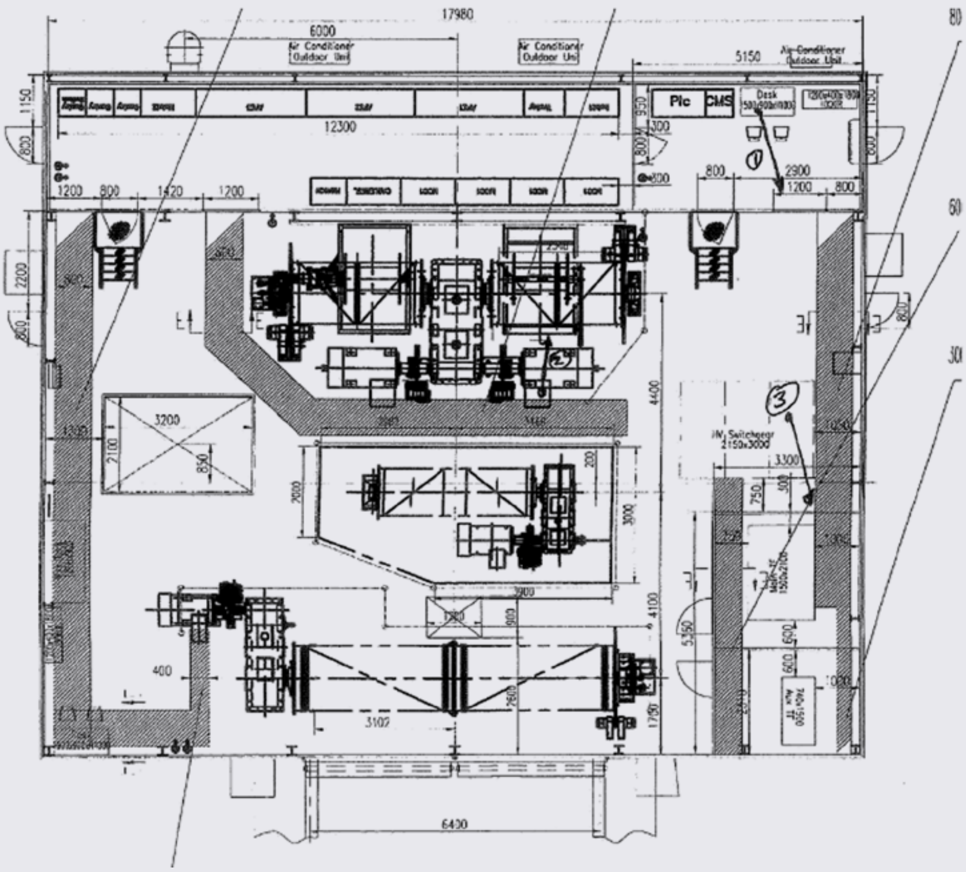



*Fig. 5: Configuration MV and LV supply to the crane's drive system with the crane switch included as part of the drive panel line-up*

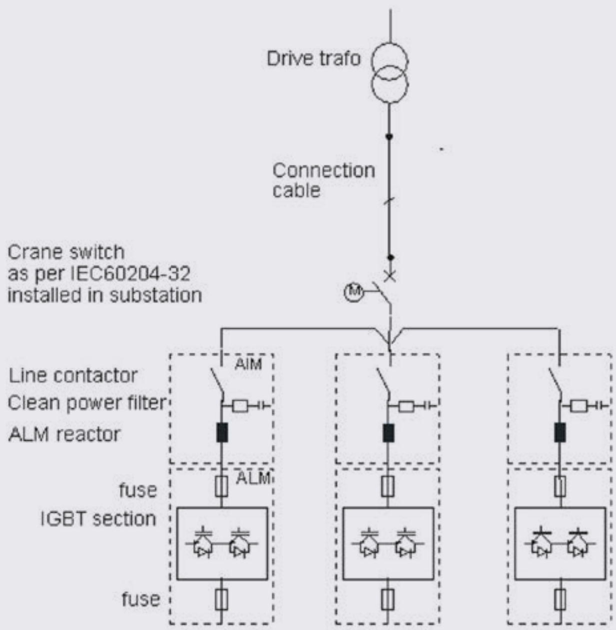



*Fig. 6: Typical situation of cable routing under machinery house floor*

In practice, these cables often run in cable ducts under the machinery house floor from one corner of the machinery house to the e-house in the other.

As the length of the cables between the transformer and the e-house on large cranes may exceed 3 meters, the prerequisites for omitting overcurrent protection for the cables in 7.2.8 has been subject of much discussion.

Initially, IEC 60204-32 had been formulated based on IEC 60364-4-43 section 434.3 'protection against overcurrent'. The section 434.3 requires an overcurrent protection device at the location where the conductor cross-section is reduced. Yet it also considers exceptions to this requirement if the following 3 criteria are simultaneously satisfied:

- there is no branch in this conductor section
- the length of the conductor does not exceed 3 m and
- further measures had been taken to reduce the risk of short circuit.

As per IEC 62271-105 properly designed protection means that the MV supply side can provide protection against short circuits on 'short' cables on the transformer secondary side. A 'short' length is to be understood as a length that does not have the relevant impedance to prevent to overcurrent relay from tripping. In practice 'short' can be extended from the mentioned 3 m to up to 10 m.

The relevant North American standard NEC/NFPA70 article 240 in contrast leaves no room for interpretation in this respect as detailed in the paragraph below.

2014 NEC article 240.4 'Protection of Conductors' section (F) 'Transformer Secondary Conductors' states:

*'Single-phase and multiphase (other than delta-delta, 3 wire) transformer secondary conductors shall not be considered to be protected by the primary overcurrent protective device'.*

Article 240.21 (Location in Circuit) continues with *'overcurrent protection shall be provided in each ungrounded circuit conductor and shall be located at the point where the conductors receive their supply'.*

North American installations and also some IEC installations therefore locate the circuit breaker of the drive in-feeder at the connection point of the secondary supply cables on the MV transformer.

*Fig. 7: Configuration MV and LV supply to the crane's drive system with the crane switch placed in close proximity to the MV transformer*

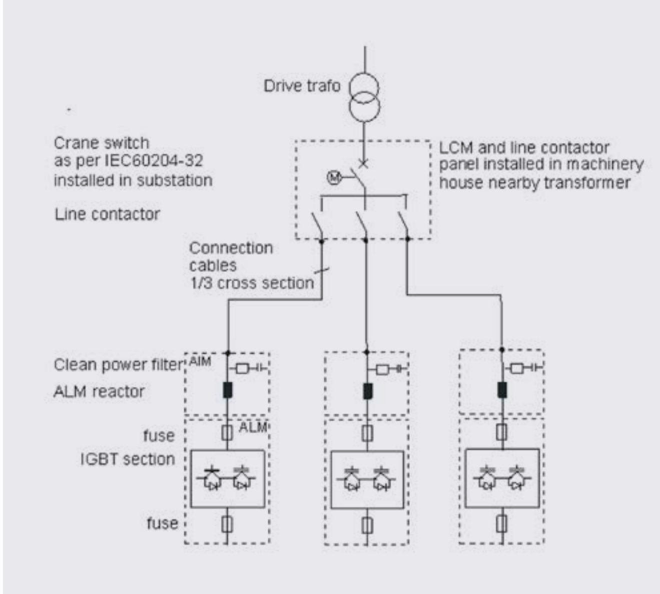



*Fig. 8: Example of panel in machinery house with cable protection fuses*

# Conclusions

The genesis of this paper originated at the 2014 PEMA Autumn meeting. The initial idea was to work on structural, mechanical and electrical standards for cranes such that eventually the resultant would be that overall crane safety could be quantified as is generally nowadays the case by applying ISO13849 or IEC62061. This paper is a first step towards this ambitious goal and as such provides an overview of the most important electrical safety standards worldwide. The scope and relevance of each standard is briefly explored with the aim of assessing its relevance for state-of-the-art technical specifications for manually operated and automatic cranes.

The standards overview resulted from work within the PEMA Equipment Design & Infrastructure committee in collecting standards relevant in the different regions and countries world-wide and comparing them in a rather complex overview table. This table then identified overlaps and gaps between the different standards. These overlaps and gaps are discussed in the paper. Special thanks to all contributing parties.

Certain chapters will receive more extensive coverage in subsequent editions of this paper.

# About the authors and PEMA

### About the authors

This paper was prepared by Gerhard Fischer of Siemens with contributions from Kenneth Fall of TMIEC, Simo Hoite of Liftech, Klaus Pohl of APMT and Pat O'Leary of PEMA.

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