IAEA Nuclear Energy Series

No. NP-T-3.3

Basic Principles

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Industrial Safety Guidelines for Nuclear Facilities

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INDUSTRIAL SAFETY GUIDELINES FOR NUCLEAR FACILITIES

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA NUCLEAR ENERGY SERIES No. NP-T-3.3

INDUSTRIAL SAFETY GUIDELINES FOR NUCLEAR FACILITIES

JOINTLY SPONSORED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND THE INTERNATIONAL LABOUR OFFICE

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FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

At present, there are over 440 operational nuclear power plants in IAEA Member States, with over 60 under construction. Nuclear power plant industrial safety practices, accidents and near miss events are routinely reviewed as part of IAEA Operational Safety Review Team (OSART) missions. Operating experience and research have shown that good industrial safety practices at nuclear facilities during all phases of their life cycle is correlated with superior performance. This performance is shown through an excellent nuclear safety culture and better cost and schedule performance.

This publication is an update of IAEA-TECDOC-535, which was published in 1990. The TECDOC was a guide to industrial safety reviews conducted in OSART missions. This new publication expands on the TECDOC and provides good practices for industrial safety management and the special implications for nuclear facilities. It also incorporates recommendations on occupational safety and health management systems from the International Labour Organization. This information is intended to help all those involved directly and indirectly in ensuring the safe operation of nuclear facilities and also to provide a common technical basis for dialogue between plant operators and regulators when dealing with industrial safety issues.

The IAEA gratefully acknowledges the work of the contributors to the drafting and review of this publication. The IAEA officer responsible for this publication was J.H. Moore of the Division of Nuclear Power.

PREFACE

Organizations responsible for the management of occupational safety and health (OSH) recognize that an OSH management system (OSHMS) that includes good hazard assessment and safe work planning can substantially reduce the potential for worker injuries. The sponsoring organizations of this publication, the IAEA and the International Labour Organization (ILO), are committed to improving OSH at nuclear facilities worldwide.

Established in 1957, one of the IAEA's statutory functions is "to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property (including such standards for labour conditions), and to provide for the application of these standards".[1] In the area of OSH, the IAEA develops safety standards and technical tools, supports its Member States in strengthening their OSH arrangements, provides for capacity building in its Member States, and performs, at the request of Member States, peer reviews on OSH arrangements (often as part of OSART missions). The IAEA also has the role of supporting the OSH of its own staff, recognizing their work in a large variety of nuclear and non-nuclear facilities around the world.

The ILO was established in 1919 by the Treaty of Versailles to bring together governments, employers and trade unions in united action for the causes of social justice and better living conditions everywhere. It is a tripartite organization, with representatives of workers and employers taking part in its work on equal status with representatives of governments. The ILO became the first specialized agency of the United Nations in 1946.

The development of international standards in the form of conventions and accompanying recommendations is one of the main functions of the ILO. These standards, which are adopted by the International Labour Conference, cover labour and social issues. As a package, they constitute the International Labour Code, which defines minimum standards in labour and social fields. The ILO has adopted more than 40 standards specifically dealing with OSH, as well as over 40 codes of practice. Nearly half of ILO instruments deal directly or indirectly with OSH issues. OSH is part of the ILO's action for the protection of workers against sickness, disease and injury arising out of employment, as mandated by the Constitution of the International Labour Organization[2]. Over the years, the ILO has collaborated with the IAEA and other bodies of the United Nations system in the development of a number of safety standards in the field of radiation safety and protection. This publication is the first, similar collaboration with the IAEA in the field of non-radiation safety.

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Statute, IAEA, Vienna (1956), as amended up to 1989.

[2] INTERNATIONAL LABOUR OFFICE, Constitution of the International Labour Organization, ILO, Geneva (1919), as amended up to 1974.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Work at nuclear facilities such as nuclear power plants, fuel fabrication facilities or waste processing and storage sites can subject workers to a number of industrial health and safety risks. Such facilities can contain hazardous processes and materials such as hot steam, harsh chemicals, electricity, pressurized fluids and mechanical hazards. Workers can be exposed to these and other hazards during normal duties (including slips, trips and falls, driving accidents and drowning). Industrial safety accidents, along with their direct impacts on the individuals involved, can negatively affect the image of nuclear facilities and their general acceptance by the public.

The IAEA and its Member States have acknowledged that good industrial safety practices are a cornerstone of the safe and efficient operation of nuclear power plants and other nuclear facilities. Specific reviews of industrial safety practices at nuclear power plants have been a part of IAEA Operational Safety Review Team (OSART) missions [1] for decades, and supplementary guidance for such reviews has been available since 1990 [2]. Industry groups such as the World Association of Nuclear Operators (WANO) and the Institute of Nuclear Power Operations (INPO) regularly collect industry safety statistics for their member operating organizations and publish specific performance objectives and criteria relating to industrial safety [3]. Furthermore, research has confirmed that organizations with better industrial safety records have greater success (better cost and schedule performance) with the implementation of their projects [4, 5]. Construction and operating organizations with better industrial safety records will often benefit from lower insurance premiums and lower costs of workplace compensation [6]. An excellent safety record most often indicates a well run, efficient and effective company, and projects a positive image [7].

1.2. OBJECTIVE

Industrial safety is the condition of being protected from physical danger as a result of workplace conditions. Industrial safety programmes in a nuclear context are the policies and protections put in place to ensure nuclear facility workers are protected from hazards that could cause injury or illness. The objective of this publication is to present good practices that nuclear organizations can and have put into place to implement high quality industrial safety programmes, and to identify things that employers can do to reduce, minimize or eliminate injuries, illnesses and other detrimental effects.

1.3. SCOPE

This publication focuses on the core aspects of industrial safety management at nuclear facilities, which is preventing injury and illness to workers. It includes all phases of facility life, from design, procurement and construction to operation and decommissioning.

Nuclear facilities often develop programmes for ionizing radiation (radiological hazards associated with the operation of a nuclear facility), employee wellness, fitness for duty, fitness for position and pandemic planning. This publication does not specifically describe such programmes. However, they are normally covered by the same overall safety policy and approaches as those which address industrial health and safety. Guidance provided here, describing good practice, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

1.4. USERS

The main target of this publication is the owner/operator of a nuclear facility or construction project, and the staff and contractors involved in occupational safety and health (OSH) activities. Such owner/operators are responsible for nuclear facilities as a whole and for the oversight and support of industrial safety practices at such facilities. Other potential users of this guide include:

- — Regulatory bodies: national and local regulators responsible for the regulatory framework surrounding facility construction, commissioning and operation.
- — Implementing organizations for nuclear energy programmes in newcomer countries: for understanding the typical industrial health and safety programme needs for the nuclear facility.
- — Installation contractors and technical support organizations: responsible for installation activities, engineering support and the construction safety management programme.
- — Designers: responsible for developing new or modifications to existing nuclear facilities and the incorporation of OSH considerations into those designs.
- — Organizations such as the IAEA that regularly send staff members to visit or inspect nuclear facilities.

1.5. STRUCTURE

Section 1 of this publication provides background information on industrial safety and related definitions. Section 2 covers the fundamentals required for industrial safety management at nuclear facilities, including the links between industrial safety and a good nuclear safety culture. Section 3 provides details on establishing an OSH policy, and Section 4 outlines the organization of an OSH management system (OSHMS), including its internal responsibility system (IRS). Section 5 provides information on how to plan and implement such an OSHMS. Section 6 details hazard identification and methods to address them. Sections 7 and 8 explore programme evaluation and actions for improvement, respectively. Section 9 concludes with best practices for organizations to achieve excellence in industrial safety. Appendices I–IX provide further details on specific hazards typical of nuclear facilities, sample OSH policies and other useful tools for those establishing an OSH programme. Annexes I and II present hazard risk assessment tools and the results of an industrial safety survey, respectively.

Organizations setting up new OSH programmes should especially note the administrative controls that are described in Section 6.6. These are typically in place at nuclear facilities, and constitute core processes that operating organizations usually implement as part of their OSHMS. Organizations utilizing contractors as part of their construction or operations workforce should especially refer to Section 6.6.10 on contractor safety programmes.

1.6. DEFINITIONS

Audit

A systematic, independent and documented process for obtaining evidence and evaluating it objectively to determine the extent to which defined criteria are fulfilled. This does not necessarily mean an independent external audit (an auditor or auditors from outside the organization).

Best practice

A process or method, typically proven through extensive industry use or validation, that when executed effectively leads to enhanced performance.

Continual improvement

An iterative process of enhancing the OSHMS to achieve improvements in overall OSH performance.

Hearing loss

Noise induced hearing loss is defined as a change in hearing threshold (often 10 dB or more) relative to the baseline audiogram.

Illness

Illnesses can take longer periods of time to develop, and include such conditions as skin disorders, respiratory conditions, poisoning and hearing loss. Other illnesses encountered in the workplace include heatstroke, heat exhaustion, freezing, frostbite and the effects of welding flash. The International Labour Organization (ILO) maintains a complete list of occupationally related diseases [8]. The 2010 revision of this list includes for the first time mental and behavioural disorders as potentially occupationally related diseases.

Injury

An injury is any wound or damage to the body resulting from an event in the work environment. Some common injury types are cuts, abrasions, fractures and burns. Sprain and strain injuries to muscles, joints and connective tissues are classified as injuries when they result from slips, trips, falls or other similar accidents.

Near miss

A near miss is an incident that did not result in an actual loss but potentially could have. For example, if an object is dropped from a crane but no one is hurt, the incident is a near miss.

Occupational safety and health management system

A set of interrelated or interacting elements to establish OSH policy and objectives, and to achieve those objectives.

Poisoning

Poisoning includes disorders evidenced by abnormal concentrations of toxic substances in the blood, other tissues, other bodily fluids or the breath that are caused by the ingestion or absorption of toxic substances into the body. Examples include:

— Metals such as cadmium, lead and mercury;
— Gases such as carbon monoxide and hydrogen sulphide;
— Organic solvents such as benzene and carbon tetrachloride;
— Insecticides such as lead arsenate and parathion;
— Other chemicals such as formaldehyde, plastics and resins.

Potential incident

A potential incident is the possibility of an event but nothing actually happens. The key difference between a near miss and a potential incident is that, with a near miss, an event did take place but the consequences were minor. With a potential incident, nothing happened at all. For example, if a worker drops a wrench from an upper deck and it hits the floor three stories below but no one is hurt then a near miss has taken place. If the same worker holds the same wrench such that, were the worker to drop it, it would fall to a lower deck, then the worker has created a potential incident.

Respiratory conditions

Respiratory conditions are illnesses associated with breathing hazardous biological agents, chemicals, dust, gases, vapours or fumes at work. Examples include asbestosis, chronic obstructive bronchitis, chronic obstructive pulmonary disease, occupational asthma, pneumonitis, toxic inhalation injuries and tuberculosis.

Skin disorders

Skin diseases or disorders are illnesses involving the worker's skin that are caused by work exposure to chemicals, plants or other substances. Examples include contact dermatitis, eczema and rashes caused by primary irritants.

Workers' health surveillance

Workers' health surveillance is a generic term which covers procedures and investigations to assess workers' health in order to detect and identify any abnormality. The results of surveillance should be used to protect and promote the health of the individual, collective health at the workplace and the health of the exposed working population. Health assessment procedures can include medical examinations, biological monitoring, radiological examinations, questionnaires and a review of health records.

Workers' representative

In accordance with the Convention concerning Protection and Facilities to be Afforded to Workers' Representatives in the Undertaking, ILO Convention No. 135 [9]:

> "the term ***workers' representatives*** means persons who are recognised as such under national law or practice, whether they are —
>
> (a) trade union representatives, namely, representatives designated or elected by trade unions or by members of such unions; or
> (b) elected representatives, namely, representatives who are freely elected by the workers of the undertaking in accordance with provisions of national laws or regulations or of collective agreements and whose functions do not include activities which are recognised as the exclusive prerogative of trade unions in the country concerned."

Workers' safety and health representative

The workers' safety and health representative is elected or appointed in accordance with national laws, regulations and practice to represent workers' interests in OSH issues at the workplace.

2. FUNDAMENTALS FOR INDUSTRIAL SAFETY IN A NUCLEAR FACILITY

A core value of any entity that undertakes to develop, design, construct or operate a nuclear facility or any party involved in oversight, support or services to that undertaking needs to ensure that all people are able to work in a manner which is safe and which protects their health and well being. One of the basic principles of nuclear energy is defined in Ref. [10], which states that "The use of nuclear energy should be such that people and the environment are protected in compliance with the IAEA Safety Standards and other internationally recognized standards."

A state of health and safety is fundamentally achieved through a robust OSHMS, coupled with excellence in leadership. An associated outcome of such a system is a committed OSH culture throughout the organization (see Fig. 1). This OSH safety culture is integral to the organization's overall safety culture, in that it includes attitudes and behaviours relating to nuclear safety, radiation safety, security and environmental protection, as well as OSH (see Section 2.4.1. for a more detailed discussion on safety culture).

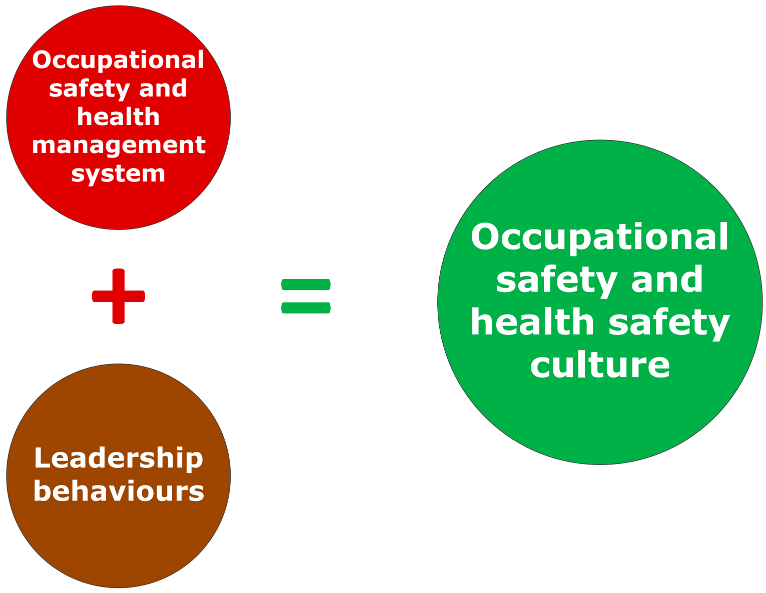


FIG. 1. Fundamentals of industrial safety.

The main objectives of an effective OSHMS are the following:

(a) To establish and implement an industrial safety policy that establishes an organization's mission objectives;
(b) To establish planning processes that consider the context for the organization's industrial safety objectives and take into account its risks and opportunities, its legal requirements and the other requirements to which it subscribes;
(c) To establish operational controls to manage industrial safety risks, legal requirements and other requirements to which it subscribes;
(d) To determine hazards and industrial safety risks associated with its activities; seeking to eliminate them, or putting in controls to minimize their potential impacts to employee health and safety;
(e) To establish work planning processes that evaluate work to be performed, associated hazards and the necessary steps to eliminate or control hazards;
(f) To determine the learning needs of all workers and establishing training programmes to provide effectively the knowledge and skills to workers to protect their health and safety;
(g) To increase awareness of industrial safety risks and continual improvement objectives through regular communications;
(h) To evaluate industrial safety performance and seeking to improve it, through appropriate corrective measures and continual improvement activities.

The OSHMS provides the framework within an organization, the roles, accountabilities, the planning, monitoring processes, operating procedures and the continual improvement structure. Leadership is accountable for the establishment of the OSHMS, to ensure individuals within the organization subscribe to and uphold high standards of safety and health, and for the outcomes and results of the OSHMS.

At a nuclear facility, the OSHMS is a part of an overall management system, which governs all activities at the facility. In fact, ILO guidance encourages the integration of OSHMS elements into overall organization management system arrangements. The ILO also stresses the importance of, at the organizational level, OSH being a line management responsibility, and not just a task strictly for OSH departments and specialists.

This section describes IAEA guidance for such an overall management system, and a framework OSHMS developed by the ILO that relates more specifically to industrial safety aspects at any facility. It also describes the linkages between industrial safety and overall nuclear safety, safety culture and the key role of the facility owner in driving industrial safety by providing programme leadership.

2.1. IAEA NUCLEAR MANAGEMENT SYSTEM GUIDANCE

Industrial safety is an integral part of overall nuclear facility safety. An effective management system helps to ensure this, and such a system needs to include a strong management commitment to safety and a strong safety culture. This includes ensuring excellence in industrial safety practices. Figure 2 shows the standard IAEA model showing how a management system is used to contribute to a healthy safety culture in an organization.

A key safety fundamental of all nuclear facilities is stated in para. 3.3 of IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [11], which states that "The person or organization responsible for any facility or activity that gives rise to radiation risks…has the prime responsibility for safety". This means that a nuclear facility licensee, when purchasing or delegating services that can affect nuclear safety, still retains responsibility for that safety and needs to have processes in place to maintain safety under all conditions. Other groups, for example vendors, suppliers, constructors, contractors or outside technical support organizations, may have some legal, professional or functional responsibilities with respect to safety; however, the prime responsibility cannot be transferred or delegated.

Management systems are a set of interrelated or interacting elements for establishing policies and objectives and enabling objectives to be achieved in an efficient and effective way. They have evolved over time from pure quality control systems (e.g. via simple checks such as inspections and tests) to quality assurance and quality management systems (such as International Organization for Standardization (ISO) standards) and to more recent integrated management system (IMS) approaches such as those described in IAEA Safety Standards Series Nos GSR Part 2 [12], GS-G-3.1 [13] and GS-G-3.5 [14]. An IMS provides a single framework for the arrangements and processes necessary to address all the goals of the organization. These goals include safety, health, environmental, security, quality and economic elements and other considerations such as social responsibility. A key difference with the IMS approach (as opposed to quality management systems such as ISO standards) is the incorporation of safety into the management system.

Nuclear facilities are required by national regulators to have a documented management system that governs the performance of their work. Specific requirements can vary; however, most regulations are aligned with

FIG. 2. IAEA safety culture and management system model.

GSR Part 2 [12], GS-G-3.1 [13] and GS-G-3.5 [14]. GSR Part 2 [12] is the higher level requirements publication, with GS-G-3.1 [13] containing specific guidance for operating nuclear facilities and related activities, and with GS-G-3.5 [14] dealing with even more specific guidance for nuclear power plants. Information on the development of a process based management system is available in Ref. [15]. Generic requirements in these safety standards with regard to the management system, management's responsibilities, resource management, process implementation, and measuring assessment and improvement all apply to a nuclear power plant's industrial safety programme.

GS-G-3.5 [14] discusses industrial safety in appendix V, on management systems for the construction of nuclear installations. Paragraph V.10(b)–(d) states:

"The principal activities of the personnel in the construction organization should include, as a minimum:

....

(b) Ensuring that suppliers are established on the site in a controlled manner in allocated areas and are provided, where appropriate, with the necessary site services, information and instructions with regard to the applicable industrial safety requirements;

(c) Preparing safety related working procedures, including industrial safety procedures, to issue to the personnel of both the construction organization and the contractors, and establishing that both the construction organization and the contractors' industrial safety arrangements on the construction site comply with the applicable requirements;

(d) Monitoring the industrial safety policies and activities of all personnel on the construction site to ensure compliance with statutory and regulatory requirements;"

Requirement 23 and para. 5.26 of IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [16] state:

"The operating organization shall establish and implement a programme to ensure that safety related risks associated with non-radiation related hazards to personnel involved in activities at the plant are kept as low as reasonably achievable.

"The non-radiation-related safety programme[2] shall include arrangements for the planning, implementation, monitoring and review of the relevant preventive and protective measures, and it shall be integrated with the nuclear and radiation safety programme. All personnel, suppliers, contractors and visitors (where appropriate) shall be trained and shall possess the necessary knowledge of the non-radiation related safety programme and its interface with the nuclear and radiation safety programme, and shall comply with its safety rules and practices. The operating organization shall provide support, guidance and assistance for plant personnel in the area of non-radiation related hazards."

"[2] 'Non-radiation-related safety' concerns hazards other than radiation related hazards; this is sometimes referred to as industrial safety or conventional safety."

A summary of selected other key IAEA management system requirements for industrial safety is given in Table 1. This publication is intended to assist operating organizations in the practical implementation of an industrial safety programme to meet the above requirements.

2.2. ILO OCCUPATIONAL SAFETY AND HEALTH GUIDANCE

2.2.1. ILO international conventions and recommendations

The ILO policy on OSH is contained in two international conventions and their accompanying recommendations. The Convention concerning Occupational Safety and Health, ILO Convention No. 155 [26], and ILO Recommendation No. 164 [27] provide for the adoption of a national OSH policy and describe the actions needed at the national and at the enterprise levels to promote OSH and to improve the working environment. The

TABLE 1. SELECTED IAEA MANAGEMENT SYSTEM CLAUSES RELATING TO INDUSTRIAL SAFETY

Topic	Paragraph in the safety standard
Construction organization and contractors to be given necessary site services, information and instructions with regard to industrial safety	4.16(b) of SSG-38 [17]
Industrial safety procedures must comply with applicable requirements	4.16(d) of SSG-38 [17]
Monitoring of industrial safety policies and activities of personnel to ensure statutory and regulatory requirements are complied with	4.16(e) of SSG-38 [17]
Safety requirements for contracts, subcontracts and site activities such as housekeeping to be defined	4.50 of SSG-38 [17]
Evidence in the field and other workplaces that safety rules, procedures and instructions are adhered to satisfactorily	3.2(b) of SSR-2/2 (Rev. 1) [16] I.1(3)(c) of GS-G-3.5 [13]
Points of particular significance include current validation of safety equipment	4.26 of NS-G-2.6 [18]
Work area housekeeping kept to standard	6.20 of NS-G-2.14 [19]
Material condition of infrequently used safety equipment is periodically monitored	6.21–6.23 of NS-G-2.14 [19]
Evaluation of health and safety risks prior to start of work is a common practice in the plant	5.12, 5.13, 6.56, 6.67 of NS-G-2.4 [20]
Fitness for duty programmes in place (covering overtime, rest breaks, drugs and alcohol use)	3.13, 4.29 of SSR-2/2 (Rev. 1) [16] 3.1, 3.2(3) of NS-G-2.4 [20] 4.5 of NS-G-2.14 [19]
Policy and control of personnel working overtime	6.61 of NS-G-2.4 [20] 4.5 of NS-G-2.14 [19]
Field operators report industrial safety problems	4.36, 7.34 of NS-G-2.14 [19]
Process and procedures for work control, testing and equipment restoration exist including Appropriate work and access permits (paras 4.26 and 4.27 of NS-G-2.6 [18]) Suitable arrangements for securing isolation points (paras 5.15 and 5.16 of NS-G-2.6 [18]) Work permits controlled from shift to shift (para. 8.9 of SSR-2/2 (Rev. 1) [16]) Change in radiological/conventional hazard conditions are controlled (paras 5.9(i) and 5.16 of NS-G-2.6 [18]) Coordination between appropriate work groups (paras 8.11 of SSR 2-2 (Rev. 1) [16] and 7.4 of NS-G-2.14 [19])	8.3, 8.6–8.11 of SSR-2/2 (Rev. 1) [16] 7.2, 7.4 of NS-G-2.14 [19] 5.9, 5.15, 5.16 of NS-G-2.6 [18]
Work authorization procedures have defined responsibilities and authorities	8.8–8.10 of SSR-2/2 (Rev. 1) [16] 4.23 of NS-G-2.6 [18] 7.4, 7.6 of NS-G-2.14 [19]
Shift crew awareness of out of service systems and equipment	Table A–1 of NS-G-2.1 [21] 7.5, 7.7 of NS-G-2.14 [19]
Sufficient safety equipment is maintained in-service or available	8.10 of SSR-2/2 (Rev. 1) [16] 7.1 of NS-G-2.6 [18] 7.4 of NS-G-2.14 [19]

TABLE 1. SELECTED IAEA MANAGEMENT SYSTEM CLAUSES RELATING TO INDUSTRIAL SAFETY (cont.)

Topic	Paragraph in the safety standard
Work process analysed for risk	8.6, 8.13 of SSR-2/2 (Rev. 1) [16] 7.2 of NS-G-2.6 [18] 7.1, 7.8, 7.10 of NS-G-2.14 [19]
Independent verification policy with respect to work authorizations	4.10, 4.26, 5.36, 7.28, 7.29 of NS-G-2.14 [19]
Arrangements made for ensuring fire safety	Requirement 22 of SSR-2/2 (Rev. 1) [16]
Status of fire hazard analysis and reviews	5.22 of SSR-2/2 (Rev. 1) [16]
Adequacy of fire protection systems	5.21 of SSR-2/2 (Rev. 1) [16] 6.6, 6.15, 10.1 of NS-G-2.1 [21] I.39 of NS-G-2.2 [22]
Portable firefighting equipment is well maintained	5.21(c) of SSR-2/2 (Rev. 1) [16] 7.1, 7.2 of NS-G-2.1 [21] 6.22 of NS-G-2.14 [19]
Fire barriers are adequately maintained	5.21(c) of SSR-2/2 (Rev. 1) [16] 3.2, 6.1, 7.1–7.3, 9.2(a), (b), Table A–1 of NS-G-2.1 [21] 9.18 of NS-G-2.6 [18]
Fire surveillance test programme	7.2, 8.1 of NS-G-2.1 [21] 6.59 of NS-G-2.4 [20]
Programme for systematic control of combustible material	5.21(b) of SSR-2/2 (Rev. 1) [16] 6.1–6.8 of NS-G-2.1 [21] 4.26, 5.15, 8.33 of NS-G-2.6 [18]
Fully qualified on-shift fire brigade available at all times	8.6, 10.3 of NS-G-2.1 [21] 4.28, 4.34 of NS-G-2.8 [23]
Personnel suitably qualified and possess the experience commensurate with responsibilities	9.3 of NS-G-2.1 [21]
Initial and refresher training undertaken by fire team	9.1–9.6 of NS-G-2.1 [21]
Fire control strategies in place (e.g. restrictions on smoking and limit use of temporary wiring)	6.9 of NS-G-2.1 [21] 4.36, 6.22 of NS-G-2.14 [19]
Local civil firefighting groups adequately instructed and trained	5.24 of SSR-2/2 (Rev. 1) [16] 2.18, 8.2 of NS-G-2.1 [21] 4.34 of NS-G-2.8 [23] GSG-7 [24]
Fire drills and exercises of appropriate scope and frequency	5.24 of SSR-2/2 (Rev. 1) [16] 3.2, 8.1, 8.6 of NS-G-2.1 [21]
Fire training facilities adequate	9.1 of NS-G-2.1 [21]
Measures to protect against explosions to be taken (fuel cycle facilities)	SSR-4 [25]
Cooperation between relevant authorities where nuclear, environmental, industrial safety and occupational health aspects are separately regulated	SSR-4 [25]

Convention concerning Occupational Health Services, ILO Convention No. 161 [28], and ILO Recommendation No. 171 [29] provide for the establishment of occupational health services which will contribute to the implementation of the OSH policy and will perform their functions at the enterprise level.

Construction is one of the world's largest industrial sectors, and it includes building, civil engineering, demolition and maintenance industries. It is, however, one of the most dangerous industries. The ILO has long recognized the need for special treatment for the construction industry, and in 1937 adopted its first convention for the industry. In 1988, the Convention concerning Safety and Health in Construction, ILO Convention No. 167) [30], and ILO Recommendation No. 175 [31] were adopted, reflecting the need for a broad approach to take preventive and protective measures to tackling the key safety and health concerns in construction and the safety of the workplace, including:

(a) Scaffolds and ladders;
(b) Lifting appliances and gear;
(c) Transport, earth moving and material handling equipment;
(d) Plant, machinery, equipment and hand tools;
(e) Work at heights, including roof work;
(f) Excavations, shafts, earthworks, underground works and tunnels;
(g) Cofferdams and caissons;
(h) Work in compressed air;
(i) Structural frames and formwork;
(j) Work over water;
(k) Demolition;
(l) Lighting;
(m) Electricity;
(n) Explosives;
(o) Health hazards;
(p) Fire precautions;
(q) Personal protective equipment (PPE) and clothing;
(r) First aid;
(s) Welfare;
(t) Information and training;
(u) Reporting accidents and diseases.

One of the key issues that ILO Convention No. 167 [30] addresses is the need for planning and coordination of safety and health on-site. It clarifies, for example, that where several contractors are working simultaneously on the same site, the main responsibilities for safety and health are upon the principal contractor, but that each employer is responsible for applying measures relating to workers under their own control. Furthermore, Art. 9 of ILO Convention No. 167 [30] states:

> "Those concerned with the design and planning of a construction project shall take into account the safety and health of the construction workers in accordance with national laws, regulations and practice."

ILO conventions, recommendations and codes of practice also exist in the area of ionizing radiation protection of workers [32–34]; however, they are not the subject of this publication.

2.2.2. ILO management systems framework

The ILO describes a national framework for OSHMSs in Ref. [35] and recommends that:

> "A competent institution or institutions should be nominated, as appropriate, to formulate, implement and periodically review establishing a coherent national policy for the establishment and promotion of OSH management systems in *organizations*. This should be done in consultation with the most representative organizations of employers and workers, and with other bodies as appropriate."

Such a policy should result in the production of national guidelines, tailored guidelines (for specific organizations or groups of organizations) and organization specific OSHMS (see Fig. 3).

Within organizations, the employer, pursuant to national laws and regulations, has the prime responsibility for OSH, including compliance with the OSH requirements. Employers and senior managers should show strong leadership and commitment to OSH activities, and arrange for the establishment of an OSHMS. The system should contain the main elements of policy, organizing, planning and implementation, evaluation and corrective actions for improvement. The ILO model for this is shown in Fig. 4 and is used as the basis for describing an OSHMS for nuclear facilities in this publication. A training package for developing such a system is also available [36].

Within each element of the model are the sub-elements described in Table 2. The model contains the systematic steps of planning the programme, implementing the programme, monitoring the programme and taking corrective action, and continually improving the programme. It is based on a simple 'Plan, Do, Check, Act' (PDCA) business process cycle that was originally developed by W. Edwards Deming in the 1950s. Deming proposed that business processes should be analysed and measured to identify sources of variations that cause products to deviate from customer requirements. He recommended that all business processes incorporate a continuous feedback loop so that managers can identify and change the parts of the process that need improvements. The IAEA uses the Deming circle process to describe a number of its recommended processes, including ageing management [37]. The methodology is used here to describe the attributes of an industrial safety programme for a nuclear facility.

The first phase of the PDCA cycle is the 'plan' phase, during which a plan is developed. In this framework, the plan phase takes inputs from the organization's OSH policy (see Section 3), external legal requirements, codes and standards, and societal and political influences, and assesses any strategic risks. It then establishes objectives, targets and improvement plans to be implemented relating to industrial safety, establishes roles and responsibilities, provides training and communicates as required (see Section 4).

The second phase of the PDCA cycle is the 'do' phase, during which the plan is carried out. In this framework, the do phase consists of all activities associated with implementing the OSH plan. It includes analysing workplace hazards, developing procedures, planning work, ensuring worker involvement, developing emergency preparedness plans and processes, and performing records management activities (see Sections 5 and 6).

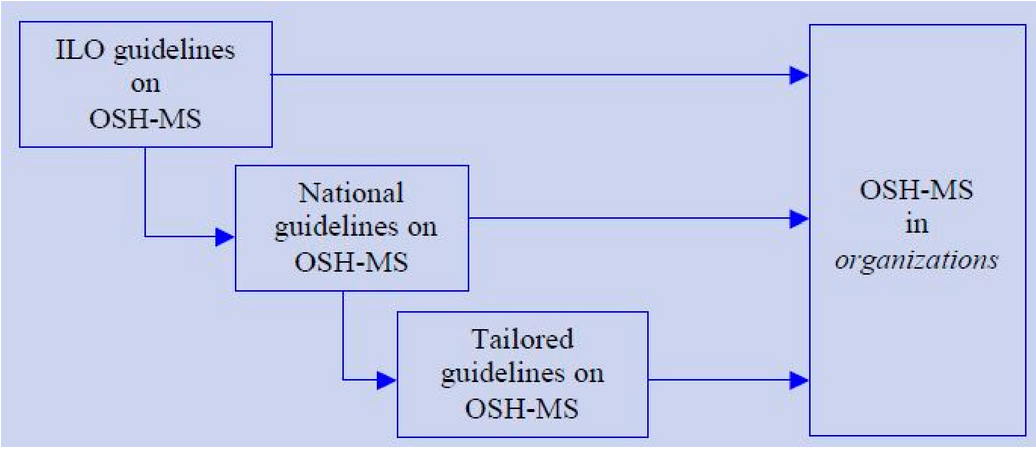
The third phase of the PDCA cycle is the 'check' phase, during which a review takes place of what was intended and what was observed in the previous step (do phase). It focuses on measuring effectiveness and analysing for improvement. In this framework, the check phase measures and analyses OSH performance, investigates incidents, audits the programme and performs compliance evaluations (see Section 7).

In the last phase of the PDCA cycle, 'act', organizations take action on the causal system to effect the desired change. The phase focuses on fully implementing the improved solution. Section 8 addresses the act phase through management oversight and review activities.

2.3. INPO AND WANO ACTIVITIES

INPO and WANO describe a set of performance objectives and criteria for nuclear power plants in Ref. [3]. Within these criteria, there is a section on industrial safety. It provides evaluation criteria for facilities relating to the following:

— A clear industrial safety policy;
— Safety committees;
— Sufficient resources;
— Leadership promotion;
— Training;
— Permanent and portable safety equipment;
— PPE;
— Warning and barriers;
— Appropriate tooling;
— Appropriate housekeeping and storage practices;
— Performance measures relating to industrial safety;
— Appropriate and well utilized corrective action and operating experience programmes.



Source: Figure 1 of Ref. [35].

FIG. 3. ILO framework for occupational safety and health management systems.

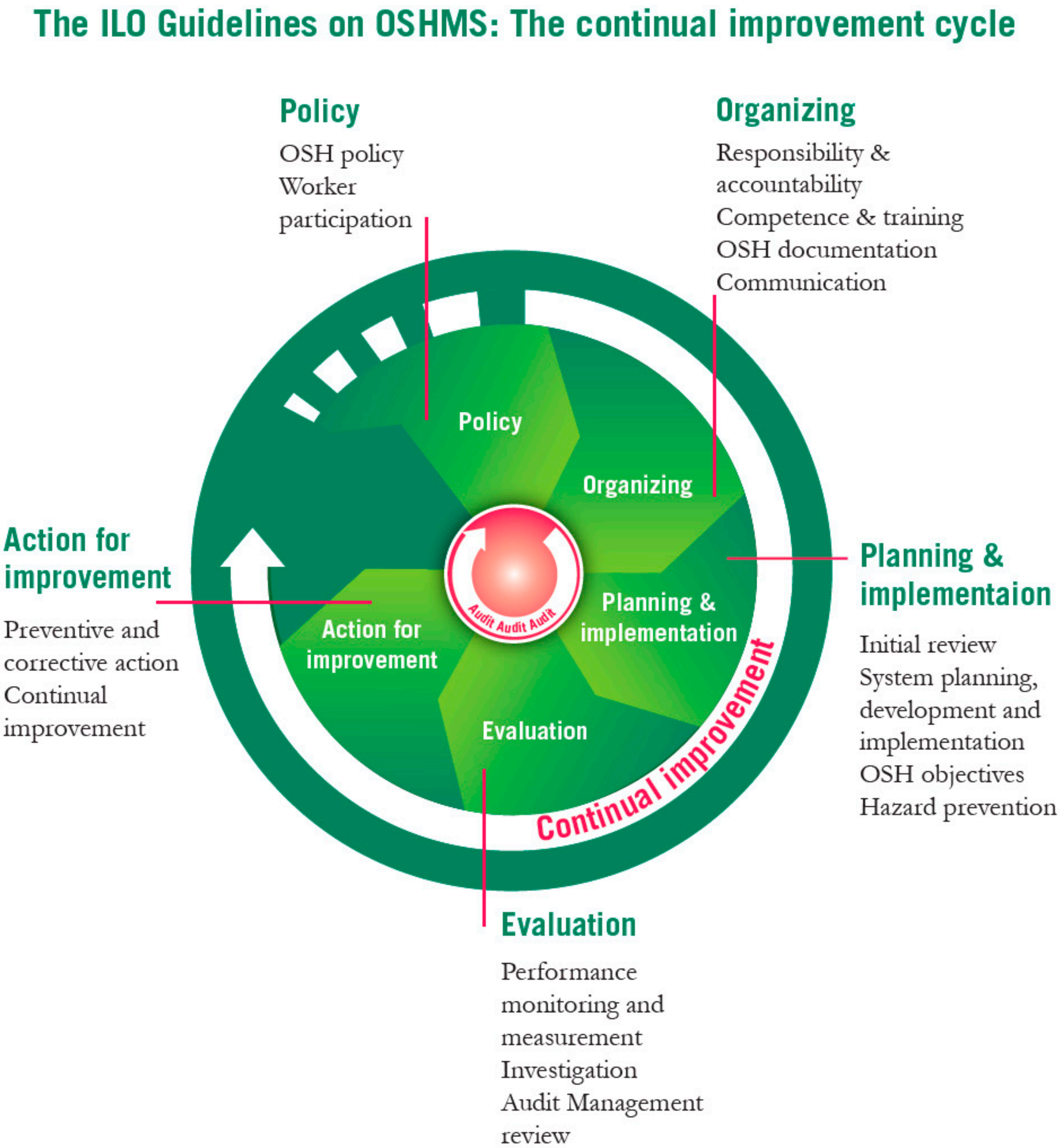


FIG. 4. ILO model of main elements of an OSHMS [36].

TABLE 2. ELEMENTS AND SUB-ELEMENTS OF AN OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM

Element and sub-element	Description
Policy	
OSH policy	Establishing an industrial safety policy that establishes its mission and objectives. Such a policy should contain stated beliefs, values, vision, mission, accountabilities and behavioural expectations and commitment to the development and maintenance of the OSHMS.
Worker participation	Ensure mechanisms are in place for worker participation in the OSH programme.
Organizing	
Responsibility and accountability	Defining responsibilities and accountabilities for leadership and workers.
OSH documentation	Documenting the OSHMS and related procedures, and ensuring its elements are integrated into the overall management system of the organization.
Communication	Increasing awareness of industrial safety risks and continuous improvement objectives through regular communications.
Planning and implementation	
Initial review	Evaluation of the organization's existing OSHMS and relevant arrangements as a basis for a new or improved system. The review covers identification of existing laws, regulations, guidelines and voluntary programmes, assessment of hazards and safety risks, whether existing controls are adequate, and a review of health surveillance data.
System planning, development and implementation	Establishing operational controls to manage industrial safety risks, legal requirements and other requirements to which it subscribes. Establishing planning processes that consider the context for the organization's industrial safety objectives and take into account its risks and opportunities, its legal requirements and the other requirements to which it subscribes.
OSH objectives	Establishment of measurable OSH objectives that are consistent with the OSH policy and based on the initial or subsequent reviews.
Hazard prevention	Determining hazards and industrial safety risks associated with its activities; seeking to eliminate them, or put in controls to minimize their potential impacts to employee health and safety. Establishing work planning processes that evaluate work to be performed, associated hazards, and the necessary steps to eliminate or control hazards. Ensuring procurement processes and specifications incorporate necessary OSH requirements. Ensuring that arrangements are established and maintained to ensure that the organization's safety and health requirements, or at least the equivalent are applied to contractors and their workers.
Evaluation	
Investigation	Ensuring that the origin and underlying causes of work related injuries, ill health, diseases and incidents are investigated and documented to identify any failures in the OSHMS.
Audit	Regular internal assessments and audits of the OSHMS to ensure it is fulfilling its organizational objectives, is compliant with internal requirements, regulatory requirements and industry requirements.

TABLE 2. ELEMENTS AND SUB-ELEMENTS OF AN OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM (cont.)

Element and sub-element	Description
Management review	Evaluating industrial safety performance and seeking to improve it, through appropriate corrective measures and continuous improvement activities.
Action for improvement	
Preventative and corrective action	Evaluating industrial safety performance and seeking to improve it, through appropriate corrective measures and continuous improvement activities.
Continual improvement	Commitment and active efforts and processes to utilize both internal and external operating experience to continually improve the OSHMS, and to evaluate and adopt industry best practices where applicable.

Note: OSH — occupational safety and health; OSHMS — occupational safety and health management system.

Standard WANO performance indicators have been developed to compare industrial safety performance between facilities (see Ref. [38] and Section 7.1). Since 2016, INPO has been developing guidelines to complement the performance objectives and criteria specific to industrial safety at nuclear power stations. They will cover leadership, training and safety standards.

2.4. SAFETY CULTURE AND LEADERSHIP

2.4.1. Safety culture

Safety culture strongly affects OSH performance. In a nuclear facility context, the term is sometimes thought to apply strictly to nuclear (reactor) safety. However, the related behaviours and attitudes needed for high nuclear reactor safety performance are equally applicable to industrial safety practices. Figure 5 illustrates how this is implemented at one operating organization, with industrial safety being considered as an integral part of overall nuclear safety.

This publication uses the broader definition of safety culture as applying to all aspects of nuclear facility construction and operation, including cultural aspects that impact on nuclear, radiation, environmental and industrial safety. The following subsections discuss this safety culture from a number of perspectives.

2.4.1.1. IAEA publications

Reference [39] states:

> “**Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.**”

Safety culture is an amalgamation of factors that may bring influence from outside of an organization (societal) or from within. These factors include beliefs, values, standards, morals and norms of acceptable behaviour. There is strong recognition of the importance of a strong safety culture to ensure that both organizations and individuals achieve high standards of safety. It is recognized that safety considerations are affected by common points of beliefs, attitudes, behaviour and cultural differences, which need to be closely aligned to the organization’s shared system of values and standards to achieve the level of safety behaviours desired. Reference [39] states:

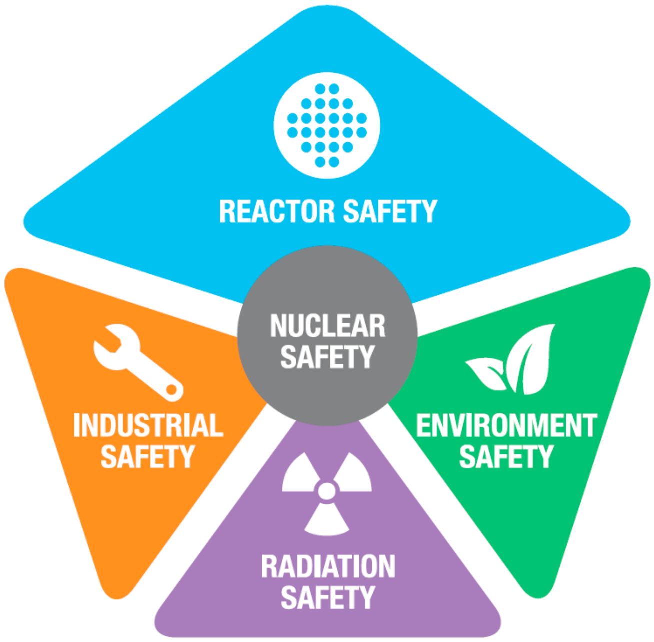


FIG. 5. Bruce Power's approach to consideration of industrial safety as part of overall nuclear safety (courtesy of Bruce Power).

"12. *Safety culture has two general components. The first is the necessary framework within an organization and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework.*"

Paragraph 3.113 of SF-1 [11] states:

"Safety culture includes:

— Individual and collective commitment to safety on the part of the leadership, the management and personnel at all levels;
— Accountability of organizations and of individuals at all levels for safety;
— Measures to encourage a questioning and learning attitude and to discourage complacency with regard to safety."

GS-G-3.5 [14], on management systems, details five overarching safety culture characteristics (see Fig. 6) and states:

"2.10. Senior management should establish and promote a set of principles to be used in decision making and promoting safety conscious behaviour. Examples of such principles used in some organizations are as follows:

(a) Everyone has an impact on safety.
(b) Managers and leaders must demonstrate their commitment to safety.
(c) Trust and open communication permeate the organization.
(d) Decision making reflects putting safety first.
(e) Nuclear technology is recognized as having unique safety implications.
(f) A questioning attitude is fostered.
(g) Organizational learning is encouraged.
(h) Training of personnel is encouraged.
(i) A proactive approach to safety is taken.
(j) Safety is constantly under review."

FIG. 6. Overarching safety culture characteristics [14].

Therefore, to achieve the desired state of safety culture within the organization, the safety programme has to include fundamental elements that will, in addition to establishing the necessary control processes for hazards and risks, define, shape, contribute and foster the beliefs, values and standards of the organization, and align morals and norms to those that the organization desires. A strong safety culture helps to ensure the effectiveness of the OSHMS. Organizations with a strong OSH safety culture might have the following (see Refs [40–42] for other IAEA publications on safety culture):

— Work instructions detailing how to perform the work safely;
— Industrial safety as a regular topic when coaching work performance;
— Group meetings routinely including time to talk about industrial safety and health;
— Individuals regularly peer coaching each other on health and safety topics;
— Safety routines and requirements included in scheduled work so sufficient time is made available to perform the work safely.

2.4.1.2. ILO perspective

The ILO defines a national preventive safety and health culture as one in which [43]:

> "the right to a safe and healthy working environment is respected at all levels, where governments, employers and workers actively participate in securing a safe and healthy working environment through a system of defined rights, responsibilities and duties, and where the principle of prevention is accorded the highest priority."

As such, a good national preventive safety and health culture would result in specific management system aspects in organizations within that country, including a robust IRS (see Section 4.1).

2.4.1.3. Construction Industry Institute research

The Construction Industry Institute (CII) has attempted to measure the extent and quality of safety culture within a company as it relates to industrial safety [44]. It developed a safety culture variable based on three variables: (i) whether a company uses safety as a criterion in giving raises to workers; (ii) whether the company performs safety perception (worker input) surveys; and (iii) whether near misses are documented. It found a clear relationship between a strong safety culture and better safety performance records. Construction firms with a strong safety culture had less than a third of the injuries as those devoid of safety culture (3.08 versus 9.85 injuries per 200 000 exposure hours). A related term used by the CII is that of 'operational excellence', which it defines as

“Doing the right thing, the right way, every time — even when no one is watching” [45]. A CII research team is evaluating the link between industrial safety performance and measures of operational excellence.

2.4.1.4. Safety culture evolution

Safety culture is evolutionary. In the early stages of development and implementation of an OSHMS, it will drive the evolution of the safety culture. However, as the safety culture evolves and matures, it is desirable that the safety culture drives the evolution of the OSHMS. This state, in which the safety culture of the organization drives the evolution of safety management and becomes a ‘way of life’ for the people involved, is a sign of the state of maturity and effectiveness of the OSHMS. This evolution can be characterized in terms of a capability maturity model. Such models were originally developed by the Software Engineering Institute as a way to improve the way software is built and maintained [46]. A four stage capability maturity model for OSH culture is described in Table 3 and Fig. 7.

2.4.1.5. Occupational safety and health culture perception surveys

Safety perception surveys can be a useful tool in assessing an organization’s OSH culture. They can be used either as part of a comprehensive improvement audit or as a standalone tool. A variety of such surveys are in use in the nuclear industry. Reference [47] describes some typical methods for designing a customized safety culture survey. Appendix IX of this publication lists some potential questions.

TABLE 3. STAGES OF DEVELOPMENT OF AN OCCUPATIONAL SAFETY AND HEALTH PROGRAMME

Stage	Description
1	Emerging: Safety is based solely on rules and regulations — the organization is almost exclusively focused on compliance to imposed safety rules and regulations, most often from external regulatory bodies. Safety is a requirement driven externally from the organization. Many accidents are seen as unavoidable and as part of the job.
2	Managing: Good safety performance becomes an organizational goal — the organization sees good safety performance as important even in the absence of external regulatory requirements. The organization adopts internal technical and process solutions to manage safety. Safety performance indicators are adopted and the organization seeks to look at trends in that performance to achieve the targets. Most safety performance indicators in use are lagging indicators. Managers may perceive that the majority of accidents are solely caused by the unsafe behaviour of front line staff.
3	Involving and cooperating: Safety performance can be continually improved — the organization continues to seek further safety performance improvements and to adopt innovative, and best practices from industry peers in that pursuit. Safety performance targets are regarded as measurement systems of progress towards a vision/mission for safety, not just as a target or indicator of having reached the desired state of safety performance. Managers and front line staff recognize that a wide range of factors cause accidents and the root causes are likely to come back to management decisions.
4	Continually improving: Safety is an ingrained value in the culture — the organization places safety as an overriding consideration in decision making, and the prevention of all injuries or harm to employees (both at work and at home) is a core company value. The organization believes that good safety behaviours are model behaviours that will contribute to overall organizational performance and success. Efforts continually to improve may drive safety performance improvements, but most often strengthen perceived areas of improvement or continually enhance safety management practices and behaviours.

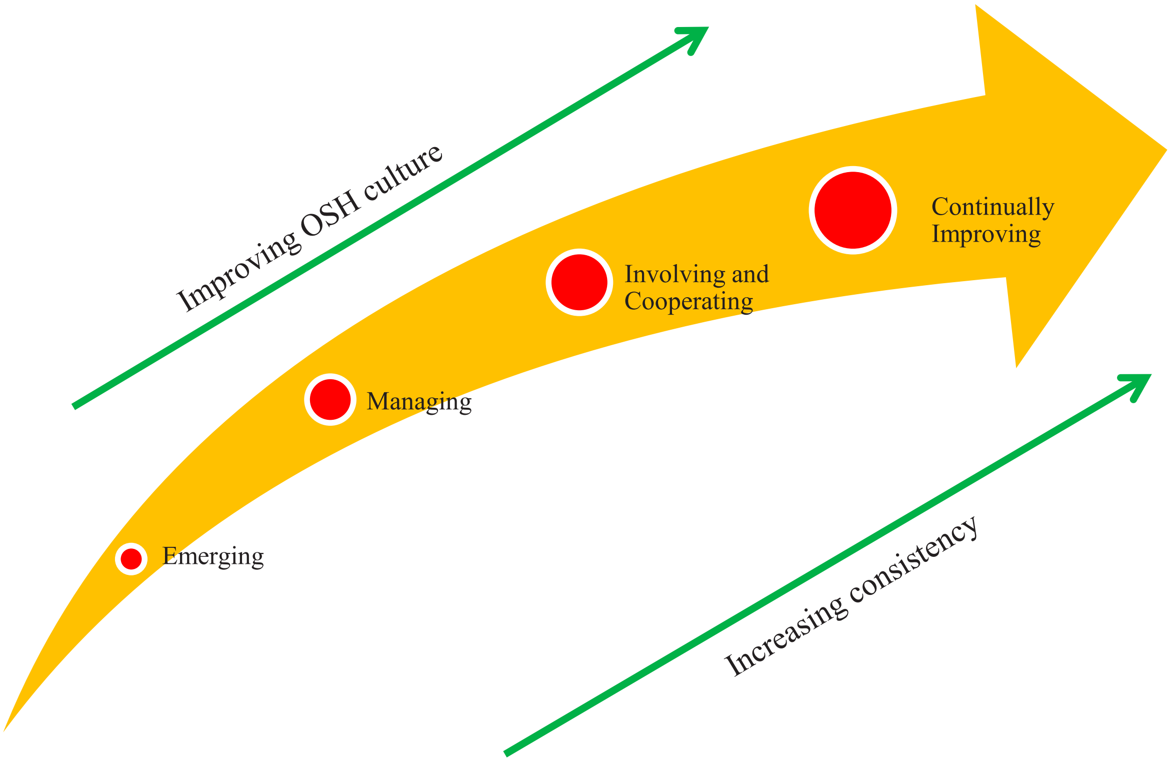


FIG. 7. Occupational safety and health culture capability model.

The Nordic Occupational Safety Climate Questionnaire (NOSACQ-50)[1] is a generic industrial safety specific survey available in 25 languages. Survey results can be submitted to the developers for incorporation into an international database. Figure 8 shows a sample NOSACQ-50 questionnaire analysis that compares answers obtained from two different departments within an organization.

DuPont has developed an on-line survey[2] that provides a measure of alignment of how different roles within an organization agree on a response to a particular question and classifies a company's OSH safety culture maturity (see Section 2.4.1.4) into four possible categories (see Fig. 9). From worst to best, the DuPont categories are reactive, dependent, independent and interdependent. A number of other good sources of information on safety perception surveys are included in Ref. [48].

2.4.2. Leadership

The leadership behaviours displayed by its personnel, especially senior executives, managers and supervisors greatly affect the organization's safety culture. The effectiveness of the OSHMS to achieve organizational objectives depends on the commitment from all levels and functions, and especially that of leadership. Leadership can ensure OSHMS effectiveness by integrating business and governance processes, strategy and decision making, and aligning industrial safety objectives with other business priorities. Thus, the OSHMS is neither regarded as separate and distinct from other business activities nor as an optional extra.

Executives, managers and supervisors should model desired safety behaviours, communicate safety expectations to employees, monitor behaviour in the organization, recognize good performance, and correct substandard conditions and poor performance. Line managers in the organization make decisions and direct the workforce. They are accountable for the performance of their workforce. They need to demonstrate ownership and appropriate alignment and judgement in the application of the safety programme. The specific duties of senior executives, managers and supervisors under the IRS are discussed further in Sections 4.2–4.4.

[1] See www.arbejdsmiljoforskning.dk/en/publikationer/spoergeskemaer/nosacq-50
[2] See https://dupontspsonline.com

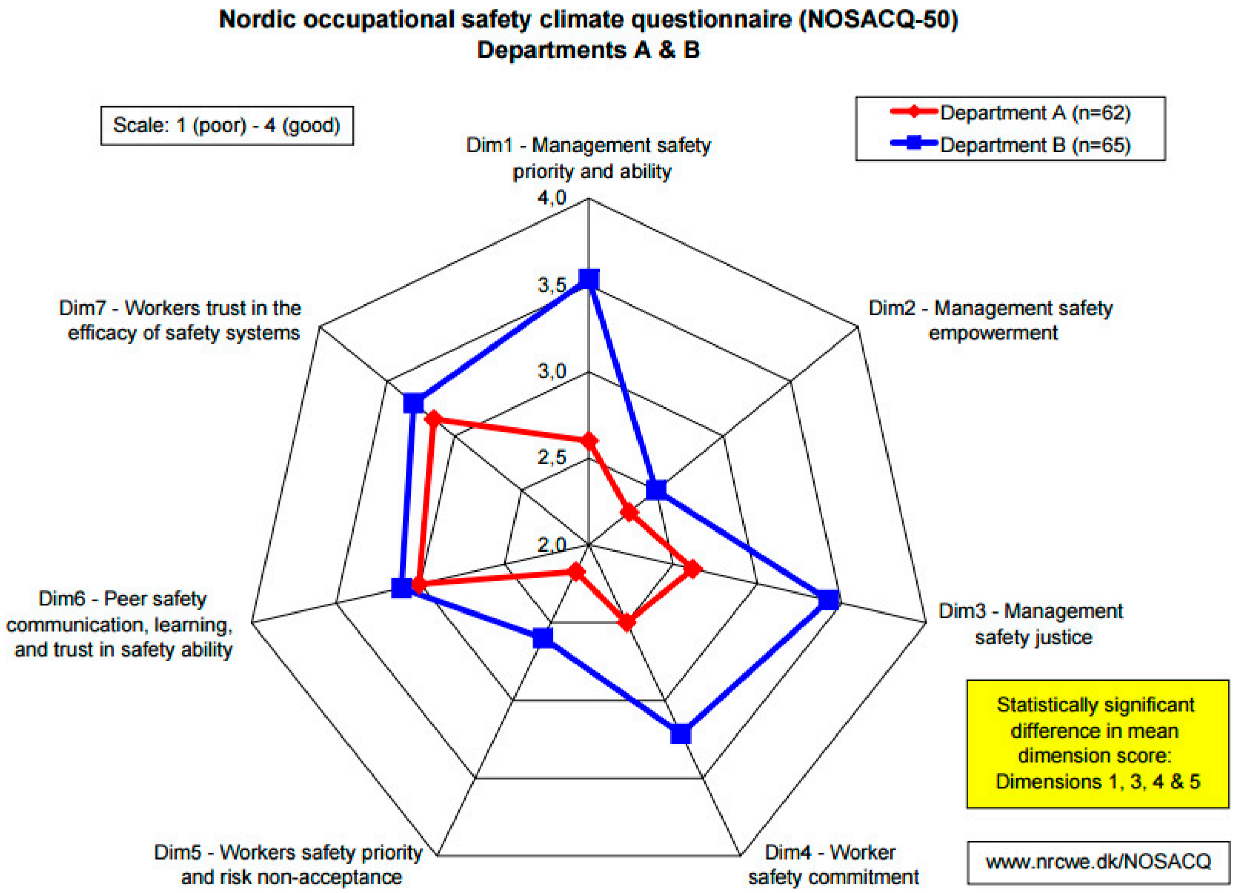


FIG. 8. Sample NOSACQ-50 survey analysis (courtesy of the National Research Centre for the Working Environment).

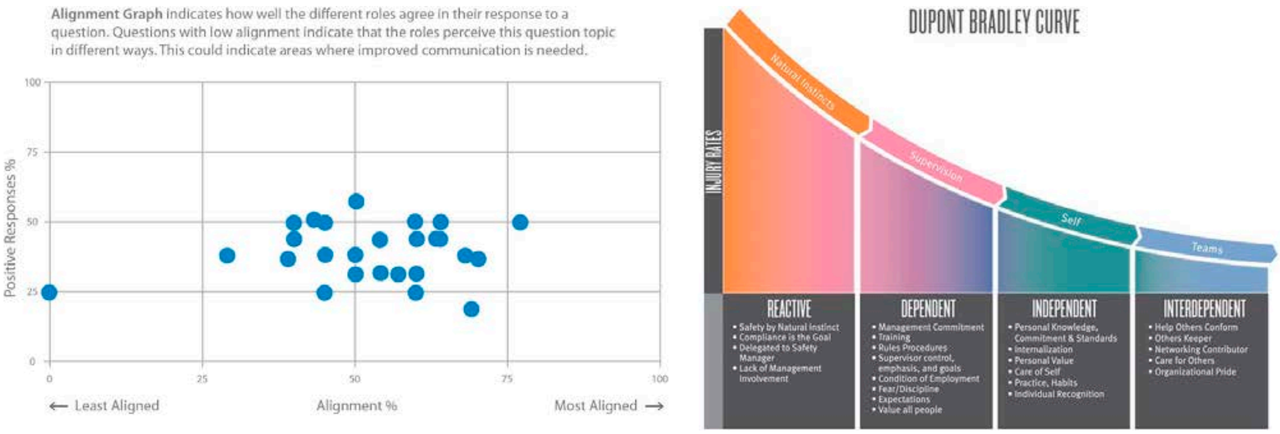


FIG. 9. Alignment graph and DuPont Bradley OSH culture curve (courtesy of E.I. du Pont de Nemours and Company).

2.4.3. The owner's role

Nuclear operating organizations regularly utilize contractors for construction and operations support activities, and in this role are considered facility 'owners'. This section provides information from two construction related organizations into the owner's role in construction project workplace safety.

2.4.3.1. Construction Industry Institute experience

The CII has conducted research into the owner's role in construction safety in the general construction industry [49, 50]. The relationship between project safety performance and the owner's influence was examined in a survey that was sent to owners with large projects budgets, with interviews conducted for projects with large worker hour exposures. Statistical analysis showed a strong relationship between safety performance and the degree of owner involvement, and that improved safety performance was possible through specific owner practices. These include careful selection of contractors, such as safety requirements in contracts, being proactively involved in project safety practices, establishing safety recognition programmes, actively participating in and verifying understanding of contractor safety training and orientation programmes and in assigning full time safety representatives to construction projects.

Traditionally, safety responsibilities have been seen as resting solely with the contractors, with owners and designers minimizing their involvement due to fear of liability exposure. Recently, however, more owners are taking a more active role in construction safety, realizing that the cost of construction accidents is ultimately their own financial burden, and they cannot with certainty shield themselves from the legal liabilities associated with worker injuries. In the United States of America, it is conservatively estimated that the average workplace compensation insurance cost accounts for 3.5% of a total construction project's cost [51]. Establishing an OSHMS programme framework for a nuclear facility that includes many of the practices described above can thus positively affect OSH outcomes and lower facility costs.

2.4.3.2. Construction Users Roundtable experience

Construction Users Roundtable (CURT) was founded 2000 by construction and engineering executives from major corporations and provides a forum for the exchange of information, views, practices and policies of construction users from an array of industries. Its primary goal is to enact broad, effective owner representation and increased owner leadership on construction industry issues in order to create a competitive advantage for owners and to develop industry standards and owner expectations with respect to safety, training and worker qualifications. CURT has published an owner's safety blueprint [52] and a China specific supplement [53] for construction projects. The blueprint emphasizes the importance of setting expectations and committing to safety at the outset of a project, establishing a common safety culture, and closely monitoring safety performance [52]:

> "During construction, the owner must 'walk the talk' on safety. Pressure to complete the project can cause owner and contractor personnel alike to focus excessively on cost and schedule issues, potentially neglecting safety. It is up to the owner to ensure that safety remains the project's core value and is not subordinated to other demands. Contractors and subcontractors will respond to this leadership by delivering what the owner demonstrates to be most important."

CURT report that a comprehensive construction OSHMS should contain system elements and user practices for the following [52]:

— Policy and leadership;
— Risk management;
— Legal requirements and standards of operation;
— Strategic planning, goals and objectives;
— Structure and responsibility;
— Programmes and procedures;
— Asset and operations integrity;
— Emergency preparedness;
— Awareness, training and competency;
— Investigation and corrective action;
— Communications;
— Document control and records;
— Measuring and monitoring;

— Audits;
— Owner review and redirection;
— Innovative safety practices.

CURT [52] finds that “the user practices and learnings listed here were deemed statistically significant in lowering project injury and illness rates and severity, and proved even more effective when used in concert with one another.” CURT also reports that the general construction market in some emerging markets can be more challenging with respect to industrial safety, and that “good safety performance can be achieved, but the challenges are numerous and the burden on owners is much greater” [53]. Some of the specific challenges are that the construction environment is more labour intensive, requiring three to four times the labour hour component of an equivalent US project. This coupled with high turnover rates (with resultant high numbers of ‘new’ workers) presents additional challenges in sustaining a robust safety programme. Cultural and communication norms can be different. There can be a strong cultural inclination against saying ‘no’ or ‘I don’t understand’, or to avoid giving information the other party may perceive negatively, even when those responses might seem appropriate. Finally, planning and scheduling difficulties can lead to safety hazards as well as quality and productivity issues: for example, poor scheduling of procurement can mean the correct tools or materials are not available to do a task safely or completely.

3. OCCUPATIONAL SAFETY AND HEALTH POLICIES

3.1. OCCUPATIONAL SAFETY AND HEALTH POLICY AND CORPORATE STRATEGY

OSH policies are the written embodiment of corporate expectations with respect to safety. They set out the overall goals and objectives of a safety programme, indicate senior management’s commitment to safety and health, and help to align individuals around that programme. A key component of an organization with a good safety culture is its safety policy. To signal their importance, OSH policies typically are signed by the highest authority of the organization (such as the board chair, president or chief executive officer), are reviewed and updated periodically to ensure that they remain relevant and appropriate, are regularly communicated within the organization to persons working under the control of the organization (i.e. including staff and contractors) and are readily available to such persons (typically posted in prominent locations).

By writing the policy, the potential for legal battles, misunderstandings and loopholes is minimized. Safety understanding and expectations can evolve over time, and current expectations are easier to enforce when they are defined in writing. It is important to ensure that industrial safety and related policy are prominent in the organization relative to other initiatives. Figure 10 shows one example whereby an operating organization shows safety as a core value within their business model.

3.2. OCCUPATIONAL SAFETY AND HEALTH POLICY CONTENT

OSH policies are usually relatively brief (one page) and contain key principles that guide safety within an organization. They typically:

(a) Articulate a challenging vision of the organization’s pursuit of a standard of safety that exceeds just regulatory compliance;
(b) Define the organizational accountabilities in a meaningful way;
(c) Communicate the core values and behaviours that need to pervade the culture of the organization;
(d) Are appropriate to the purpose of the organization and to the nature of the organization’s safety risks and opportunities;
(e) Provide a framework for setting and achieving the organization’s safety objectives;
(f) Include a commitment to satisfy applicable legal and other requirements to which the organization subscribes;

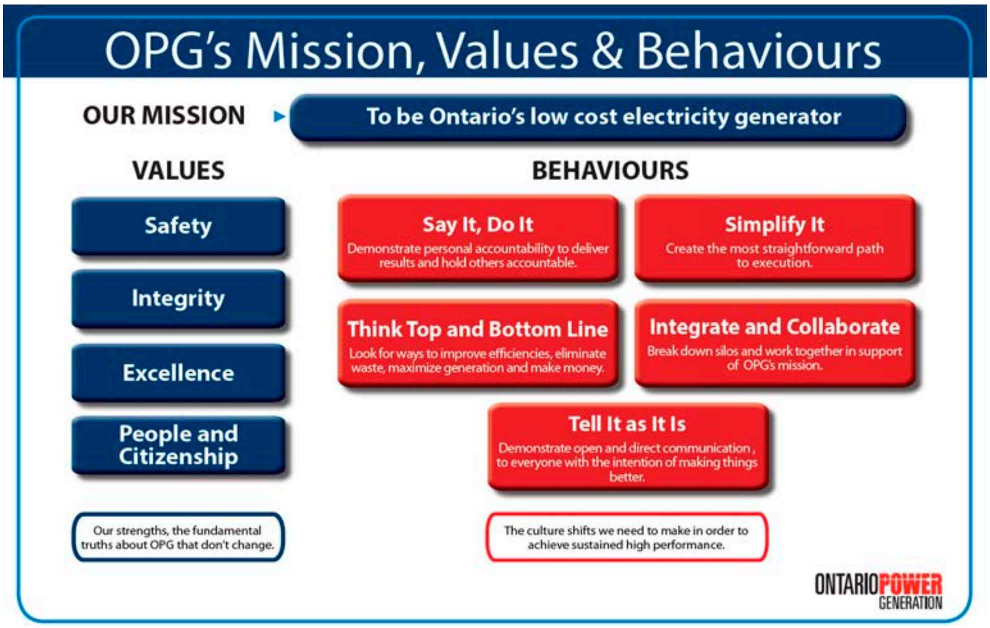


FIG. 10. Example of an operating organization business model showing safety as a core value (courtesy of Ontario Power Generation).

(g) Include a commitment to protect workers and their co-workers from injury and ill health through the control of safety risks via a hierarchy of controls;
(h) Include a commitment to continual improvement of the OSHMS to enhance the organization's safety performance;
(i) Include a commitment to worker participation, hazard awareness and consultation.

Policies should be readily available to, and be known by, all staff and should be regularly reviewed and updated as necessary. Senior executives should regularly communicate the importance of the policy. Reviewing the safety policy with potential job applicants will set expectations and help the applicants to determine whether they are suitable for the organization. A sample policy is provided in Box 1 (see also Appendix II).

3.3. WORKER PARTICIPATION

Worker participation is a process that allows employees to exert some influence over their work and the conditions under which they work, and is a key part of any OSHMS. OSH practices most directly impact on the health and safety of workers, and workers are most familiar with on-site conditions and what barriers they might face in working safely. Involvement of workers in the process of developing and improving the OSHMS can improve efficiency in an organization by improving cooperation and communication, and contribute to efficiency improvements by raising employee morale and commitment. The concept has various titles, including employee involvement, consultation, industrial democracy and employee voice.

Workers can become involved in OSH directly and indirectly. Direct participation includes teamwork, self-managing teams, quality circles, workers' assemblies consisting of all employees, and individual and collective exercises of job or task discretion or autonomy. Indirect methods include representative participation, such as trade unions, works councils, joint consultative committees, OSH committees and employee representation on company boards.

The CII has performed research on the impact of safety perception surveys within a company as a way of tapping into worker information and gauging their involvement [44]. Such surveys can pose questions on how safe workers feel on-site, how the company and top management's commitment to safety is perceived, and whether they feel they will never be asked to perform dangerous work. Companies which performed such surveys were more likely to have better safety records.

BOX 1. SAMPLE OCCUPATIONAL SAFETY AND HEALTH POLICY STATEMENT

At [Name of organization], we care about the safety, health and well being of our employees. We value the contributions our employees make towards our success. We support local community interests and value honesty, integrity and teamwork.

We Value Our Employees

Our business operates with a goal of zero damage to people, property, product and the environment. It is our policy to provide safe working conditions. At [Name of organization], everyone shares equally in the responsibility of identifying hazards, following safety rules and operating practices. All jobs and tasks must be performed in a safe manner, as safety is crucial to the quality of our products/service.

We shall ensure that employees are involved in decisions that have an impact on their health and safety, either individually, as a group or through their employee representative groups.

We shall ensure that work is planned and performed to protect workers. We shall provide employees with the information, training, tools, procedures and support required to do their jobs safely.

Safety Policy

At [Name of organization], no phase of the operation is considered more important than accident prevention. It is our policy to provide and maintain safe working conditions and to follow operating practices that will safeguard all employees. No job will be considered properly completed unless it is performed in a safe manner.

We shall meet or exceed all applicable health and safety legislative requirements as well as other associated health and safety standards to which we subscribe. We shall require that our contractors maintain a level of safety equivalent to that of our employees while at our workplaces.

We are committed to the prevention of workplace injuries and ill health, and to continual improvement of our employee health and safety performance. We shall set health and safety targets as part of our annual business planning process. Health and safety performance against these targets shall be regularly measured and evaluated to ensure the effectiveness of our health and safety systems.

[Name of organization] is concerned about the health and good work habits of our employees. All workers are accountable to execute their personal and work activities in such a manner as to prevent circumstances that can lead to incidents that could endanger their own health and safety and the health and safety of their co-workers. In the event a worker is injured or unable to perform your job, we want to help them to obtain the best treatment, so they can return to their regular job as soon as possible.

4. ORGANIZING THE OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM

4.1. INTERNAL RESPONSIBILITY SYSTEM

Every individual within an organization has personal duties and rights with respect to OSH. The arrangement of responsibilities, duties and rights is often referred to as the IRS (see Fig. 11). The IRS is a system within an organization where everyone has personal and shared responsibility for working together cooperatively to prevent occupational injuries and illnesses. It is based on the principle that workplace parties themselves are in the best position to identify health and safety problems and identify solutions.

The duties to create a healthy and safe workplace fall on every individual, to the degree they have authority to do so (based upon their position) and the ability to do so (based upon their expertise and qualifications). Each person is expected to take the initiative on health and safety issues and work to solve problems and make improvements on an ongoing basis. These duties are in addition to typical worker rights to participate in the OSH process, to know about workplace hazards and protection methods, to refuse unsafe work and to have certified individuals stop potentially unsafe work. Figure 12 represents this arrangement of authority, accountability and responsibility in a hierarchical structure, similar to the structures of the organization.

A well functioning IRS allows the established hierarchy to resolve OSH issues internally. When OSH issues arise beyond the authority or responsibility of the parties involved, the OSH issue should be escalated within the

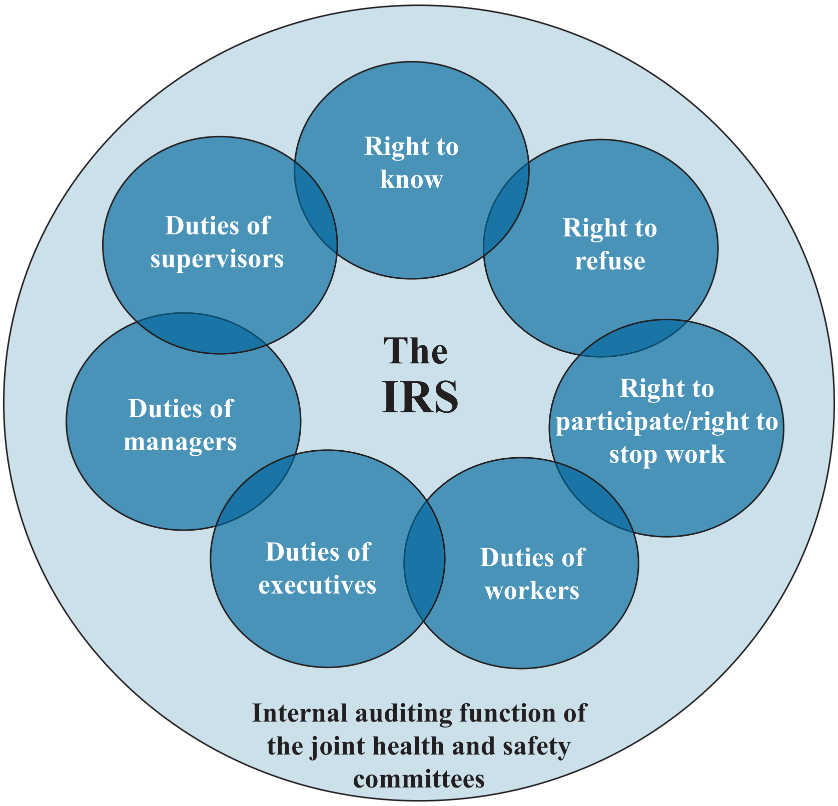


FIG. 11. Duties and rights within the internal responsibility system.

Note: H&S — health and safety; V-P — vice-president.

FIG. 12. Structure of authority, responsibility and accountability in the internal responsibility system.

organization to a position which does have the requisite authorities to resolve it. It is for this reason it is called the 'internal responsibility' system. Specific responsibilities within the IRS are typically described in legislation, regulations and company policies and procedures. Typical duties of executives and senior managers, managers, supervisors and workers are described in Sections 4.2–4.5.

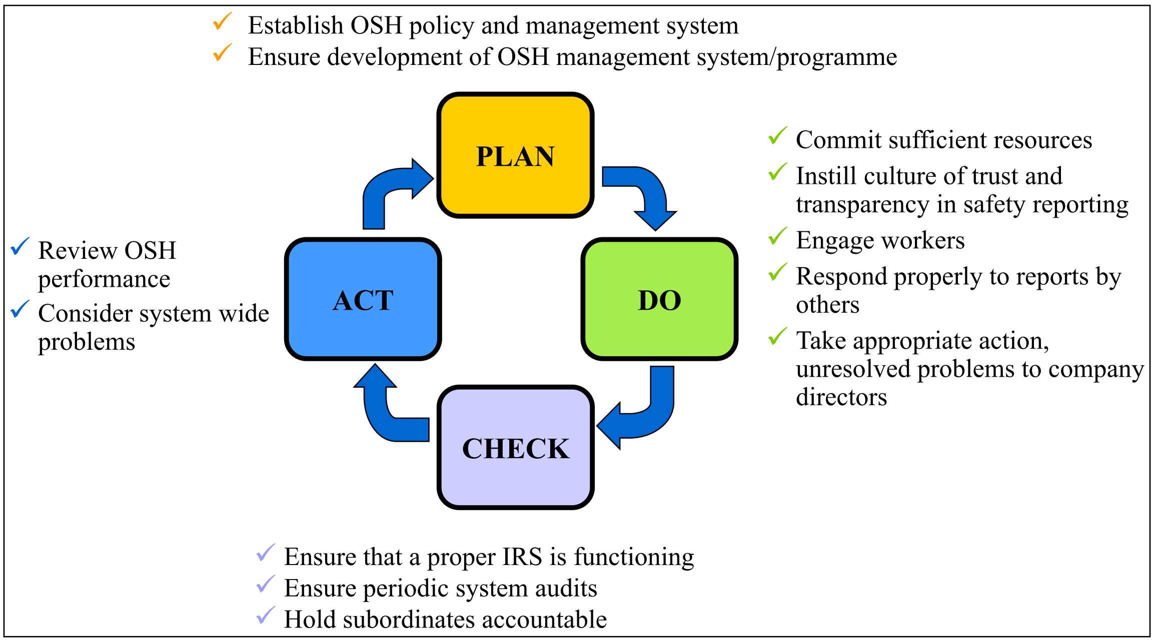


FIG. 13. Senior manager expectations under the internal responsibility system.

4.2. DUTIES OF EXECUTIVES AND SENIOR MANAGERS

Executives and senior managers have a duty to provide leadership for the OSH programme, take the initiative and inspire others (see Fig. 13). They are responsible for the following:

(a) Creating and developing comprehensive OSH policy and an OSHMS commensurate with the size, scale, complexity and risk of the organization's operations;
(b) Committing the necessary resources (financial, human and organizational) to ensure the effective operation of the OSHMS (i.e. employee time, engineering and process improvements, personal protective clothing and training, recognition events and awards);
(c) Instilling a culture of trust and transparency in the reporting of safety conditions, hazards, risks and incidents;
(d) Engaging workers in the operation of the OSHMS with the purpose that worker participation will contribute to the accuracy of the system, improve the effectiveness and practicality of solutions and ensure labour–management balance and transparency;
(e) Responding properly to concerns and reports;
(f) Taking unresolved problems to company directors;
(g) Holding subordinates accountable;
(h) Ensuring through methods such as audits that a proper IRS and OSHMS are functioning, that they are focused, robust, and continually learning and contributing to the organization's objectives;
(i) Ensuring periodic system audits are performed;
(j) Reviewing OSH performance;
(k) Considering and addressing system wide problems.

The UK Health and Safety Executive has produced a guide [54] for leading health and safety at work for use by all directors, governors, trustees, officers and their equivalents in the private, public and third sectors.

4.3. DUTIES OF MANAGERS

Managers have the responsibility to improve continually OSH for all employees. This helps to create a culture in which everyone shares responsibility for the well being of his or her fellow workers. They are expected (see Fig. 14):

(a) To develop, implement and improve OSH programmes, ensuring that knowledge of the organization's context as well as potential safety risks are considered.
(b) To use initiative to reduce risk through changes in managerial processes, ensuring the integration of OSHMS requirements into the organization's business processes.
(c) To solve OSH problems according to their level and authority.
(d) To respond properly to concerns and reports, ensuring, for example, that:
— Workplace hazards are systematically identified, risks evaluated and prioritized, and action is taken to improve safety performance where deemed necessary;
— The organization establishes processes for consultation and active participation of workers;
— Workers are protected from reprisals.
(e) To encourage reporting by supervisors.
(f) To engage in OSH leadership activities, for example:
— Promoting continual improvement and supporting those contributing to OSH effectiveness;
— Promoting and leading organizational culture with regard to the OSHMS;
— Communicating the importance of effective safety management of, and conforming to, OSHMS requirements;
— Ensuring that persons working under the control of the organization are aware of their responsibilities within the OSHMS and the potential consequences of their actions or inactions on others in the workplace;
— Taking safety performance into account in strategic planning, including ensuring that the safety policy and related safety objectives are established and are compatible with the strategic direction of the organization.
(g) To allocate resources (financial, human and organizational) properly to maintain and improve the OSHMS.
(h) To ensure supervisors are competent.
(i) To work cooperatively with workers, supervisors and other managers and personnel.
(j) To seek advice from OSH professionals when needed.
(k) To take unresolved problems to senior management.
(l) To hold supervisors and workers accountable.
(m) To consider problems with the OSHMS.
(n) To evaluate OSH performance and to assess programmes to ensure the OSHMS achieves the intended outcomes.

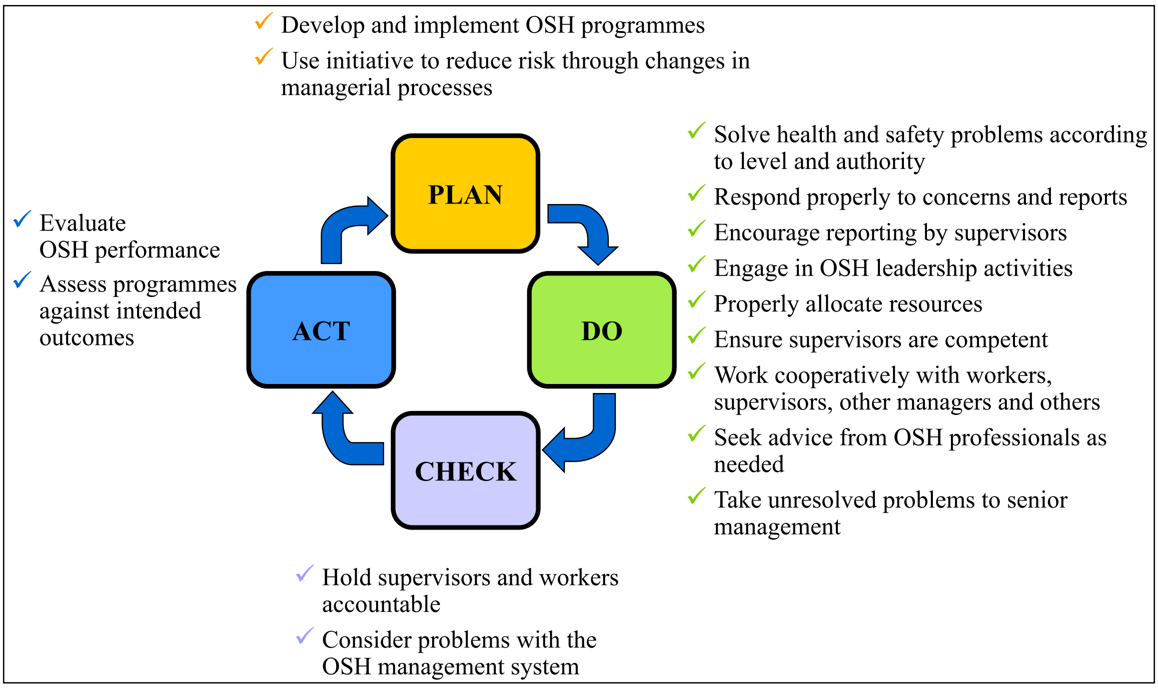


FIG. 14. Manager expectations under the internal responsibility system.

4.4. DUTIES OF SUPERVISORS

Direct or first line supervisors in a work environment have the responsible (see Fig. 15):

(a) To meet all legislative and company requirements;
(b) To ensure workers are qualified for the assigned work;
(c) To ensure job safety planning is conducted;
(d) To ensure workers are provided with a safe place to work and instructions;
(e) To ensure workers have and use proper PPE, tools and equipment;
(f) To observe and coach employees to correct unsafe behaviours;
(g) To conduct tailboards/pre-job briefings and post-job briefings;
(h) To enforce rules and requirements, applying discipline when needed;
(i) To take the initiative to reduce risk;
(j) To respond properly to concerns and reports;
(k) To solve OSH problems according to their level and authority;
(l) To encourage the reporting of hazards;
(m) To work cooperatively with workers, other supervisors, and managers and other personnel;
(n) To seek advice from OSH professionals as needed;
(o) To take unresolved problems to senior management;
(p) To monitor compliance to the job plan and to coach staff.

4.5. DUTIES OF WORKERS

Typical duties of all employees include meeting legislative requirements, conducting personal and work activities in a manner to prevent injury to themselves or others, reporting issues, and cooperating to resolve them,

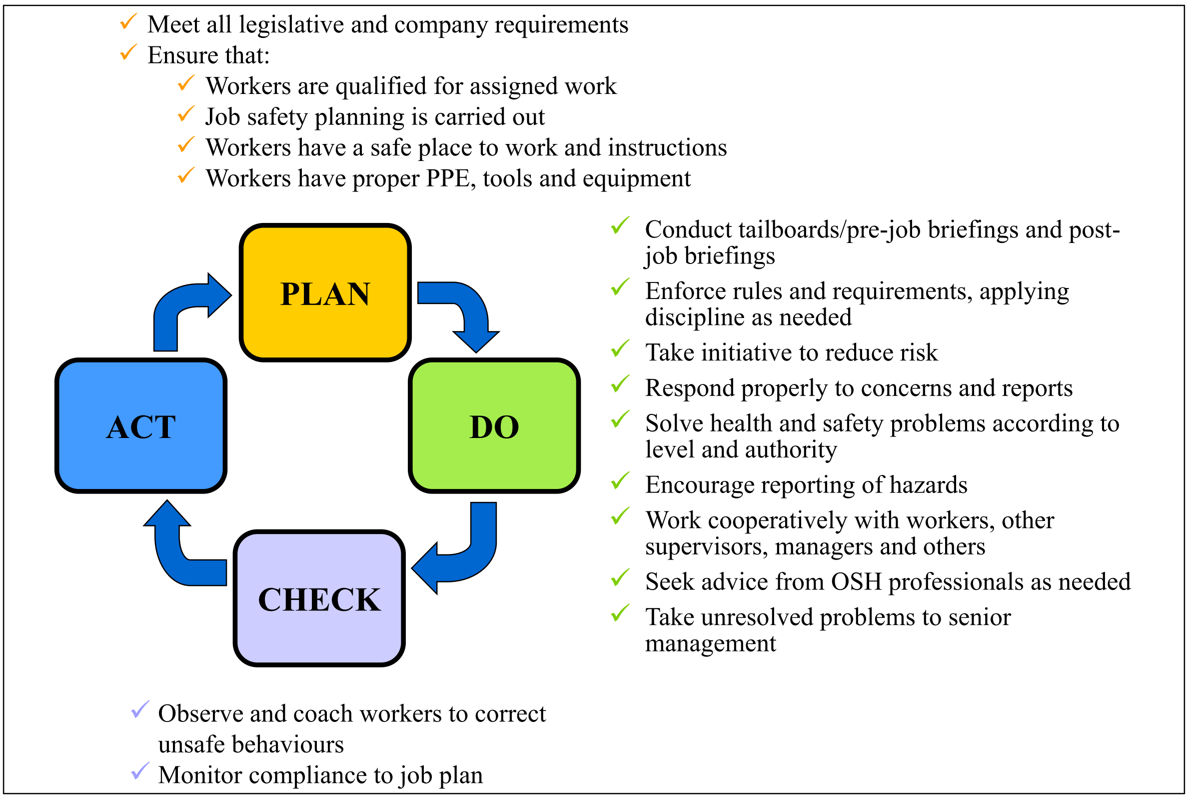


FIG. 15. Supervisor expectations under the internal responsibility system.

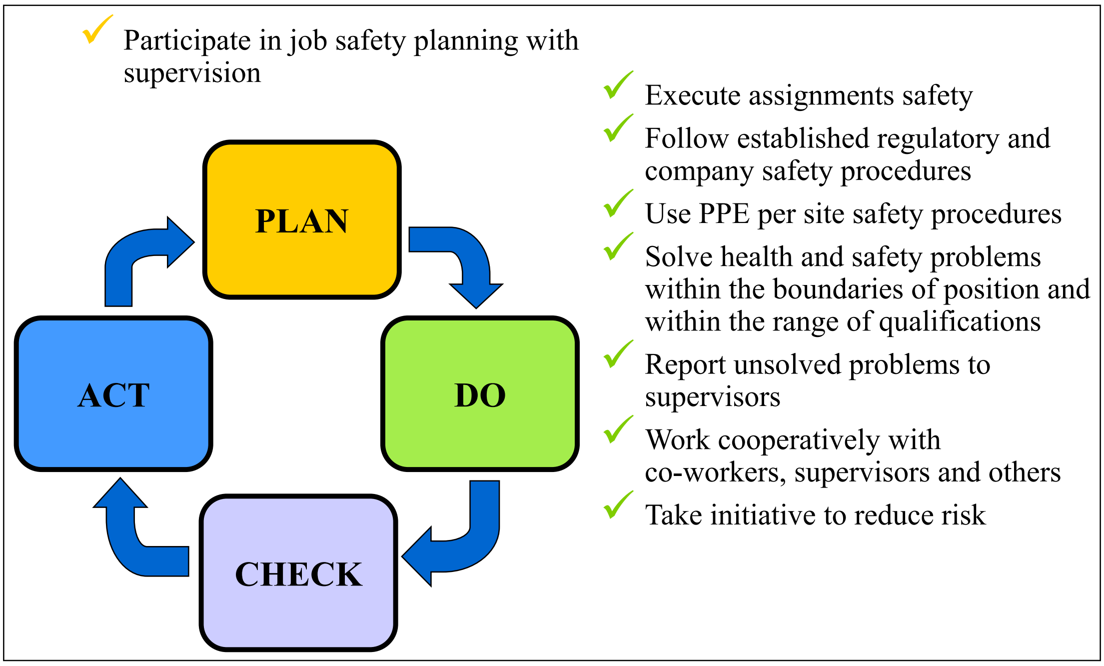


FIG. 16. Worker expectations under the internal responsibility system.

and taking the initiative to reduce risks. Typical rights include the right to participate in OSH improvements, the right to know about workplace hazards and ways to protect against them, and the right to refuse or stop work that could lead to accidents. In performing work activities employees have thus the responsible (see Fig. 16):

(a) To participate in job safety planning with supervision;
(b) To execute assignments safely (e.g. following established procedures, not removing or making ineffective a required protective device, not using equipment in a way that endangers any worker and not engaging in pranks or contests);
(c) To follow established safety procedures;
(d) To use PPE as defined in site safety procedures;
(e) To solve OSH problems within the boundaries of their position and within their range of qualifications;
(f) To report unsolved problems to supervisors;
(g) To work cooperatively with co-workers, supervisors and other personnel;
(h) To take the initiative to reduce risk.

4.6. CONTRIBUTORY ORGANIZATIONS

Many other organizations contribute to OSH (see Fig. 17). Provide advice, training and valuable insights into improving OSH performance, they include the following:

— OSH committees (OSHCs) — also called joint health and safety committees;
— Safety, engineering and purchasing departments;
— Worker representatives and trade unions;
— Safety associations;
— Suppliers;
— Government departments and ministries;
— Agencies such as workplace compensation boards.

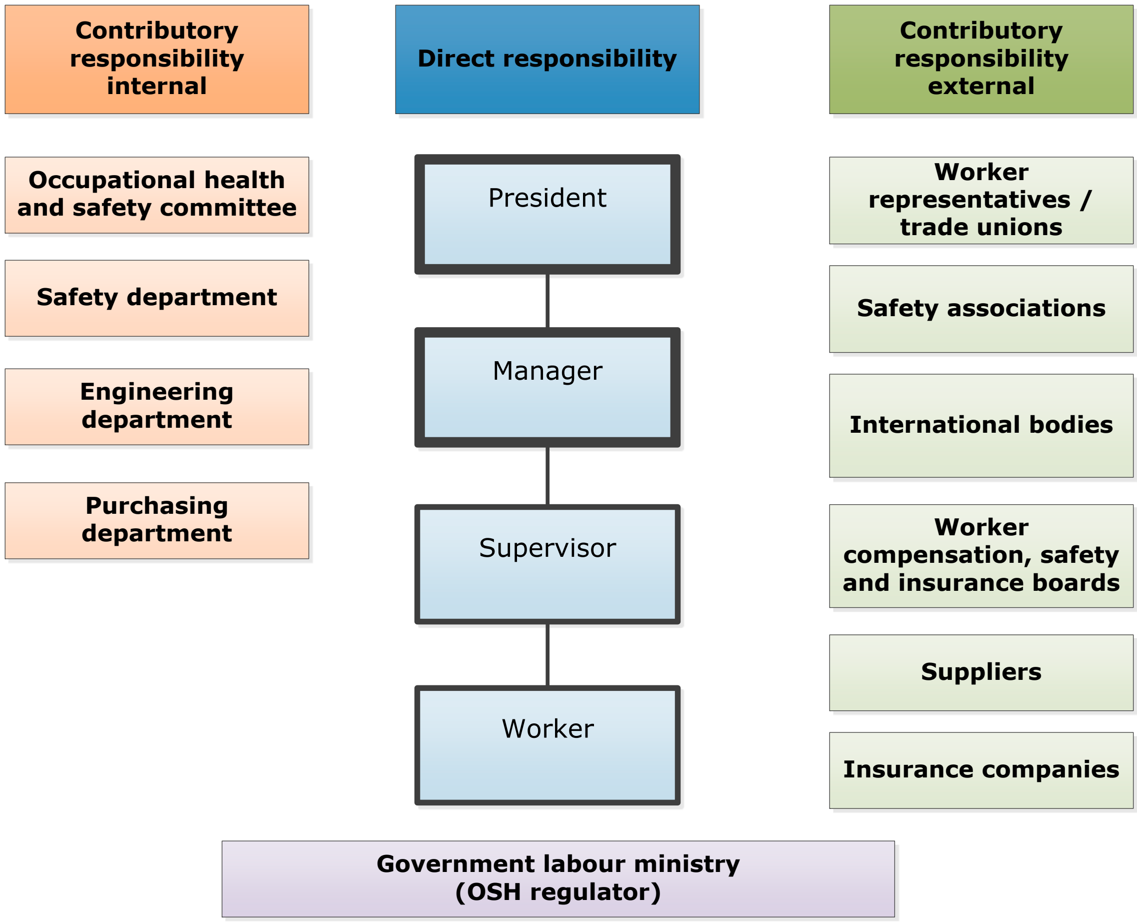


FIG. 17. Contributory bodies to the internal responsibility system.

4.6.1. Occupational safety and health committees and worker involvement

Workers should have input and opportunity to make recommendations on the safety programmes and practices within their organization. This ensures a balanced and transparent environment for the safety programme and for its continual improvement. Workers can be involved in OSH programmes by participating in setting OSH policy, planning, implementation oversight, performance evaluation and improvement objectives. Managers and supervisors need to provide workers (and their representatives, as appropriate) with timely access to information relevant to the OSH programme, identify and remove obstacles and barriers to participation wherever possible, and encourage the timely reporting of work related hazards, risks and incidents. Barriers can include the lack of response to employee input or suggestions, reprisals (supervisory and peer) for reporting, or any policy practice or programme that penalizes or discourages participation.

Although not directly part of the hierarchical structure of the IRS, the OSHC is a critical element in ensuring the overall functioning of the IRS. Comprising representatives of management and workers and serving as a joint advisory body, the OSHC has a contributive responsibility for OSH. They can also provide a secondary pathway for the resolution of OSH issues or problems by providing counselling and facilitation when the normal hierarchical chain of the IRS is unable to find a resolution. They can make recommendations to management and provide feedback to workers. They can provide insight into the functioning of the IRS (e.g. in understanding why the IRS was not able to deal with an issue) and should promote and monitor this as a key part of their mandate.

In some jurisdictions, OSHC members are required to receive certification training to perform their duties effectively. Such training typically includes basic certification in health and safety law, hazard identification and control, investigation techniques and prevention resources, as well as workplace specific training on the specific hazards at the workplace covered by the OSHC.

4.6.2. Industrial safety department

An organization's safety staff broadly coordinate OSH programme direction, and consult with, and support, line management with regard to compliance, workplace compensation, regulatory training, industrial hygiene and regulatory auditing. They can be occupational safety experts, industrial hygienists, ergonomists, work protection experts, occupational medicine and nursing professionals, or similar staff. Most safety staff do not perform actual line safety functions but are primarily advisors to workers and first line supervision on control and protection measures.

According to a 1997 survey by the American Society of Safety Engineers [55], a safety professional typically spends 56% of the time on safety management, which includes establishing the safety policy. Approximately 12% is spent ensuring that the work area complies with regulations, and 8% is spent on site specific technical issues. Since OSH professionals are equipped to dealing with safety issues and physical, chemical and biological hazards wherever they occur, they increasingly address environmental health and safety issues, such as levels of emissions released into the air and water of neighbouring communities.

4.6.3. Radiation protection group

Most nuclear facilities have separate staff to manage aspects of industrial health and safety and radiation protection. Effective cooperation between these two groups is essential to ensure that items such as PPE and the related procedures are consistent and appropriate for both purposes.

4.6.4. Engineering department

Engineering typically evaluates the safety of nuclear power plant operations and maintenance activities, such as certifying the design and proper installation of scaffolding and temporary work platforms. Other engineering organizations can be involved in activities such as procurement related equipment specifications and inspections (see Section 6.6.9), the design of engineering controls (see Section 6.5), pre-start health and safety reviews (see Section 6.6.4), constructability reviews (see Section 6.3.3.2), project management and contractor oversight (see Section 6.6.10).

The choices designers make during the design process can play a key role in facilitating safer methods of construction and operation. Prefabrication and modularization, for example, which most large construction firms indicate have a positive impact on safety [5], can only be initiated through design. Similarly, implementing modern building information management systems, which can provide 4-D visualizations of construction activities and assist in improving construction safety, can only be implemented early in the design. Other productivity related technology (e.g. mobile technology, virtual environments used for training and cloud based document management systems) which requires engineering or other technical support can have a positive impact on safety.

4.6.5. Purchasing

The procurement organization is the interface between a company and its outside suppliers of material and services. Such an organization, in conjunction with engineering, needs to ensure that procurement processes and specifications incorporate necessary OSH requirements. OSH procurement controls are discussed in more detail in Section 6.6.9.

4.6.6. Worker representatives

Since the 19th century, workers have organized in trade unions and other worker representative organizations to strengthen their efforts at improving workplace health and safety, job conditions, working hours, wages, contracts and social security. Cooperation between workers and their organizations and professionals has been instrumental in improving regulation and legislation affecting worker health. Such representative bodies can play a role in promoting worker involvement and in improving OSH practices and policies. They often have OSH expertise and experience that can be useful for both workers and employers. In some jurisdictions, worker representative bodies appoint worker safety representatives and participate in accident investigations.

4.6.7. Safety associations

Organizations and associations dedicated to improving workplace or construction health and safety can be governmental or non-governmental bodies, and cooperation can be beneficial to companies wishing to improve OSH practices (see Table 4).[3]

4.6.8. International bodies

International bodies such as the ILO provide support to OSH regulators by using input from workers, employers and governments to ensure that their views can be reflected in international labour standards and in shaping policies and programmes. Such standards are regularly incorporated into national labour laws and regulations on OSH.

4.6.9. Workplace compensation, safety and insurance boards

Many jurisdictions establish workplace compensation and insurance programmes to protect employees and employers from the financial hardships associated with work related injuries and occupational diseases. They are often separate organizations from the safety regulators described in the previous section. Such boards typically have a claims process and provide compensation to workers for expenses such as medical and rehabilitation costs and loss of earnings. For employers, coverage generally means that if a work related injury occurs, employers do not need to worry about being sued by their covered workers. The board can provide confirmation to third parties (e.g. potential customers) that a contractor/subcontractor is registered with the insurance scheme and that their account is in good standing.

Funding for such programmes is typically through insurance premiums paid by enrolled companies, with the premium amounts determined by a company's business activity, payroll and safety record. Safety records for employers are based on their accident and claim cost experience in comparison to the industry rate group average. Thus, the organizations that administer such programmes have detailed knowledge of the safety performance of individual companies in a particular area (via a mandatory reporting process), and employers via their premiums are incentivized to reduce the frequency of accidents and occupational diseases.

4.6.10. Suppliers

Suppliers can bring specialized safety knowledge to an organization, including the latest trends in PPE, methods to eliminate or control hazards (e.g. new and safer scaffolding, better lifting equipment, safer chemicals, safer construction methods, and OSH software), up to date regulatory advice, and assistance in qualitative and quantitative safety studies and hazard analyses. Some suppliers even provide comprehensive systems that can help to demonstrate the safety and sustainability of their customer's organizations.

When acting as a provider of engineering or construction services, suppliers can have a direct impact on the safety practices on a particular job site through their leadership, internal management system and practices.

4.6.11. Insurance companies

Insurance companies that provide construction or operational coverage to organizations regularly visit and audit work sites as part of their due diligence processes that ensure that the insured party is taking reasonable actions to protect the assets that are insured. They often can provide support to OSH by providing information on the adequacy of practices and systems at the insured facility that can impact on OSH. If the auditors observe, for example, poor housekeeping or poor material condition of critical fire suppression systems, they will report it to the owner and require the situation to be remedied, or else insurance premiums will rise.

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[3] See www.ilo.org/legacy/english/osh/en/story_content/external_files/List%20of%20OSH%20Periodicals.pdf for a list of OSH periodicals compiled by the ILO.

TABLE 4. SELECTED SAFETY ASSOCIATIONS

Organization	Web site
American Industrial Hygiene Association (AIHA)	www.aiha.org
American Society of Safety Engineers (ASSE)	www.asse.org
Arab Institute for Occupational Safety and Health (AIOSH)	www.aiosh.org
ASEAN Occupational Safety and Health Network (ASEAN–OSHNET)	www.aseanoshnet.org
Asia Pacific Occupational Safety and Health Organization (APOSHO)	www.aposho.org
Asociación Latinoamericana de Seguridad e Higiene en el Trabajo (ALASEHT)	www.alaseht.com
Baltic Sea Network on Occupational Health and Safety (BSN)	www.balticseaosh.net
Center for Chemical Process Safety (CCPS)	www.aiche.org/ccps
CPWR – Center for Construction Research and Training (CPWR)	www.cpwr.com
Construction Safety Council (CSC)	https://buildsafe.org
Construction Users Roundtable (CURT)	www.curt.org
Canadian Centre for Occupational Health and Safety (CCOHS)	www.ccohs.ca
European network for occupational health and safety experts (EUROSHNET)	www.kan.de/en/networks/euroshnet
European Network of Safety and Health Professionals Organisations (ENSHPO)	www.enshpo.eu
Federal Institute for Occupational Safety and Health (BAuA)	www.baua.de
French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS)	www.inrs.fr
International Association of Labour Inspection (IALI)	www.iali-aiit.org
International Commission on Occupational Health (ICOH)	www.icohweb.org
International Ergonomics Association (IEA)	www.iea.cc
National Institute for Occupational Health (NIOH) (South Africa)	www.nioh.ac.za
National Institute of Occupational Health and Poison Control	www.niohp.net.cn
International Network of Safety and Health Practitioner Organisations (INSHPO)	www.inshpo.org
International Occupational Hygiene Association (IOHA)	http://ioha.net
International Safety Equipment Association (ISEA)	https://safetyequipment.org
Korea Industrial Safety Association	www.safety.or.kr
Korea Occupational Safety and Health Agency (KOSHA)	http://kosha.or.kr
National Institute for Occupational Safety and Health (NIOSH)	www.cdc.gov/niosh

TABLE 4. SELECTED SAFETY ASSOCIATIONS (cont.)

Organization	Web site
Nuclear Industrial Safety and Health Association (NISHA)	http://mynisha.org
Partnership for European Research in Occupational Safety and Health (PEROSH)	www.perosh.eu
Safety Institute of Australia (SIA)	https://sia.org.au
Workplace Safety and Prevention Services (WSPS)	http://wsps.ca
World Safety Organization (WSO)	http://worldsafety.org

4.6.12. Occupational safety and health regulators

OSH regulators typically regulate the non-radiation safety aspects of health and safety at nuclear facilities. In some cases, these are in a support or subordinate role to the main nuclear power plant regulatory body, while in other cases they regulate independently. In addition to regulatory activities, OSH regulators normally take an active role in promoting workplace health and safety by providing training, communications and awareness materials, organizing events such as national safety stand-downs, and collecting safety data and statistics. Table 5 lists some key regulators in countries with operating nuclear power plants.

4.7. TRAINING, QUALIFICATIONS AND COMPETENCIES

4.7.1. Need for training

Well trained, qualified and competent workers are critical to industrial safety programme performance. Training ensures that people have the basic knowledge to perform a certain task; qualification ensures that they are certified to perform the task, while competence means that they can actually perform the task safely and correctly to the required standard. Training can help to correct gaps in knowledge or substandard practices and can recalibrate worker understanding of expectations. Competence organizations need systematically:

(a) To determine the necessary criteria for competence to evaluate the worker;
(b) To ensure that the worker's competence is based on appropriate education, training, qualification and experience;
(c) To take actions, where applicable, to acquire the necessary competence and to evaluate the effectiveness of the actions taken;
(d) To retain appropriate documented information as evidence of competence.

Training consists of both generic and job specific training depending on the duties assigned and ongoing employee communication. Table 6 provides industrial safety training qualifications maintained by a nuclear operating organization. It contains a mix of hazard specific, equipment specific, site specific and process or procedure specific qualification training.

Generic initial and refresher safety training typically promote awareness of an organization's industrial safety policy, workplace hazards and control measures employed at the facility. Topics can include the general aspects of fall protection, access to scaffolds and ladders, lockout/tagout and work protection, hazard recognition, confined space entry, job safety analysis (JSA), security, safety data sheets and hazard information, and emergency procedures.

Recommendations for developing job specific training are provided in Ref. [56] and paras 4.13 and 4.14 of NS-G-2.8 [23]. Training content needs to be regularly reviewed and updated to incorporate the latest knowledge, procedures, applicable standards, worker input and field experience. The number of individuals with key qualifications should be tracked, and succession plans developed to ensure sufficient qualified staff remain available.

TABLE 5. SELECTED OCCUPATIONAL SAFETY AND HEALTH REGULATORS

	Regulator	Web site
Brazil	Ministries of Labour, Health and Social Security	https://empregabrasil.mte.gov.br
Canada	Ontario Ministry of Labour (for plants in Ontario)	www.labour.gov.on.ca
	New Brunswick Department of Post-Secondary Education, Training and Labour (for Port Lepreau Nuclear Generating Station)	www2.gnb.ca/content/gnb/en/departments/ post-secondary_education_training_and_labour.html
	WorksafeNB	www.worksafenb.ca
China	State Administration of Work Safety (SAWS)	www.chinasafety.gov.cn
Europe	European Agency for Safety and Health at Work (EU–OSHA)	https://osha.europa.eu
Finland	Ministry of Social Affairs and Health, Department of Occupational Safety and Health	https://stm.fi/en/occupational-safety-and-health
	Finnish Safety and Chemicals Agency (Tukes)	www.tukes.fi
France	Nuclear Safety Authority (ASN, regulates occupational safety and health at nuclear facilities)	www.french-nuclear-safety.fr
	Selected non-nuclear regulatory bodies include	
	Ministry of Labour (responsible for OSH policy)	http://travail-emploi.gouv.fr
	Steering Committee on Working Conditions (COCT)	http://travail-emploi.gouv.fr/ministere/acteurs/ instances-rattachees/article/ coct-conseil-d-orientation-des-conditions-de-travail
	French Agency for Food, Environmental and Occupational Health and Safety (ANSES)	www.anses.fr
Germany	German Social Accident Insurance (DGUV)	www.dguv.de
International	International Labour Organization (ILO)	www.ilo.org
	World Health Organization (WHO)	www.who.int
Russian Fed.	Ministry of Labour and Social Protection	www.rosmintrud.ru
Slovakia	Ministry of Labour, Social Affairs, and Family of the Slovak Republic (and National Labour Inspectorate)	www.employment.gov.sk www.ip.gov.sk
South Africa	Department of Labour	www.labour.gov.za
Sweden	Swedish Work Environment Authority	www.av.se
UK	Health and Safety Executive (HSE)	www.hse.gov.uk
USA	Occupational Safety and Health Administration (OSHA)	www.osha.gov

TABLE 6. INDUSTRIAL SAFETY TRAINING QUALIFICATIONS FOR A NUCLEAR OPERATING ORGANIZATION

Qualification No.	Qualification name	Applicable locations
5412	Advanced defensive driving	OPGN
26863	Chemical protection CO_2 portable monitor — Drager X-AM 7000 multi-gas instrument	OPGN
120	Chemical protection carbon dioxide	PND
214	Class I & II industrial lift truck (electric rider)	OPGN
18673	Class I & II industrial lift truck (electric rider) — evaluator	OPGN
210	Class III industrial lift truck (electric hand truck)	OPGN
18674	Class III industrial lift truck (electric hand truck) — evaluator	OPGN
211	Class IV, V & VII industrial lift truck (internal combustion rider)	OPGN
18675	Class IV, V & VII industrial lift truck (internal combustion rider) — evaluator	OPGN
16393	Class VIII industrial lift truck — personnel burden carrier	OPGN
216	Defensive driving course — >10 000 km/year	OPGN
6109	Combination unit air brakes	OPGN
19293	Compressed air worker	OPGN
224	Confined space entry worker	OPGN
225	Confined space — attendant	OPGN
223	Confined space entry — coordinator	OPGN
31464	Confined space — issuing authority/controlling authority	OPGN
27003	Confined space gas tester — entry (Drager X-AM 7000)	OPGN
27004	Confined space gas tester — remote only (Drager X-AM 7000)	OPGN
1089	Confined space gas tester —remote only	DND
36245	Confined space gas tester remote only (Altair)	DND
36587	Drager X-AM 7000 (hydrogen only) surveyor	OPGN
4849	Bacharach surveyor	OPGN
4850	Drager surveyor	DND
4853	Gastec surveyor	OPGN
1326	Genesis Gastech surveyor	OPGN
32924	MSA: Altair 4X gas monitor AND MSA: Altair 5X gas monitor — tracking	OPGN

TABLE 6. INDUSTRIAL SAFETY TRAINING QUALIFICATIONS FOR A NUCLEAR OPERATING ORGANIZATION (cont.)

Qualification No.	Qualification name	Applicable locations
4650	Elevating work platform — self-propelled paved/slab	OPGN
4648	Elevating work platform boom-type	OPGN
4649	Elevating work platform self-propelled off/slab	OPGN
4651	Elevating work platform — rolling	OPGN
10372	Elevating work platform — spider	OPGN
1137	Fall protection	OPGN
10955	Reactor auxiliary bay fall arrest life line	DND
1059	Fall protection equipment inspector	OPGN
37655	Working at heights–construction projects	OPGN
388	First aid — emergency	OPGN
4851	Heat stress surveyor	OPGN
4852	Hydrazine/ammonia surveyor	OPGN
1141	Hydrogen hazard awareness	OPGN
14993	Human performance field simulator — non-supervisor	PND
14992	Human performance field simulator — supervisor	PND
5410	Industrial safety	OPGN
6108	Joint health and safety committee member	OPGN
419	Job safety analysis	OPGN
28284	Miller series 51 tripod training	PND
494	Noise exposed — health services	PND
707	Professional driver	OPGN
5128	Propane cylinder exchange process	OPGN
8732	Core training for conventional safety staff	OPGN
1051	Transportation of dangerous goods	OPGN
30524	Cart caddy shorty (laundry silo pusher)	PND
30645	E-Series hydro mobile equipment	DND
30664	Confined space retrieval system	OPGN

TABLE 6. INDUSTRIAL SAFETY TRAINING QUALIFICATIONS FOR A NUCLEAR OPERATING ORGANIZATION (cont.)

Qualification No.	Qualification name	Applicable locations
23323	Conventional respiratory protection — selector, supervisor, user	OPGN
19613	Fit tester	OPGN
5270	Full face air purifying respirator (MSA type)	OPGN
5275	Full face air supplied respirator (MSA type)	OPGN
5268	Half mask air purifying and air supplied respirator (MSA type)	OPGN
28624	Willson SAF-T-FIT N9520 — fit test	OPGN
28625	MSA FR 401 N95 mask — fit test	OPGN
28626	3M 8110S-N95 mask — fit test	OPGN
28627	AO-PLEATS PLUS — N95 mask — fit testing	OPGN
34604	Type 1 asbestos operation qualification	OPGN

Source: Ontario Power Generation.
Note: Fire and rescue crew training is not included in the table. DND — Darlington Nuclear Division (only); OPGN — Ontario Power Generation Nuclear (corporate wide); PND — Pickering Nuclear Division (only).

Studies in the construction industry have shown that the most effective means of communicating safety to employees is via face to face pre-job briefings held on-site at the beginning of the shift. In recent years, behavioural training has also emerged as a critical piece of training programmes [5]. First line supervisors and senior management should actively support training efforts, including auditing of training courses, to ensure that appropriate training is being delivered and to demonstrate the importance of such training. Training programmes need to be regularly reviewed and updated to incorporate recent changes in legislation, requirements, policies and recommended practices.

The ILO International Training Centre[4] offers classroom instruction and distance learning training in OSH topics, and the Europe based Napo Consortium has produced a number of general industrial safety related videos[5] available in many languages. The Canadian Standards Association has published a standard on OSH training programmes [57].

4.7.2. Safety professional certification

Having individuals in a safety department or in associated support roles certified by a qualification agency can assist in ensuring individuals have sufficient, up to date knowledge of OSH best practices. They can help with risk assessment and analysis, make hygiene measurements, recommend tools, develop training and education material, and develop systems and procedures. Table 7 lists some organizations involved in such certification and the location of the head office.

[4] See www.itcilo.org
[5] See www.napofilm.net

TABLE 7. INDUSTRIAL SAFETY AND HYGIENE CERTIFICATION ORGANIZATIONS

Country/Organization	Typical designations	Web site
Brazil		
Associação Brasileira de Higienista Ocupacionais (ABHO)	Occupational Hygienists Certificate (HOC) Occupational Hygienists Technical Certificate (THOC)	www.abho.org.br
Canada		
Board of Canadian Registered Safety Professionals (BCRSP)	Canadian Registered Safety Professional (CRSP) Professionnel en sécurité agréé du Canada (PSAC)	https://bcrsp.ca
Canadian Society of Safety Engineering (CSSE)	Certified Health and Safety Consultant (CHSC)	www.csse.org
Canadian Registration Board of Occupational Hygienists (CRBOH)	Registered Occupational Hygienist (ROH) Registered Occupational Hygiene Technologist (ROHT)	www.crboh.ca
China		
State Administration of Work Safety (SAWS)	Certified Safety Engineer	www.chinasafety.gov.cn
Sweden		
Swedish Association of Occupational and Environmental Hygiene (SYMF)	Swedish occupational and environmental hygienist (adapted IOHA programme)	www.symf.nu
Switzerland		
Swiss Society for Occupational Hygiene (SGAH/SSHT)	IOHA programme	www.sgah.ch
United Kingdom		
International Institute of Risk and Safety Management (IIRSM)	Occupational Safety and Health Consultant (OSHCR)	www.iirsm.org
Institution of Occupational Safety and Health (IOSH)	Associate/Technical membership (AIOSH/Tech IOSH) Graduate membership (Grad IOSH)	www.iosh.co.uk
International Occupational Hygiene Association (IOHA) and Occupational Hygiene Training Association (OHTA)	International Certificate in Occupational Hygiene (ICertOH)	http://ioha.net www.ohlearning.com
United States of America		
Board of Certified Safety Professionals (BCSP)	Certified Safety Professional (CSP) Associate Safety Professional (ASP) Graduate Safety Practitioner (GSP) Occupational Health and Safety Technologist (OHST) Construction Health and Safety Technician (CHST) Safety Trained Supervisor (STS) Safety Trained Supervisor Construction (STSC) Certified Environmental, Safety and Health Trainer (CET)	www.bcsp.org
Institute of Safety and Health Management	Certified Safety and Health Manager (CSHM) Associate Safety and Health Manager (ASHM) Certified Safety Management Practitioner (CSMP)	https://ishm.org
American Board of Industrial Hygiene (ABIH)	Certified Industrial Hygienist	http://abih.org

4.7.3. Orientation training

Individuals with access to a nuclear construction site or facility require some level of orientation training. Industrial safety expectations should be part of this training and be adapted as necessary according to worker individual capabilities, including language skills and literacy. Topics on industrial safety training can include the following:

(a) Organization's safety policy and concern for OSH;
(b) Worker rights and responsibilities under the IRS;
(c) Requirements for wearing PPE on the site;
(d) Major hazards present and methods to protect against them;
(e) Where to locate additional workplace hazard information (e.g. safety data sheets and safety department contacts);
(f) Expectations with regard to travelling around the site (e.g. warning signs, access to ladders, scaffolds and access to designated areas);
(g) Expectations with regard to workplace housekeeping and waste disposal (e.g. photos or physical mock ups of good practice);
(h) First aid, fire and emergency response procedures (e.g. how to summon help);
(i) Behaviour expectations with regard to encountering unexpected conditions or procedures that cannot be followed as prescribed;
(j) Expectations not to touch or operate field devices, especially those locked or tagged out for work protection.

CII research [44] on the correlation between injury rates and whether corporate field employees or subcontractors receive orientation training on construction sites finds an approximate 40% reduction in injury rates for companies that conduct orientation training.

4.7.4. Training facilities and skills demonstration exercises

Nuclear facility construction and operation requires suitable training facilities. Although traditional classrooms are acceptable for some subjects, industrial safety often requires practical demonstration of skills learned. This is particularly true for procedures which are difficult to describe fully in a classroom setting and the risk of incorrect application is high (see Fig. 18). Examples include:

— Using fall protection devices;
— Rescue techniques (i.e. confined space rescue and elevated/high angle rescues);
— Using scaffolding;
— Using aerial lift equipment;
— Using craning and rigging;
— Ladder access and egress;
— Donning and doffing PPE;
— Accessing confined spaces;
— Measuring and monitoring atmospheric gas;
— Traversing work surfaces;
— Use fire extinguishers.

4.7.5. Just-in-time training

Just-in-time training can be developed for hazardous or infrequently performed tasks. Such training ideally occurs at or near the site and just prior to the performance of the work. It consists of a review of key skills needed to perform the task safely and correctly. This coaching allows staff to become familiar with the use of actual tools and safety equipment, improves knowledge transfer and retention, and reinforces tactile skill knowledge.

Modern tools such as e-learning and building information systems can also be used to demonstrate both the right way to perform a particular task and the consequences of doing it the wrong way. Mobile devices

FIG. 18. Skills demonstration exercise (courtesy of Chicago Bridge and Iron Company).

such as smartphones and tablets facilitate the delivery of training videos, photographs and instructions to field staff. A recent survey of construction companies indicated generally positive benefits of using mobile devices (more than 75% of responses were positive) [5].

4.7.6. Young worker training

Younger workers often lack awareness and experience of the risks they may be exposed to, and OSH training is essential during early career steps and apprenticeship programmes to reduce accident rates. Some countries include basic OSH risk prevention training in primary, secondary and technical schools. The European Agency for Safety and Health at Work has produced guides integrating OSH into education programmes [58, 59]. Careful supervision by an experienced employee or mentor during early career stages is advised.

4.8. DOCUMENTATION

4.8.1. Documentation needs

OSHMSs and their related procedures need to be documented and integrated into the overall management system of the organization. A typical OSH programme can include 200 or more documents, including procedures, forms and work instructions. Typical examples include the following:

(a) The organization’s OSH policy.
(b) Organizational roles and responsibilities relating to OSH.
(c) A list of applicable laws, rules and regulations and how the organization complies.
(d) Implementing procedures and lists for:
  — Training and qualification requirements;
  — Safety meeting requirements;

— PPE requirements and usage;
— Job planning requirements;
— Constructability, operability, maintainability and safety (COMS) review processes;
— Hazard recognition processes;
— Worker involvement through processes such as OSHCs;
— Observation and coaching programmes;
— Housekeeping programme;
— Fitness for duty programme;
— First aid and emergency response procedures;
— Lessons learned programme.

(e) Key metrics and performance indicators.
(f) Improvement plans for work groups.
(g) Incident investigations and corrective actions.
(h) Audit and self-assessment findings.
(i) Lessons learned findings.

4.8.2. Occupational safety and health management software

Well implemented OHS software systems can help to influence an organization's culture at all levels by fostering awareness and shared accountability for workplace safety and health. Commercial suppliers of software dedicated to health and safety management include AssessNET, CMO COMPLIANCE, CRedit360, Det Norske Veritas (DNV GL), EcoIntense, EMEX, Enablon, Enviance, Gensuite, IHS, Intelex, Locus Technologies, MetricStream, ProcessMAP, Rivo, SAP, SCRIM Safety First and VelocityEHS (formerly KMI). Such software can assist organizations:

(a) To create and store OSH documentation;
(b) To record, track, monitor and report on continuing legislation compliance;
(c) To record, monitor, resolve and close incident investigations (including creating on-line forms);
(d) To execute safety audits and resolve non-conformances;
(e) To track training and qualification records;
(f) To record behaviour based observations;
(g) To plot performance metrics;
(h) To identify trends.

A sample system from one vendor is shown in Fig. 19. Increasingly software data entry and information retrieval are done using field tablet computers, which increases productivity and the availability of information on job sites. Other specialized dedicated software is available to manage work protection/lockout tagout activities, assist in risk management, manage safety data sheets, assist with incident investigations, manage employee wellness programmes, produce facility warning labels and signage, perform ergonomic assessments or to deliver OSH training.

At a nuclear facility, many OSH software functions are often integrated into enterprise wide management system software which performs various functions for the entire facility. For example, all audits (not just industrial safety) would be recorded in a common system. Where separate OSH software is used, OSH information should be to the extent possible integrated with any enterprise systems to minimize data duplication and errors.

Before selecting a software product, a team of OSH professionals and key stakeholders should be formed to define its requirements (functional, technical and reporting requirements). Once chosen and purchased, sufficient resources are required to migrate data, populate the system with information on jurisdiction and company specific codes, standards and procedures, and test and train on the system.

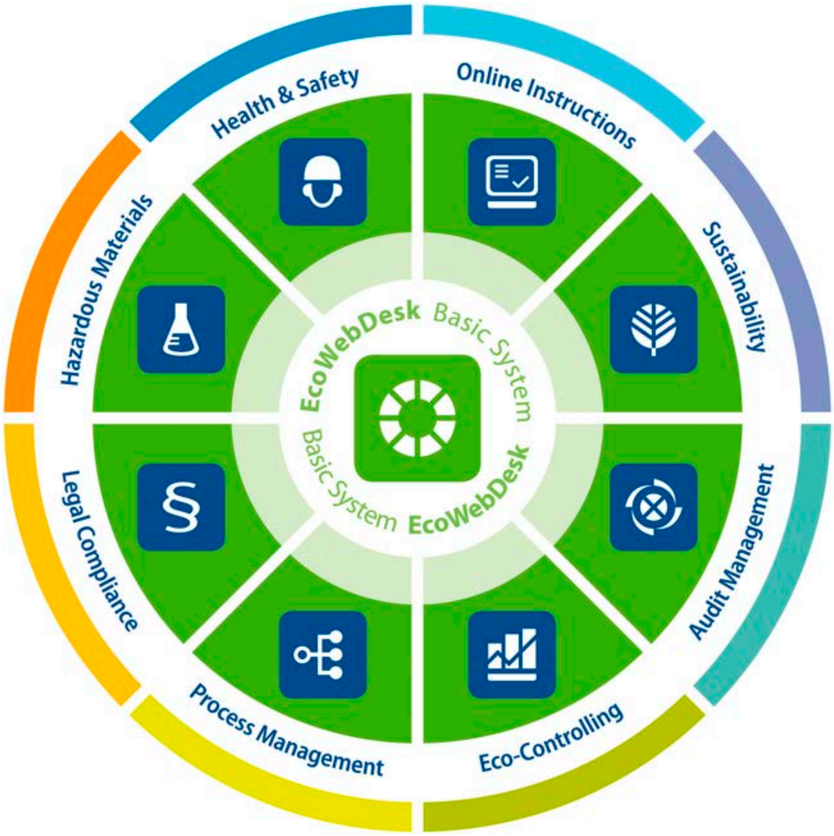


FIG. 19. Sample occupational safety and health management software modules (courtesy of EcoIntense GmbH).

4.9. COMMUNICATION

The organization's safety philosophy needs to be written, taught to employees, continually reinforced, practised daily and be an ingrained company value. Workers have to believe that safety is equal to other business objectives and they, as workers, are the most important resource. Workers should also be aware that management believes all injuries and illnesses are preventable, that line management is held responsible for safety, that all employees are accountable for safety and that working safely is a condition of employment.

The programme and its specific requirements needs to be well communicated to the workers. Organizations need to determine the required internal and external information and communications relevant to the OSH management programme, including:

(a) What information to disseminate.
(b) What it will communicate.
(c) When to communicate it.
(d) To whom to communicate it:
  — Internally among the various levels and functions in the workplace;
  — With contractors and other visitors to the workplace;
  — With external interested parties.
(e) How to communicate it (taking into account workforce diversity aspects such as language, culture, and literacy, the use of plain writing techniques for written communications can increase understanding and message retention [60]).
(f) How it will receive, maintain documented information and respond to relevant communications.
(g) Objectives to be reached by informing and communicating.
(h) What processes will be used to evaluate whether the communication has been successful.

Regular communications on OSH should generally be undertaken throughout the organization. Senior management needs regularly to communicate the vision, priorities and objectives, where the organization is currently performing against those priorities, and key focus areas, initiatives and observed good practices. Some typical communication methods and topics are discussed in the following subsections.

4.9.1. Policy and programme awareness

An organization's safety philosophy and its values need to be regularly communicated, and workers in the organization need to understand the safety philosophy and how it relates and affects the execution of their duties. Regular communication is thus recommended surrounding the OSH policy. This should include how the policy relates to other business drivers, and how individuals contribute to safety and benefit from it. Operating organizations typically have processes to do this whenever the policy is revised, or otherwise on a regular basis (often annually or biannually).

4.9.2. Event related employee communications

Events and near miss incidents should be communicated throughout organizations via a rapid communication process. This serves two purposes: to alert the organization of an event and what corrective measures are being undertaken at least in the short term for other parts of the organization to assess and consider; and to maintain a healthy sense of vulnerability and transparency across the organization that safety events are occurring and to encourage vigilance and questioning at all times. Figure 20 shows a sample incident advisory bulletin.

4.9.3. Hazard reminder programmes

Regular reminders to workers about hazards can help improve OSH performance. This can include the following:

— Facility signage (see Section 6.3.2.4);
— Event communication programmes (see Section 4.9.2);
— Home or holiday hazard reminder communications (see Section 6.6.16);
— Field job assists at locations where specific tasks are typically performed or where PPE requirements change;
— Emails from executives that reinforce safety messages;
— Participation in company, national or international safety awareness days such as the ILO World Day for Safety and Health at Work.[6]

4.9.4. Recognition and safety promotion programmes

Employee recognition programmes can be used to celebrate and encourage good practices with respect to safety or other business goals such as milestone or outage completions. They are a regular feature of many corporate safety programmes. Such programmes can include such activities as peer to peer recognition, whereby peers thank their co-workers for specific help or assistance or when good practices are observed, or management appreciation programmes, whereby managers and supervisors provide the recognition.

Safety can also be promoted through communications programmes, sometimes with the provision of safety related articles such as first aid kits, fire extinguishers or car safety equipment to personnel or to the general community. The Dampierre nuclear power plant in France was recognized with an OSART good practice in 2015 for its safety innovation incentive scheme, in which a trophy is awarded for the best safety improvement idea.[7]

[6] See www.ilo.org/safework/events/safeday
[7] See www-ns.iaea.org/downloads/ni/s-reviews/gp-2009/1.5.pdf

Melted electrical plug – High Potential Near Miss (HIPO)

This information is being forwarded to advise you of a potential hazard either in the workplace or at your homes. Any incident or near-miss has the potential to be a serious accident. Please review and ensure that the necessary steps are taken to avoid a similar type of accident at your location.

DATE: 31 Jan. 2014	VC Summer – 01-31 – INC-35476

Advisory Cause: 125V/30A plug attached to a 250V/30A receptacle was found with a melted spot, while attached to an electrical panel.

While conducting a per shift work area inspection, an industrial rodbuster foreman smelled a peculiar odor omitting form the portable electrical panel skid located on the West side of the Rebar Fabrication Shop. He called for an electrical foreman to come and check out the electrical panel. While investigating the smell the electrical foreman noticed a melted plug from the panel which in turn caused the breaker on the panel to trip. Upon investigation the power plug was a 125V/30A plug attached to a 250V/30A receptacle. The Electrical Superintendent performed the technical review of the plug and receptacle and concluded that the plug was a 125V/30A plug to service a 220V/30A dual heater/air-conditioner being used in an office conex next to the fabrication pad. The wrong plug (125V/30A) was used to create job made cord to fit the portable panel skid. The plug was in place for the last eight months and it is speculated that the plug was forced into the 250V/30A receptacle. Additionally, it is speculated by the Electrical Superintendent that the wiring within the plug may have been loose allowing arcing to occur inside of the plug causing it to heat and melt.

Figure 1

Figure 1 Damage to electrical power plug.

Figure 2

Figure 2 Damage to electrical receptacle.

CORRECTIVE ACTION(S) TAKEN:

1. Create a team to find all job made plugs to verify correct plug use and to identify the "gap" that was present that allowed; plug to be installed incorrectly, pass assured grounding monthly, and the Hu-P error identification that preceded the individual to forcibly install the plug into the incorrect receptacle.

DISTRIBUTION

Projects:	Offices:	Circulation:
All Projects Worldwide	All offices worldwide	Local Safety Meetings Project Meetings Individuals

FIG. 20. Sample incident advisory bulletin (courtesy of Chicago Bridge and Iron Company).

The CII reports a number of interesting findings on the effectiveness of incentive programmes in driving construction safety [44]:

(a) Programmes that reward safe behaviours as opposed to incidence of injuries tend to produce better safety benefits (fewer injuries).
(b) Programmes that include supervisors in the incentive programme had better safety results.
(c) Programmes that gave awards to groups of workers (e.g. a crew) had better safety results than those targeted at individuals.
(d) Programmes that are progressive in nature (e.g. value of award increases as time without injury increases) can be counterproductive (may discourage reporting of injuries).
(e) Safety incentive programmes are not essential to the success of a safety programme (the benefits for some incentive types might not be statistically significant, and some good safety programmes had no incentive schemes).

5. PLANNING AND IMPLEMENTING THE OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM

Good planning is needed to set up an industrial safety programme for a nuclear facility. A good understanding is needed of both the internal and external environments in which such a programme will exist and includes: the business objectives of the construction and operating organizations involved; the national social, political, regulatory and cultural context; and the legal framework for industrial safety in the applicable jurisdiction. A programme that meets industry standards in one jurisdiction or at one site can require significant adaptation if used at other locations with different personnel or in different environments. Programmes thus need to be adapted to the specific requirements for each nuclear facility.

5.1. INITIAL REVIEW

A review of existing OSH arrangements provides a basis for a new or improved management system. Such as review should cover existing laws, regulations, guidelines and voluntary programmes, assess hazards and safety risks, investigate whether existing controls are adequate, and review employee health surveillance data for trends.

5.1.1. Identify legal and other requirements

Regulatory and legal compliance is an absolute commitment and non-negotiable value of nuclear organizations. Organizations need to establish, implement and maintain processes to identify and assess current laws and requirements on its industrial safety risks and industrial safety management programme, and determine how to apply and meet these requirements. Requirements can include voluntary standards, corporate goals, codes of conduct and social or cultural norms to which the organization subscribes. Contact with key stakeholders such as regulatory bodies, standards making organizations, industry associations, and internal company personnel (e.g. worker representatives, management and OSH services personnel) is encouraged.

It should be noted that occupational safety law does not require companies establish a risk free environment. However, it typically requires companies to take every precaution reasonable under the circumstances to protect the worker. In order to comply with this high standard, companies attempt to create an environment where the risk is as low as reasonably achievable — the ALARA principle. In a nuclear environment, ALARA applies equally to radiological and industrial safety risks, and recognizes that rarely can all risk in a task be eliminated. Hence, the objective is to reduce the risk to an acceptable level — as low as reasonably achievable — where the chance of injury is very unlikely.

Table 8 describes some major industrial safety management codes and standards, and Table 9 contains a list of selected national, state or provincial regulations relating to industrial safety. The ILO also maintains a public database of national industrial safety legislation called LEGOSH (Legislation on Occupational Safety and Health).[8] Regional, state or provincial legislation is not included in the LEGOSH database, so it might not contain all applicable legislation for a given location.

Table 10 shows an example of a portion of a hazard registry adapted from one maintained by the Canadian operating organization Ontario Power Generation. It has columns for the applicable hazard, OSH legislation or regulations related to the hazard, and operational control or processes developed by the operating organization to meet the requirements of the legislation or regulation.

5.1.2. Identify external social and political influences and other requirements

Social, political, cultural, business objectives and other influences invariably have an impact on an organization's OSH programme. Industry is increasingly aware of the moral, legal and economic reasons for implementing good OSH practices. Governments and society in general are increasingly less tolerant of poor

[8] See www.ilo.org/dyn/legosh/en

TABLE 8. SELECTED INTERNATIONAL STANDARDS RELATING TO INDUSTRIAL SAFETY

Source and documents	Description
American Society of Safety Engineers (ASSE)	
ANSI/ASSE A10.1, Pre-project and Pre-task Safety and Health Planning [61]	Establishes the elements and activities for pre-project and pre-task safety and health planning in construction. This standard is to assist construction owners, project constructors and contractors in making pre-project and pre-task safety and health planning a standard part of their planning processes. This standard is also intended to assist owners in establishing a process for evaluating project constructor candidate safety and health performance and planning practices.
ANSI/ASSE A10.6, Safety and Health Program Requirements for Demolition Operations [62]	Applies to the demolition of buildings and other structures.
ANSI/ASSE A10.8-2011, Scaffolding Safety Requirements [63]	Establishes safety requirements for the construction, operation, maintenance and use of scaffolds used in the construction, alteration, demolition and maintenance of buildings and structures.
A10.26-2011, Emergency Procedures for Construction and Demolition Sites [64]	Applies to emergency procedures involving fires, collapses, hazardous spills and other emergencies; emergency rescue of injured or ill workers; on-site provision of first aid and medical care; evacuation of injured or ill workers; pre-planning; and training on emergency procedures.
ANSI/ASSE Z359, Fall Protection Code [65]	Includes all ANSI/ASSE fall protection/arrest codes.
British Standards Institute (BSI)	
OHSAS 18001:2007, Occupational Health and Safety Management Systems [66]	OSHMS specification compatible with ISO 9001 and ISO 14001. Covers issues such as planning for hazard identification, risk assessment/control, OSH management, awareness and competence, training, communication, emergency preparedness and response, performance measuring and improvement.
OHSAS 18002:2008, Occupational Health and Safety Management Systems: Guidelines for the Implementation of OHSAS 18001:2007 [67]	Provides guidelines for implementation of OHSAS 18001:2007 [66]. Describes intent, typical inputs, processes and typical outputs, against each requirement of OHSA 18001:2007 [66], and explains how to work towards implementation and registration against the standard.
BS 45002-0:2018, Occupational Health and Safety Management Systems: General Guidelines for the Application of ISO 450001 [68]	Provides guidance for OSHMSs.
Canadian Standards Association (CSA)	
CSA Z1000-14, Occupational Health and Safety Management [69]	Provides a model for establishing, implementing and maintaining an OSHMS. It includes guidance on (a) establishing, maintaining, and improving an OSHMS that will identify and eliminate OSH hazards, and assess and control risk; (b) ensuring conformity with its OSH policy; and (c) demonstrating conformity with the standard by (i) making a self-determination and self-declaration; (ii) receiving confirmation of its self-declaration by an outside party, independent of the organization; or (iii) gaining certification/registration of its OSHMS (to this standard) by an outside organization.

TABLE 8. SELECTED INTERNATIONAL STANDARDS RELATING TO INDUSTRIAL SAFETY (cont.)

Source and documents	Description
CAN/CSA-Z1001-13, Occupational Health and Safety Training [57]	Provides essentials of managing a health and safety training programme and a method to recognize OSH training practices.
CAN/CSA-Z1002-12, Occupational Health and Safety: Hazard Identification and Elimination and Risk Assessment and Control [70]	Focuses on protecting workers through hazard identification, control and elimination where possible. Puts forward a structure for improved worker safety and provides employers with a framework for successful implementation of risk assessment methodologies that can be incorporated into their existing OSHMS.
CAN/CSA-Z1003-13/BNQ 9700-803/2013, Psychological Health and Safety in the Workplace: Prevention, Promotion, and Guidance to Staged Implementation [71]	A voluntary standard intended to provide systematic guidelines for Canadian employers that will help enable them to develop and continually improve psychologically safe and healthy work environments for their employees.
SPE Z1003 IMPLEMENTATION HB. Assembling the Pieces: An Implementation Guide to the National Standard for Psychological Health and Safety in the Workplace [72]	Helps users to understand where to start and how to move their organization through the initial planning stages to full implementation of the Z1003 standard.
CSA Z1004-12, Workplace Ergonomics: A Management and Implementation Standard [73]	Sets out requirements and provides guidance for the systematic application of ergonomics to the development, design, use, management and improvement of work systems through the implementation of an ergonomics process.
CSA Z1006-10, Management of Work in Confined Spaces [74]	Covers worker participation, change management and identifying, eliminating and controlling hazards related to confined spaces. Also, addresses emergency situations and threats faced by would be rescuers.
CSA Z462, Workplace Electrical Safety [75]	Offers direction on integrating electrical safety programmes into OSHMSs, provides details on recognized methods for identifying electrical hazards and risk assessment, defines best safety practices and training for work on and around electrical equipment.
CSA Z463 Guideline on Maintenance of Electrical Systems [76]	Provides direction for organizations seeking to design and implement an effective electrical maintenance plan.
Det Norske Veritas (DNV)	
International Safety Rating System (ISRS) [77]	A widely used safety measurement system whose first edition was developed in 1978 by Frank Bird, a safety management pioneer following his research into the causation of 1.75 million accidents. The system was formerly managed by the International Loss Control Institute, which was incorporated into DNV in 1995. The ISRS has been implemented on thousands of sites worldwide and has been regularly updated to reflect best practice. It now includes sustainability management measures. The processes covered by the publication and related tools now include: leadership; planning and administration; project management; risk evaluation; risk control; risk monitoring; human resources; compliance assurance; training and competence; communication and promotion; asset management; contractor management and purchasing; emergency preparedness; learning from events; results and review.

TABLE 8. SELECTED INTERNATIONAL STANDARDS RELATING TO INDUSTRIAL SAFETY (cont.)

Source and documents	Description
IAEA (see Table 1)	
NS-G-2.1 [21] NS-G-2.4 [20] NS-G-2.6 [18] NS-G-2.8 [23] NS-G-2.14 [19] GSR Part 2 [12] GS-G-3.5 [14] SSR-2/2 (Rev. 1) [16] SSG-38 [17] GSG-7 [24] SSR-4 [25]	Various IAEA safety standards dealing with nuclear facility management systems, construction, operations and maintenance.
International Labour Organization (ILO)	
C155, Convention concerning Occupational Safety and Health and the Working Environment [26]	Provides for the adoption of a coherent national OSH policy, as well as action to be taken by governments and within enterprises to promote OSH and to improve working conditions.
C167, Convention concerning Safety and Health in Construction [78]	Covers preventative and protective measures related to construction activities.
C170, Convention concerning Safety in the Use of Chemicals at Work [79]	Covers classification, labelling, employer responsibilities, duties and rights of workers, and responsibilities of exporting states related to the use of chemicals at work.
Safety and Health in the Use of Machinery [80]	Sets out principles concerning safety and health in the use of machinery and defines safety and health requirements and precautions applicable to governments, workers and employers and also to designers, manufacturers and suppliers of machinery.
Protection of Workers against Noise and Vibration in the Working Environment [81]	Code of practice on occupational safety and occupational health protection against noise and vibration in the work environment — covers responsibility of government, employers and workers, measurement, exposure limits, identification and control of hazards, protective equipment, medical examination of employees and monitoring.
Encyclopaedia of Occupational Health and Safety, www.iloencyclopaedia.org	A web based knowledge platform for sharing OSH information and good practices.
International Organization for Standardization (ISO)	
ISO 45001:2018, Occupational Health and Safety Management Systems: Requirements with Guidance for Use [82]	A new standard for global OSH, with the goal of providing governmental agencies, industry and other affected stakeholders with effective, usable guidance for improving worker safety in countries around the world. In the new standard, an organization has to look beyond its immediate health and safety issues and take into account what the wider society expects of it. Organizations have to think about their contractors and suppliers as well as, for example, how their work might affect their neighbours in the surrounding area. This is much wider than just focusing on the conditions for internal employees and means organizations cannot just contract out risk.

TABLE 8. SELECTED INTERNATIONAL STANDARDS RELATING TO INDUSTRIAL SAFETY (cont.)

Source and documents	Description
Organisation for Economic Co-operation and Development (OECD)	
OECD Guidelines for Multinational Enterprises [83]	OECD members include Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, the Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States of America. The OECD has produced a set of guidelines for multinational enterprises that recommends multinational companies to take adequate steps to ensure OSH in their operations, and to encourage enterprises to work to raise the level of performance in all parts of their operation even where this may not be formally required by existing in countries in which they operate. Section VI (Environment) of the guidelines covers both environment and industrial safety recommendations for multinationals in some detail, including the establishment of a management system to address and continually improve industrial safety performance.
Standards Australia	
AS/NZS 4801:2001, Occupational Health and Safety Management Systems: Specifications with Guidance for Use [84]	Specifies requirements for an OSHMS to enable an organization to formulate a policy and objectives taking into account legislative requirements and information about hazards or risks.
International Finance Corporation (IFC)	
Environmental, Health, and Safety General Guidelines [85]	Contains information on cross-cutting environmental, health and safety issues potentially applicable to all industry sectors. Section 2 of the guidelines covers OSH, including sections on general facility design and operation, communication and training, physical hazards, chemical hazards, biological hazards, radiological hazards, personal protective equipment, special hazard environments and monitoring. When a project is proposed for financing by the IFC, the IFC conducts due diligence of the client’s commitment and capacity to manage risks. Where there are gaps in capacity, the IFC and the client agree on a plan to improve the company’s environmental, social and corporate governance performance. The IFC supervises environmental and social aspects of projects throughout the duration of their investment, including industrial health and safety risks.

Note: OSH — occupational safety and health; OSHMS — occupational safety and health management system.

TABLE 9. SELECTED NATIONAL, STATE OR PROVINCIAL REGULATIONS RELATING TO INDUSTRIAL SAFETY

Country and organization	Document	Description
Canada		
Ontario Ministry of Labour	Occupational Health and Safety Act	Ontario provincial legislation on occupational safety and health. Covers establishment of a provincial prevention council, duties of employers and other persons, toxic substances, work refusals, prohibition of reprisals, notices, enforcement, offences and penalties, and regulations. Subsidiary regulations cover various specific aspects including construction projects (Ontario Regulation 213/91), industrial establishments (Regulation 851), designated substances (Regulation 490/09) and diving (Regulation 629/94).
France		
Ministry of Labour	Code du travail	Provides employment law provisions at a national level, including provision of sanitation, safety and working conditions committees.
	Code de la santé publique	Covers national health provisions, including those related to workplaces (e.g. radioactive sources, lead, asbestos, noise exposures, hazardous substances, etc.).
Germany		
German Social Accident Insurance (DGUV)	DGUV Vorschrift 32, Kernkraftwerke	Accident prevention regulations specific to nuclear power plants. When items are not covered refer to applicable thermal power plant regulation (DGUV Regel 103-009, Wärmekraftwerke und Heizwerke).
South Africa		
Department of Labour	Occupational Health and Safety Act	Act providing for the health and safety of persons at work and safety of persons in connection with the use of machinery and related matters.
United Kingdom		
Health and Safety Executive (HSE)	Construction (Design and Management) Regulations 2015 (CDM 2015)	Law that applies to the whole construction process on all construction projects, from concept to completion; and what each duty holder must or should do to comply with the law to ensure projects are carried out in a way that secures health and safety.
Office for Nuclear Regulation (ONR)	The Regulation of Conventional Health and Safety on UK Nuclear Sites, NS-INSP-GD-051	Gives details of the arrangements and responsibilities of Field Operations Directorate (FOD), Hazardous Installations Directorate and ONR inspectors for the regulation of conventional health and safety on nuclear sites. FOD regulates all conventional health and safety legislation on nuclear sites.
United States of America		
Occupational Safety and Health Administration (OSHA)	29 CFR 1910, Occupational Safety and Health Standards	US Federal regulations governing occupational safety and health. Subparts A–Z cover various administrative and hazard specific aspects.
Department of Energy (DOE)	10 CFR 851, Worker Safety and Health Program	Outlines the requirements for a worker safety/health programme to ensure that DOE contractors and their workers operate a safe workplace.
	10 CFR 707, Workplace Substance Abuse Programs at DOE Sites	Establishes policies, criteria, and procedures for developing and implementing programmes that help to maintain a workplace free from the use of illegal drugs.

TABLE 10. EXAMPLE LIST OF HAZARDS VERSUS REGULATIONS AND OPERATIONAL CONTROLS

Hazards	OSH regulation or external hazard	Operational controls
Craning, hoisting and rigging Falling objects, flying objects, struck by, crushed by, line of fire issues	Ontario Regulation 851 (52) Supporting a worker Ontario Regulation 851 (56) Signaller Ontario Regulation 851 (60) Operating near power lines Ontario Regulation 851 (14) Guardrails Ontario Regulation 851 (34)–(36) Overhead protection Ontario Regulation 851 (45), (46) Material handling Ontario Regulation 851 (51) Lifting devices Ontario Regulation 851 (54) Mobile equipment Ontario Regulation 851 (72) Collapse of structure Ontario Regulation 851 (80) Head protection Ontario Regulation 851 (82) Foot protection Ontario Regulation 213 (31)–(34), (150)–(179), (207–210) Construction projects	OPG hoisting and rigging handbook OPG Safety rule 2.0 Working at heights OPG Safety rule 2.2 Falling objects OPG Safety rule 3.3 (tables) Limits of approach to live electrical equipment N-STD-MA-0009 Temporary grounding, bonding, drains and disconnection of electrical equipment leads N-PROG-MA-0004 Conduct of maintenance N-STD-MA-0018 Hoisting and rigging N-MAN-09180-10000 Hoisting and rigging handbook N-STC-76540-10000 Design of material handling and lifts tools N-INS-09180-10012 Inspection and maintenance requirements for hoisting and rigging equipment N-INS-09180-10012 Lift planning

industrial safety practices. The nuclear industry is especially aware of the linkages between good industrial safety practices, nuclear safety culture, plant performance and public acceptance of nuclear power. This has led, for example, to an increase in the use of formally trained and certified industrial and safety professionals. This social and political context is one of the influencers of OSH programmes and needs to be understood by those setting up programmes for their organizations.

5.1.3. Hazard assessment

An assessment of workplace hazards is a critical initial and ongoing part of an OSH programme. Section 6 covers hazard identification, prevention and control in more detail.

5.1.4. Health surveillance data assessment

Health surveillance data can provide insight into the overall effectiveness of current OSH programmes. Organizations regularly track employee health data on exposures to such hazards as noise (hearing loss data), designated substances such as asbestos, and radiation. Sick leave and absence records can also provide insight into overall worker health.

5.2. SYSTEM PLANNING, DEVELOPMENT AND IMPLEMENTATION

5.2.1. Initial planning

OSH programmes are planned, developed and implemented through a system of operational controls and planning processes. The goal of OSH planning is to ensure that the proposed OSHMS ensures compliance with national laws and regulations has comprehensive, clear and prioritized performance objectives, a comprehensive set of OSH performance measurement measures, has clearly defined responsibilities, has processes for continual improvement, and has adequate resources assigned to it. Each of these areas is covered in more detail elsewhere in this publication (Section 3 for policy, Section 5.3 for objectives, Section 7.1 for performance measures, and Section 8 for continual improvement).

Documentation should exist that describes the OSHMS in detail (see Section 4.8). Results from the initial review (see Section 5.1) and any subsequent reviews should be used as inputs to the planning process. An oversight structure can useful in managing this. A potential model used in some jurisdictions is the following:

(a) A senior leader responsible for the overall OSH programme;
(b) A top tier executive safety team that provides oversight to safety and risk management staff and various safety committees;
(c) An implementing safety organization that oversees and provides support to the line organization (as per Section 4.6.2), and develops detailed OSH policies, objectives and procedures for approval by the executive team and other senior management bodies as appropriate.

Such a structure promotes ownership by the line organization management and supervisors, and a sense of teamwork with the safety organization.

5.2.2. Change management

Organizations typically implement change management processes to address temporary or permanent changes to their operations, including industrial safety management programmes. This ensures that such changes do not cause deterioration in performance. Changes impacting OSH may be because of the following:

— Corrective actions resulting from reviews of incidents and non-conformities;
— New products, processes, services or facility modifications being considered;
— Changes in knowledge or information about hazards;
— Changes to work processes, procedures, equipment, tooling, organizational structure, staffing, products, services, contractors and suppliers;
— Technology and equipment developments;
— Changes to legal or other requirements.

Typical processes involve the individual or organization initiating the change performing an assessment of the impact of the change on existing facility processes, individuals, and organizations and proposing compensatory actions to address any negative impacts. Actions might include purchasing new safety equipment, performing training and changing procedures. In the case of planned changes, permanent or temporary, this assessment is to be undertaken before the change is implemented. A change management board of senior managers normally reviews and accepts the change, as well as the actions designed to address its impact.

5.3. OCCUPATIONAL SAFETY AND HEALTH OBJECTIVES, TARGETS AND MEASURES

Organizations need to establish measurable OSH objectives that are consistent with the OSH policy and based on the initial or subsequent reviews. These objectives are typically established at different organizational levels to help to encourage continual improvement throughout the organization. Factors such as technological options, financial, operational and business requirements and worker participation methods are all considered when establishing these objectives. To be useful, the objectives need:

(a) To be consistent with the industrial safety policy;
(b) To take into account applicable legal requirements and other requirements;
(c) To be measurable (if practicable);
(d) To be monitored;
(e) To be communicated;
(f) To be updated as appropriate.

Goals should be well defined, quantifiable and set for all levels of employees. Upper management goals are often numeric, while middle management goals are often both numeric and activity based. Lower management goals are typically activity based, while employee goals need to be both activity and outcome based.

Planning needs to take place to determine how the organization will achieve industrial safety objectives. As part of this planning, the organization needs to determine specifically:

— What will be done;
— What resources will be required;
— Who will be responsible;
— When will it be completed;
— How will it be monitored;
— How will the results be evaluated;
— How will it be integrated into its business processes.

Section 7.1 discusses performance monitoring, including establishing performance measures for industrial safety. Such measures invariably need to be linked to these OSH objectives.

6. IDENTIFYING AND ADDRESSING HAZARDS

Determining which hazards exist at a facility and how to address them is a key part of OSH programmes. This section is the core of the programme for industrial safety management. It covers fundamental processes for identification of hazards, and prevention and elimination of hazards through engineering and administrative processes.

6.1. DEFINITION

A hazard is defined as a condition, event or circumstance that could lead or contribute to an unplanned or undesirable event. In industrial safety, the unplanned or undesirable event is a personal injury or ill health. Such hazards can occur during routine, non-routine and emergency activities. They can be caused by situations under or not under the direct control of the applicable operating or construction organization; from outside, in the vicinity of, or inside the normal workplace; and can cause injury or ill health to people both at, or away from, the workplace.

6.2. HIERARCHY OF PREVENTION AND RISK ASSESSMENT

6.2.1. Safety basics and hierarchy of controls

Industrial safety hazards are best addressed using a hierarchy of prevention and protection, which is often referred to as the five safety basics:

(1) Identify the hazards and monitor them for change;
(2) Eliminate the hazards whenever practical;
(3) Control the hazards when they cannot be eliminated;
(4) Protect the workers by providing and using PPE;
(5) Minimize the severity of an injury if an accident occurs.

The basics are a set of barriers between energy sources and potential injuries to workers (see Fig. 21). Some examples of safety basics methods in action are shown in Table 11 and the hierarchy in Fig. 22.

FIG. 21. Safety basics (courtesy of Ontario Power Generation).

TABLE 11. SAFETY BASICS STEPS

Hierarchy step	Examples
Eliminating the hazard by removing the activity from the work process or substitution with a less hazardous process/material	Substitution with less hazardous chemicals Using different manufacturing processes Changing the design to eliminate the concern
Providing engineering controls to address the hazard at its source	Local exhaust ventilation Isolation rooms Machine guarding Adding acoustic insulation
Providing administrative and work practice control measures to reduce the amount of exposure	Job rotation Training in safe work procedures Lockout and tagout Workplace monitoring Limiting exposure times or work duration
Protect again injuries by providing appropriate PPE in conjunction with training, use and maintenance of the PPE	Standard PPE (e.g. hard hat, safety glasses, work boots, gloves, etc.) Job specific PPE (fall arrest, arc flash ensemble, breathing apparatus, etc.)
Minimize severity of injury	First aid treatment Emergency response personnel Medical evacuation

Note: PPE — personal protective equipment.

Once hazards are identified, it is more effective to eliminate them, or provide physical or administrative controls, rather than provide PPE to protect against them. A typical sequence of barriers is shown in Fig. 23. It is analogous to the hierarchy of control, from the most effective to least effective, with some barriers being more effective than others. In practice, a combination of elimination, engineering control and administrative control methods are used together to help to minimize potential risks. For example, when dealing with a noise hazard it is more effective to reduce or eliminate the noise as a first goal where feasible (e.g. by purchasing quieter equipment, moving noisy equipment into enclosures or adding sound insulation), apply control measures (e.g. limiting personnel access to a noisy area), and then apply personal protective measures such as hearing protection (e.g. ear plugs to protect against any residual hazard).

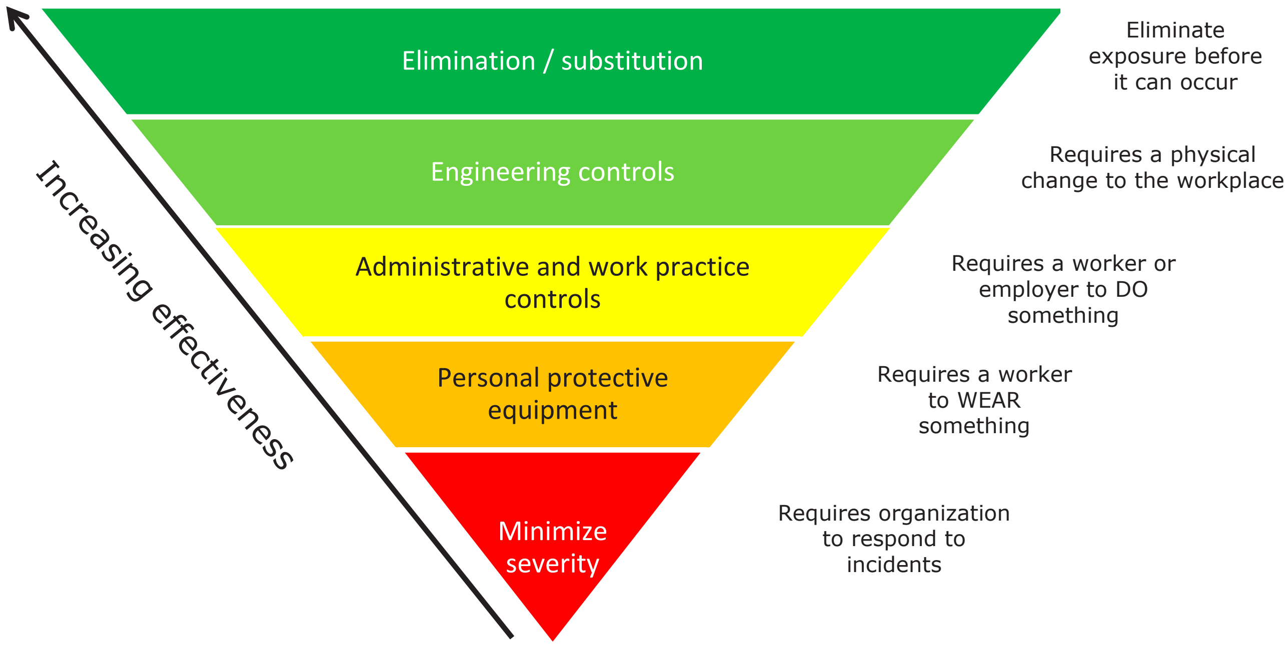


FIG. 22. Hierarchy of controls.

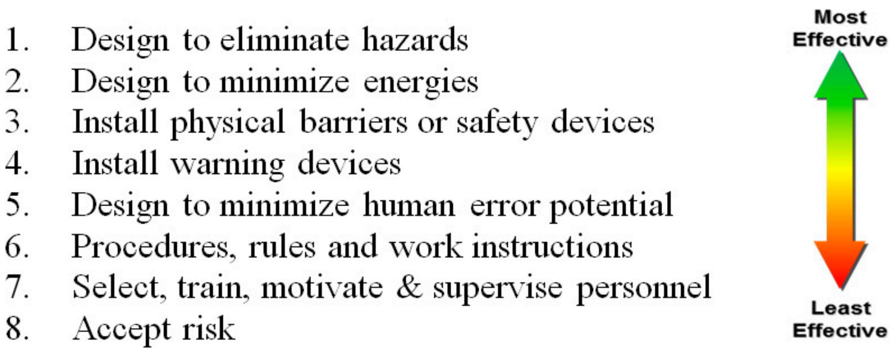


FIG. 23. Barrier effectiveness sequence.

6.2.2. Risk assessments

A risk assessment is a thorough examination of a workplace to identify objects, situations and processes that may cause harm. After identification is complete, organizations evaluate how likely and severe the risks are, and then decide on what measures should be in place to prevent or control effectively the harm from happening. The 'what measures' step is to determine the combination of the elimination, engineering control, administrative control, PPE or minimize severity actions that should be implemented. The ILO provides a guide to the process (see Fig. 24).[9]

6.3. HAZARD IDENTIFICATION

Prior to addressing hazards, they need to be identified. In a complex environment such as a nuclear facility, this can be a difficult task. Hazards may stem from infrastructure, equipment, materials, substances and the physical conditions of the workplace, or from changes in organizational structure, operations, processes, activities, personnel and the industrial safety management programme.

[9] See Ref. [86] and www.ccohs.ca/oshanswers/hsprograms/risk_assessment.html

Risk Assessment template		Enterprise:	Section/Unit:	Date:
STEP 1 **What are the hazards?**	**STEP 2** **Who might be harmed and how?**	**STEP 3** **What are you already doing?**	**What further action is necessary?**	**STEP 4** **How will the assessment be put into action?**
Spot hazards by: ■ walking around the workplace; ■ asking workers what they think; ■ checking manufacturers' instructions; ■ contacting your trade association. Don't forget long-term health hazards.	Identify groups of people. Remember: ■ some workers have particular needs; ■ people who may not be in the workplace all the time; ■ members of the public; ■ if the workplace is shared think about how the work affects others present. Say how the hazard could cause harm.	List what is already in place to reduce the likelihood of harm or make any harm less serious.	Make sure that risks have been reduced 'so far as is reasonably practicable'. An easy way of doing this is to compare what is already being done with good practice. If there is a difference, list what needs to be done.	Remember to prioritize. Deal with those hazards that are high-risk and have serious consequences first. Action by whom — Action by when — Done

FIG. 24. ILO 5 step risk assessment template (reproduced from Ref. [86] with permission courtesy of the ILO).

Hazard identification can take two main forms: identification methods and techniques relating to plant systems and processes, and those relating to specific work activities. For new designs or facility modifications, specific processes are often invoked to ensure that sufficient safety reviews take place as part of the design process. Each of these will be reviewed in the following three subsections.

6.3.1. Hazard identification techniques for systems and processes

The UK Health and Safety Laboratory has done research into process hazard identification techniques [87]. Some 40 techniques were identified from a literature search of over 1000 references. The techniques were divided into four categories (process, hardware, control and human hazards identification) depending on the area in which they are predominantly applied. These four areas are described further below and a comparison of the methods as they are applied to the nuclear industry in terms of time/cost and usage is given in Table 12. The most applicable process hazard identification methods for nuclear are the hazard and operability study (HAZOP), fault tree analysis (FTA), failure mode and effect analysis (FMEA), functional FMEA, failure modes, effects and criticality analysis (FMECA), the computer hazard and operability study (CHAZOP), task analysis, and hierarchical task analysis (HTA).

6.3.1.1. HAZOP and CHAZOP analyses

HAZOP analysis is extensively used in the chemical process industry. It performs a systematic search for deviations that may have harmful consequences. Each HAZOP element is defined in terms of its intention (what it is supposed to do), and potential deviations (ways of functioning that may lead to hazardous situations) [88]. Guide words (such as 'no', 'not', 'more', 'less', 'as well as', 'part of', 'reverse' or 'other than') are used to uncover different types of deviations, and the analysis is conducted in a team environment [88].

Guide word usage is illustrated in Ref. [88] using an example of a pump designed to pump a liquid through a pipe. The pump can supply no liquid, more liquid than designed, less than designed or can pump something else as well as the intended liquid. Each of these deviations would be analysed for their potential consequences, and applicable safety measures would be proposed to deal with the consequences. Safety measures might include changes to the process, process parameters, physical design, or routines (e.g. monitoring). HAZOP is of greatest benefit during the design of a system, as it allows changes to be most easily made to the design.

With the advent of more computer or digital controls for systems, a variation of HAZOP analysis for computer controlled systems is CHAZOP. Such analyses are similar to HAZOP studies, however, they focus more on such topics as system architecture, safety related features, system failure modes, utility or power supply failures, input/output signals and complex control schemes. Input/output signals, for example, are analysed using guide words such as 'low', 'high', 'drifting', 'invariant' and 'bad' to determine their impact on safety.

TABLE 12. PROCESS HAZARD IDENTIFICATION APPLICABILITY (*adapted from Ref. [87]*)

Hazard identification technique	Nature of results	Life cycle phase	Time/cost[a]	Applicability to nuclear[a]
Process				
HAZOP	Qualitative	Any phase	3	4
'What if?' analysis	Qualitative	Any phase	2	3
CHA and concept safety review	Qualitative	Concept	2	3/2
PHA	Qualitative	Design/operation	2	2
FTA	Both	Design/operation/mods	3	4
CCA	Both	Design/operation/mods	3	3
Pre-HAZOP	Qualitative	Design stage	1	3
Standards/codes of practice/literature review	Qualitative	Concept/design	1	3
FIHI	Qualitative	Design/operation	2	2
Checklists	Qualitative	Concept/design	2	2
CEX	Qualitative	Design/operation	2	1
MOSAR	Semi-qualitative	Operation/mods	2	1
GOFA	Semi-qualitative	Design/operation/mods	2	2
Matrices	Qualitative	Design stage	2	1
Inherent hazard analysis	Qualitative	Design stage	2	2
Hardware				
Safety audit	Qualitative	Any phase	3	4
FMEA	Qualitative	Design/operation/mods	3	4
Functional FMEA	Qualitative	Design/operation/mods	3	4
FMECA	Qualitative	Design/operation/mods	3	4
MOp	Qualitative	Design/operation/mods	3	2
Maintenance analysis	Both	Operation/mods	3	3
Sneak analysis	Qualitative	Design/operation	2	2
Reliability block diagram	Quantitative	Design/mods	2	2
Structural reliability analysis	Quantitative	Design/construction	2	2
Vulnerability assessment	Qualitative	Design/mods	2	2
DEFI method	Quantitative	Design stage	2	2
Control				
CHAZOP	Qualitative	Design/mods	3	4
Structured methods	Qualitative	Design stage	2	2

TABLE 12. PROCESS HAZARD IDENTIFICATION APPLICABILITY (cont.) (*adapted from Ref. [87]*)

Hazard identification technique	Nature of results	Life cycle phase	Time/cost[a]	Applicability to nuclear[a]
State transition diagrams	Qualitative	Design stage	2	2
Petri nets	Qualitative	Design stage	2	1
GRAFCET	Qualitative	Design stage	2	1
Human				
Task analysis	Both	Design/operation/mods	2	4
HTA	Qualitative	Operation/mods	3	4
AEA	Both	Operation/mods	3	3
Human reliability analysis	Semi-qualitative	Operation/mods	3	3
Pattern search method	Qualitative	Operation/mods	2	2
PHEA	Semi-qualitative	Design/operation/mods	3	3

[a] 1 = low, 4 = high.

Note: AEA — action error analysis; CCA — cause–consequence analysis; CEX — critical examination of system safety; CHA — concept hazard analysis; CHAZOP — computer hazard and operability study; FIHI — functional integrated hazard identification; FMEA — failure mode and effect analysis; FMECA — failure modes, effects and criticality analysis; FTA — fault tree analysis; GOFA — goal oriented failure analysis; GRAFCET — GRAphe de Commande Etat-Transition; HAZOP — hazard and operability study; HTA — hierarchical task analysis; MOp — maintenance and operability study; MOSAR — method organized systematic analysis of risk; PHA — preliminary hazard analysis; PHEA — predictive human error analysis.

6.3.1.2. Fault tree analysis

Reference [88] provides the following definition:

> "A fault tree is a diagram showing logical combinations of causes of an accident or an undesired event — *the top event.... Fault Tree Analysis* (FTA) is used to identify combinations of faults that can lead to the top event. It can also be used to estimate the probability of the top event."

It is extensively used in nuclear safety analysis, but can also be applied to industrial safety. A binary approach is adopted in that either an event occurs or it does not. Systems and events are modelled using Boolean logic (e.g. using 'and' and 'or' gates). Modelling is typically done by selecting the top event of interest, summing up known causes, constructing the fault tree, confirming its logic and assessing results. Some disadvantages are that the method can be time consuming, requires expertise and training and may give the illusion of high accuracy when significant errors may be present [88]. A simple example of a fault tree for a room lighting system is provided in Fig. 25.

6.3.1.3. Failure modes and effects analysis

FMEA has been in use since the 1950s and looks at the ways in which a component might fail and the effects and consequences that might arise [88]. Several descriptions are available in Refs [89–91].

A variant of FMEA is FMECA, which in principle looks at the criticality of a particular effect. In practice, criticality is often implicitly included in standard FMEA analysis, as it is a function of the effect and its frequency [88]. FMEA is typically performed via the following main steps [88]:

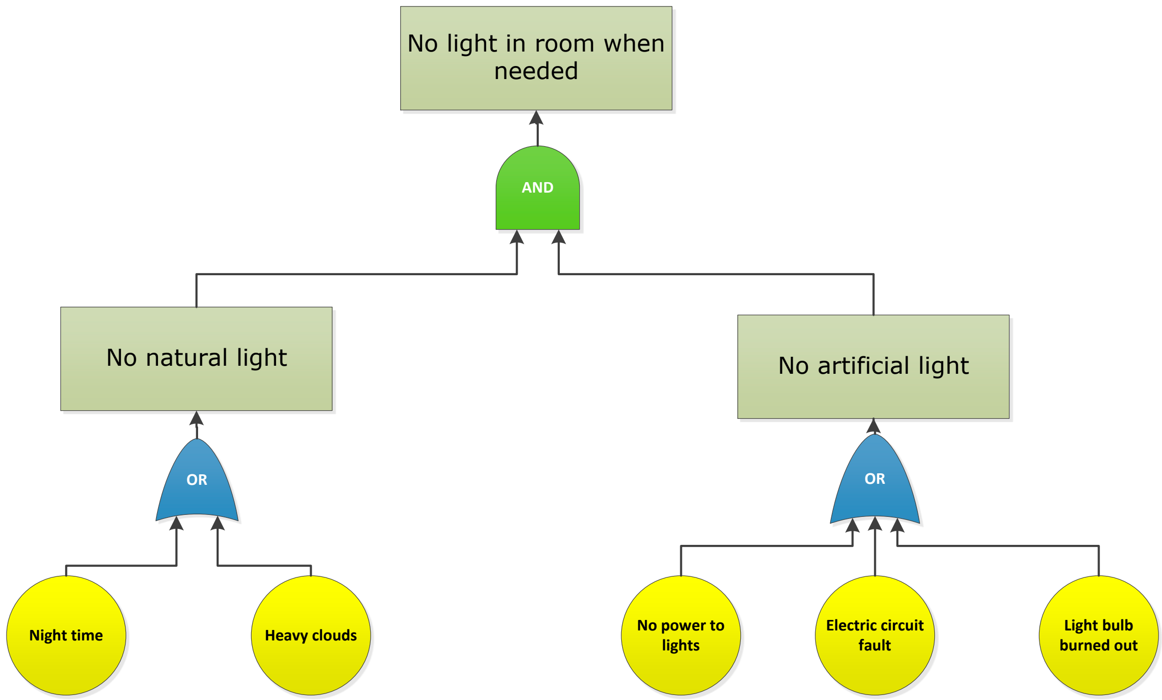


FIG. 25. Simple fault tree for top event of no light in a room when needed.

"1) Aim, scope and assumptions are defined.
2) The system is divided up into different units, often components, but sometimes functions modelled in a block diagram.
3) Failure modes are identified for the various units, one by one.
4) Conceivable causes, consequences and frequencies of failure are estimated for each failure mode.
5) An investigation is made into how the failure can be detected.
6) An estimation of severity is made.
7) Recommendations for suitable control measures are made."

A detailed analysis using FMEA can take extensive effort, and the amount of documentation can be large. A disadvantage of FMEA is that all components are analysed and documented, including failures with small consequences.

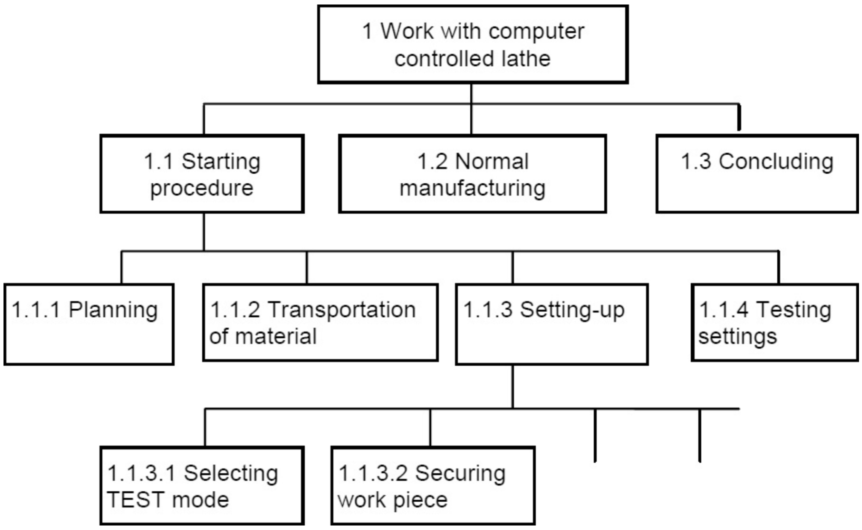
6.3.1.4. Task analysis

Task analysis covers a variety of human factor techniques. There are a large number of methods documented, roughly divided into action oriented and cognitive task analysis approaches [88]:

"• Action-oriented approaches, which give descriptions of the operator's behaviour at different levels of detail, together with indications of the structure of the task.
• Cognitive Task Analysis (CTA), which focuses on the mental processes that underlie observable behaviour, and may include decision-making and problem-solving.

....

"Hierarchical Task Analysis (HTA) is perhaps the most widely used kind of task analysis.... The outcome is an extensive description of the task and the activities involved. Results are usually presented as a diagram [see Fig. 26]."



Source: Figure 12.6 of Ref. [88].

FIG. 26. Hierarchical task analysis of work on a computer controlled lathe.

6.3.1.5. Process hazard identification

These methods are used to identify and evaluate possible hazards due to process maloperation. They predominantly deal with hazards due to deviation from normal operating conditions (e.g. temperature and pressure) and the presence of harmful materials (see Table 13).

6.3.1.6. Hardware hazard identification

These methods are used to identify and evaluate possible hazards due to hardware (physical equipment) maloperation. They predominantly deal with hazards relating to the failure of components. Table 14 provides a description of each method and references for further information.

6.3.1.7. Control hazard identification

These methods are used to identify and evaluate possible hazards due to control failures (software and control scheme) maloperation. Table 15 provides a description of each method and references for further information.

6.3.1.8. Human hazard identification

Human tools assess hazards associated with the interaction of the human operators with processes. They are used to identify hazards occurring due to human error while performing standard procedures, and due to improper safety measures if an initial hazard occurs. Table 16 shows a description of each method and references for more information.

6.3.2. Hazard identification for specific locations or work activities

6.3.2.1. Hazard identification for specific work

(a) Typical hazards

Each job should be evaluated for the specific hazards that workers might encounter. Figure 27 shows major typical hazard types that might be encountered at a nuclear facility (note hazardous substances and special on-site conditions are not shown), and Table 17 lists typical hazard categories and subcategories. Appendix I provides further detail into the specifics of such hazards and some potential methods that can be used to address them.

TABLE 13. PROCESS HAZARD IDENTIFICATION METHODS

Method	Description	Ref.
HAZOP	Hazard and operability study conducted by 4–6 people producing a comprehensive evaluation of the process, examining consequences of failures and producing recommendations for methods to minimize or mitigate the hazard. Computer packages are available that can aid in the performance of HAZOPs.	[88, 92–94]
‘What if?’ analysis	Uses a creative brainstorming methodology to evaluate any aspect of a process. Poses a number of questions that begin with ‘What if’ to attempt to identify hazards. Results often documented in table format containing the ‘What if’ question asked, the related hazard or consequence, safeguards present and recommendations if applicable.	[88, 94, 95]
CHA and concept safety review	CHA is a literature review of previous incidents, allowing identification of areas of specific concern. It uses keywords and a partitioned process flow diagram, identifies dangerous disturbances and consequences generated by each word for each partition, and generates recommendations for design changes or safeguards. Concept safety review is a similar process done at a conceptual design stage.	[94, 96, 97]
PHA	The approach is similar to HAZOP, although it splits the process into larger sections, generally major process items and associated lines and heat exchangers. Assessment starts with the examination of ‘dangerous disturbances of the plant’ and is developed until immediate causes can be identified.	[94, 96–98]
FTA	Graphically represents a combination of faults leading to a predefined undesired event. Uses logic gates to show all credible paths from which the undesired event could occur. Probabilities or frequencies can be allocated to the initiating conditions, and using the logic present in the developed tree the probability or frequency of the event can be calculated.	[88, 94, 98–102]
CCA	Combines hazard identification and quantification methodology of FTA with event tree analysis. Can investigate incidents past hazards (e.g. item rupture) to the possible consequences (e.g. fire). Can produce quantitative results, but can be time consuming and expensive for complex systems.	[103]
Pre-HAZOP	Top down approach performed during early design where it would be impracticable to perform a full HAZOP study. Uses more wide ranging guide words (such as fire, explosion/detonation) and evaluates if any redesign is required.	[92]
Standards/codes of practice/literature review	Ensure that design criteria meet minimum safety requirements that have been identified from international or national legislation or in-house requirements.	
FIHI	Produces a system functional model formally defined in terms of intents, methods and constraints. HAZOP like guide words are applied to each intent, and possible causes and consequences for each deviation are discussed	[104]
Checklists	Applies experience of everyday operations and previous incidents in similar plants through the use of evaluation checklists. Assessment team identifies potential hazards and recommendations for their minimization.	[105, 106]
CEX	Precursor to HAZOP using brainstorming techniques to formulate a series of questions (such as ‘What’, ‘When’, ‘How’ and ‘Where’) which can be related to a particular activity or operation. Requires a statement of the design intent describing what is to be achieved.	[96, 97, 107]
MOSAR	Uses a series of steps to examine the safety of a process, which is taken as a series of interacting subsystems. Tables are filled out for hazard identification, adequacy of prevention, interdependency, operating safety, logic trees, severity, protection objectives, technological barriers, utilization barriers and residual risk acceptability.	[108, 109]

TABLE 13. PROCESS HAZARD IDENTIFICATION METHODS (cont.)

Method	Description	Ref.
GOFA	Uses a system analysis approach to develop a system diagram which is then used in hazard identification. Uses a top down technique which is a hybrid of failure mode effect analysis and fault tree analysis.	[94, 110]
Matrices	Performed during early stages of process design and development, and looks at interactions between chemicals, materials, operators, utilities, energy sources and the environment.	[111]
Inherent hazard analysis	Performed early in process design. Used to minimize inherent process dangers, predominantly due to the presence of hazardous reactants, intermediates or products. The process is initially divided into basic process items, and each item is evaluated with the help some basic questions.	[112]

Note: CCA — cause–consequence analysis; CEX — critical examination of system safety; CHA — concept hazard analysis; FIHI — functional integrated hazard identification; FTA — fault tree analysis; GOFA — goal oriented failure analysis; HAZOP — hazard and operability study; MOSAR — method organized systematic analysis of risk; PHA — preliminary hazard analysis.

TABLE 14. HARDWARE HAZARD IDENTIFICATION METHODS

Method	Description	Ref.
Safety audit	Subjects all areas of organizations to critical examination to minimize loss. Consists of an on-site walk-through inspection, and can vary from an informal routine function (which is primarily visual) to a formal in-depth evaluation. Should include interviews with employees (including operators, managers and maintenance workers), as well as applying additional techniques such as checklists and audits of such things as policies, procedures, attitudes, emergency plans and accident records.	[113–116]
FMEA	Identifies potential hazards associated with a process by investigating the failure modes for each item. Detailed methodologies are available but can be time consuming and expensive.	[88, 94, 117]
Functional FMEA	Uses FMEA methodology but breaks down the process into a functional diagram instead of hierarchical or block reliability diagrams. All aspects of the design can be examined with no distinction made between whether the function is implemented by hardware, software or human action.	[94, 117]
FMECA	Uses the same methodology as FMEA though two additional steps are required: determine the severity of effects caused by failures, and evaluating their frequency. Severity and frequency of events are then compared to produce a criticality rating.	[88, 94, 100, 117]
MOp	Performed during early design, requiring a team similar to that for HAZOP studies. The process is divided into a number of sections and questions posed with regard to whether equipment can be properly isolated and drained for maintenance, what plans are there to deal with mechanical failure, and whether there are spares available.	[118]
Maintenance analysis	Used to identify equipment availability, and can also be used to identify particular hazards associated with maintenance. Questions on, for example, what failures can occur, how they would be detected and what preparations are needed for repair.	[119]
Sneak analysis	First developed in the aerospace industry to identify why spacecraft rockets would accidentally fire, or not fire, when required. Looks at the unintended flow of material, energy or information from one area to another.	[94, 120, 121]

TABLE 14. HARDWARE HAZARD IDENTIFICATION METHODS (cont.)

Method	Description	Ref.
Reliability block diagram	Produces a pictorial representation of the reliability of a process. Used to indicate required functioning components, and is applied primarily to systems without repair, and where the order of failure does not matter. It is assumed that there are only two possible states for each component: operational or faulty.	[100, 122]
Structural reliability analysis	Examines structures associated with a process to identify built-in safety margins. Can also be used to assess the effect of a partial failure on the overall structure and the process.	[119]
Vulnerability assessment	Used to evaluate the safety of plant items if a failure occurs in a nearby item. Hazards are deemed significant if it can directly impinge on required safety systems needed for its mitigation, or will cause a secondary hazard in adjacent items.	[123]
DEFI method	Used to evaluate possible failures relating to a piece of equipment. Often used in the computer industry to test prototype hardware as it is developed. A computer is used to send failure inputs to the piece of equipment, and consequence and failure rates can be calculated.	[119]

Note: FMEA — failure mode and effect analysis; FMECA — failure modes, effects and criticality analysis; HAZOP — hazard and operability study; MOp — maintenance and operability study.

TABLE 15. CONTROL HAZARD IDENTIFICATION METHODS

Method	Description	Ref.
CHAZOP	As with HAZOP it can be performed at a number of stages in the process development and is split into two formats which can be performed in conjunction with the appropriate stage of HAZOP. Reviews critical computer features such as system architecture, safety features and performance after system or utility failures.	[88, 94, 124–126]
Structured methods	Used to identify the appropriate software structure that needs to be developed, and should be performed early in design. Some methods include: Structured English (used to expand ideas and functions from vague generalities to precise statements in a hierarchical fashion); Specification language (similar to that of structured English and incorporates a graphical format known as ‘requirements net’ (network), and uses more restrictive verbs and nouns); SADT (expresses activities of a control system by the use of diagrams that resemble conventional engineering blocks).	[127]
State transition diagrams	Represents sequence of operation of programmable systems through control loop diagrams.	
Petri nets	Applies a graphical methodology with bubbles and arcs representing the process (bubbles identify places, while arcs indicate transactions that occur). Can easily represent the flow structure of a computer control program which incorporates constructs as ‘If-Then-Else’, ‘Do While’ or ‘Goto’.	[128, 129]
GRAFCET	Graphical method of specifying control sequences developed in France in the 1970s. Defines orders of actions to be executed, and actions themselves. Tailored towards batch processes.	[129, 130]

Note: CHAZOP — computer hazard and operability study; GRAFCET — GRAphe de Commande Etat-Transition; HAZOP — hazard and operability study; SADT — structured analysis and design techniques.

TABLE 16. HUMAN HAZARD IDENTIFICATION METHODS

Method	Description	Ref.
Task analysis	A method for analysing a task in terms of its goals, operations and plans. Assesses what people might do while performing the operations (e.g. actions, responses, errors, plans). The writing of operating instructions constitutes a less formalized type of task analysis, and may likewise serve to identify hazards.	[88, 94, 131]
HTA	Uses the same methodology as task analysis, though a hierarchy is placed on the order of the tasks to be investigated. Methodology produces either a tree structure, with the most complex task on top and simplest on the bottom, or a list of steps required to be performed.	[88, 94, 131]
AEA	Uses the output from a hierarchical task analysis as a starting point. Each step is analysed to identify errors which human operators can commit, and their effects on the process are evaluated. Errors are divided into unconscious slips, mistakes, conscious violation or sabotage.	[94, 119]
HRA	Used to quantify (estimate) human errors and their impact on system failure rates.	[94, 132–134]
Pattern search method	Used to identify hazards due to a number of errors. Attempts to look for common causes which could lead to the errors and identifies areas of importance for safety.	[94, 119]
PHEA	Uses hierarchical task analysis to plan tasks, looking for errors and consequences, recovery methods and strategies to reduce errors.	[94]

Note: AEA — action error analysis; HRA — human reliability analysis; HTA — hierarchical task analysis; PHEA — predictive human error analysis.

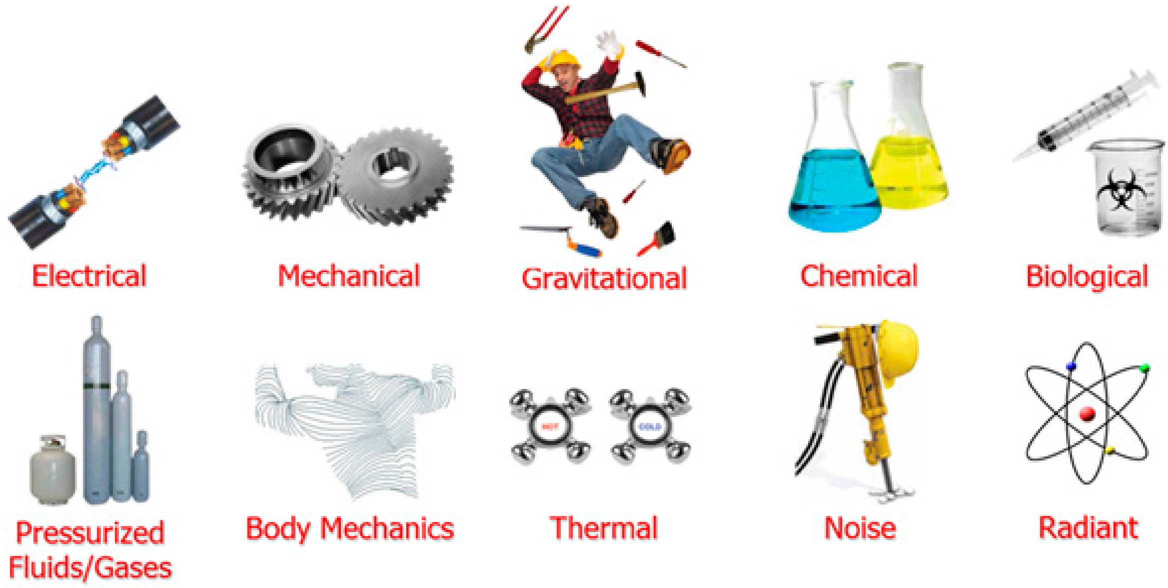


FIG. 27. Typical hazard categories (courtesy of Ontario Power Generation).

TABLE 17. HAZARD CATEGORY EXAMPLES

Hazard category and subcategory	More detail in Appendix I, Section
Mechanical	I.1
Striking, crushing or shearing	
Cutting, severing, stabbing or puncture	
Entanglement, drawing in or trapping	
Impact	
Friction or abrasion	
Driving (including forklifts)	
Gravitational	I.2
Falling objects	
Working at heights	
Craning and hoisting (includes related electrical hazards)	
Stairwell related hazards	
Slips and trips	
Electrical	I.3
Physical impacts	
Arc flash	
Live line work	
Thermal	I.4
Contact with hot objects	
Cryogenic hazards	
Extreme heat and cold	
Noise	I.5
Chemical	I.6
Hazardous materials	I.7
Exposure to designated substances	
Body mechanics	I.8
Industrial related musculoskeletal disorders including manual exertions, vibration, etc.	
Office related musculoskeletal disorders	
Compressed or pressurized fluids or gases	I.9
Biological	I.10
Exposure to bacteria, viruses or disease	
Hazards from exposure to other employees or general society	
Exposure to wildlife and poisonous plants	
Radiant hazards	I.11
Ionizing radiation	
Non-ionizing radiation (electromagnetic fields, ultraviolet radiation, etc.)	

TABLE 17. HAZARD CATEGORY EXAMPLES (cont.)

Hazard category and subcategory	More detail in Appendix I, Section
Special worksite or personnel conditions	I.12
Confined spaces	
Trenching, digging and excavation	
Working on, near or under water	
Hot work	
Poor lighting and visibility	
Buried or hidden services	
Adverse weather	
Power and hand tools	
Dusty environments	
Commissioning, operation and maintenance of pressure vessels	
Work schedule	
Psychosocial conditions	
International travel	
Working alone	
Remote workers	
Disruptive events	
Facility specific hazards	

(b) Hazards by occupation

For construction activities, the ILO has prepared in its encyclopaedia of OSH[10] a table of typical hazards encountered by each specific construction trade (see Table 18).

(c) Line of fire recognition

A useful concept to aid in hazard recognition is the 'line of fire'. The line of fire is the path of a moving object that could potentially injure someone or the potential path of an object that may move. Injuries can occur when workers are caught in (when a worker is caught inside or in between different objects), struck (when a worker is struck by an object) or injured by releases of energy (when a worker is in the path of released hazardous energy such as steam). Line of fire injuries can occur with the following:

— Heavy equipment;
— Machinery;
— Hand and power tools;
— Material handling;
— Mobile equipment;
— Excavations;
— Unsafe behaviours.

Often workers place themselves in the line of fire by making a decision based on imperfect information. They may believe that times of exposure are small enough to protect themselves, that they are so familiar with the job that the need to worry about the line of fire hazard is not necessary, that the job cannot be done in another way to avoid the line of fire, or that they make an unconscious error in not recognizing the hazard. Individuals should be trained to always ask themselves 'What can hurt me while I'm doing this task?', and take necessary precautions to avoid working in the line of fire.

[10] See www.iloencyclopaedia.org

TABLE 18. HAZARDS ENCOUNTERED BY CONSTRUCTION OCCUPATION

Occupation	Hazards
Brickmasons and stonemasons	Cement dermatitis, awkward postures, heavy loads
Hard tile setters	Vapour from bonding agents, dermatitis, awkward postures
Carpenters	Wood dust, heavy loads, repetitive motion
Drywall installers	Plaster dust, walking on stilts, heavy loads, awkward postures
Electricians, electrical power installers and repairers	Heavy metals in solder fumes, awkward posture, heavy loads, asbestos dust
Painters	Solvent vapours, toxic metals in pigments, paint additives
Paperhangers and carpet layers	Knee trauma, awkward postures, glue and glue vapour
Plasterers	Dermatitis, awkward postures
Plumbers, pipefitters and steamfitters	Lead fumes and particles, welding fumes
Soft tile installers	Bonding agents
Concrete and terrazzo finishers and glaziers	Awkward postures
Insulation workers	Asbestos, synthetic fibres, awkward postures
Paving, surfacing and tamping equipment operators	Asphalt emissions, gasoline and diesel engine exhaust, heat
Rail and track laying equipment operators	Silica dust, heat
Roofers	Roofing tar, heat, working at heights
Sheet metal duct installers	Awkward postures, heavy loads, noise
Structural metal installers	Awkward postures, heavy loads, working at heights
Welders and solderers	Welding emissions, metal fumes, lead, cadmium
Drillers (earth, rock) and air hammer and pile driving operators	Silica dust, whole body vibration, noise
Hoist and winch operators	Noise, lubricating oil
Crane and tower operators	Stress, isolation
Excavating and loading machine operators, grader, dozer and scraper operators	Silica dust, histoplasmosis, whole body vibration, heat stress, noise
Highway and street construction workers	Asphalt emissions, heat, diesel engine exhaust
Truck and tractor equipment operators	Whole body vibration, diesel engine exhaust
Demolition workers	Asbestos, lead, dust, noise
Hazardous waste workers	Heat, stress

6.3.2.2. Research on hazard recognition and warnings

The CII has performed research on hazard recognition of construction projects [135]. It found that work crews could regularly miss up to 80% of known hazards. As part of the research, it developed a number of tools for hazard recognition, all of which provide benefits in improving group communications around hazard identification, increased employee participation and engagement, and an enriched safety culture (see Table 19).

Technology is becoming more available that allows for proactive warning of workers on construction sites of imminent danger in real time [136–138]. This includes technologies designed to assist in the following:

(a) The observation of construction activities (technology installed on workers, equipment and materials);
(b) Providing location data of construction resources (technology to track physical location of workers, equipment and materials);
(c) Providing alerts for workers too close to hazardous areas or equipment (ground workers or equipment operators);
(d) Allowing data visualization for project participants (4-D models of key construction activities, such as craning operations);
(e) Training (virtual training environments designed to enhance learning);
(f) Decision making (use of above technologies to enhance other best safety practices in other fields such as production or security).

Examples of such systems are shown in Figs 28 and 29. Figure 28 shows a crane collision warning system installed at a China National Nuclear Corporation project in China. A system calculates the position of crane components in real time and provides alerts if limits of approach are met. Figure 29 shows an example of a resource tracking system used on a construction site. In this system tags on workers, equipment and material are detected via an array of antennas that can pinpoint locations at all times. If an object is close to entering a 'forbidden zone' the system can trigger an alert. Passive radiofrequency identification systems can also be used for active work zone safety and obstacle avoidance detection [140]. Such systems can assist in understanding the flow of resources on construction job sites, and enhance both safety and productivity of related activities.

TABLE 19. CII TOOLS TO IMPROVE HAZARD RECOGNITION

Tool name	Description
Safety meeting quality metric (SMQM)	This metric incorporates nine evaluation criteria used to evaluate the quality of pre-job briefings surrounding industrial safety. The briefings are evaluated as to whether there is appropriate: — Job identification; — Basic step identification; — Hazard identification; — Location of discussion; — Supervisor leadership; — Crew participation; — Documentation; — Job changes; — Evaluation. Briefings are categorized in each of the above areas as mature, less mature or least mature based on their quality and completeness. Within each category, a different score is assigned and an overall briefing score obtained.
System for augmented virtuality safety (SAVES)	An augmented reality training tool that provides participants with a virtual environment that replicates actual project conditions. Users control an avatar that can explore the game's 3-D construction environment. Users are asked to identify all hazards, their energy sources and the appropriate severity level of risk that each hazard introduces.
Hazard identification and transmission (HIT) board	A large magnetic board that facilitates pre-job hazard discussions. Workers review energy sources to identify hazards that they may encounter during work.

FIG. 28. Crane collision warning system components (courtesy of the China National Nuclear Corporation).

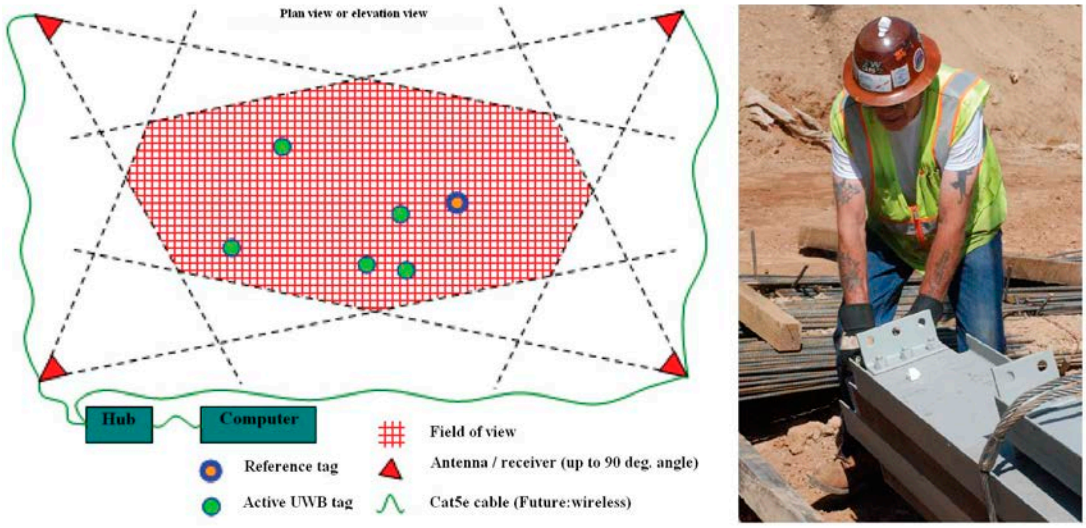


FIG. 29. Ultrawideband receiver and hub system with tags on an ironworker's hat and material (reproduced from Ref. [139] with permission).

6.3.2.3. Facility hazard surveys

Maintaining an ongoing facility registry of workplace hazards is considered good practice. Such a registry can be used during work assessment to plan job activities and protective measures. Development of such a registry can occur during early phases of design and construction and maintained up to date as new information is obtained. All workgroups at a facility can be part of this activity, which may be accomplished by rotating area housekeeping responsibilities, identifying ownership areas for each group, or holding special 'hazard hunt' days (see Fig. 30) to identify previously unacknowledged workplace hazards. New facilities should have special attention paid during design to assist in minimizing hazards, and an initial hazard survey should be done late in construction or during commissioning to attempt to detect previously unknown hazards.

Manufacturers' instructions or data sheets for chemicals and equipment should be reviewed as they can be very helpful in explaining hazards and putting them into perspective. Accident and sickness records for older facilities may identify less obvious hazards. Non-routine operations (e.g. maintenance, cleaning operations or changes in operating cycles) and long term hazards to health (e.g. high levels of noise or exposure to harmful substances) should be reviewed.

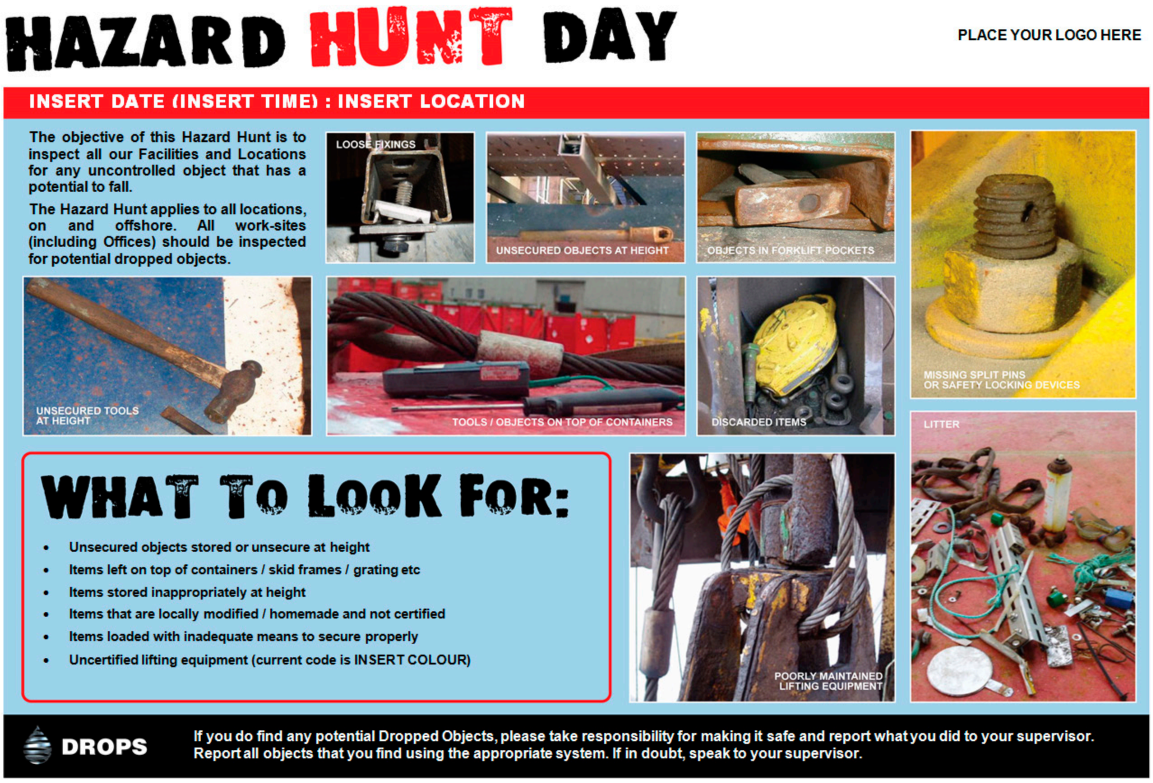


FIG. 30. Poster promoting hazard identification day (reproduced from Ref. [141] with permission courtesy of Dropped Objects Prevention Scheme).

6.3.2.4. Signage

Significant risks or hazards that cannot be avoided or controlled in any other way, should be marked in the field with appropriate signage. Various jurisdictions have regulations relating the minimum requirements for the provision of workplace safety signs (examples include Refs [142–149]). Signage requirements can include those prohibiting activities (e.g. no smoking, entry or touching), warnings (e.g. flammable, toxic, explosive, corrosive, radioactive, or otherwise hazardous material, electrical, thermal or others hazards), PPE requirements, emergency escape or first aid equipment location signs, firefighting signs and traffic routes (see Fig. 31 for a sample sign for lockout tagout requirements). Other requirements for posting in many jurisdictions can include mandatory posting of a company's OSH policy, workplace violence and harassment policies, and copies or summaries of applicable laws and regulations surrounding OSH, including the rights and responsibilities of workers, supervisors and employers.

6.3.2.5. Hazardous material labelling

Most jurisdictions have regulations surrounding workplace hazardous materials labelling, transport and communication of hazards to workers. The guiding principle of such regulations is that workers have a 'right to know' about the hazards of chemicals used in their workplaces.

Regulations typically include requirements for cautionary labelling of containers of controlled products (including temporary containers when such products are decanted from larger supplier containers), provision of safety data sheets (also known as material safety data sheets) to workers, and education and training programmes for workers, managers and supervisors. Safety data sheets are prepared by product manufacturers and contain information on hazards and on the safe usage of such products. Programmes to implement such regulations are often called WHMIS (workplace hazardous material information systems) or REACH (registration, evaluation, authorization and restriction of chemicals) programmes.

FIG. 31. Examples of facility signage regarding lockout safety (courtesy of W.H. Brady Inc.), hard hat usage (courtesy of China National Nuclear Corporation) and fire prevention (courtesy of Nucleoeléctrica Argentina SA).

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS), a recent United Nations initiative, is standardizing product and transport labelling and the formats for safety data sheets on a worldwide basis. The standard pictograms[11] to be applied for hazard communication (not including transport and shipping labelling) are given in Fig. 32 and standard content for a safety data sheet is given in Table 20.

6.3.3. Hazard identification for new engineering designs or modifications

6.3.3.1. Modification scoping reviews

A preliminary hazard review should be included as part of the reviews needed for a nuclear facility's modification preliminary approval to proceed. This allows the modification approvers to consider the potential hazards to be incurred and the potential cost and difficulty of addressing them. It also serves to sensitize the design team and other project team members as to the OSH issues to be dealt with during the design process. Some considerations at this stage can include the following:

(a) Are any new OSH risks being introduced as part of the modification?
(b) What is the probability and severity of the risks being introduced during installation or operation? (Table 21 shows a potential ranking scheme based on one in use by a nuclear operating organization; higher risk modifications based on the scoping receive higher levels of scrutiny during design and during approvals.)
(c) Will the design require a pre-start health and safety review (see Section 6.6.4)?
(d) Will the new process or facility impact on existing or require new OSH field equipment or emergency response arrangements (e.g. rescue equipment, emergency showers, fire extinguishers, fire planning and OSH training)?

[11] Available at www.unece.org/trans/danger/publi/ghs/pictograms.html

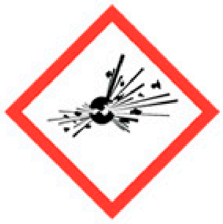
Flame

- Flammables
- Pyrophorics
- Self-heating
- Emits flammable gas
- Self-reactives (types B-F)
- Organic peroxides (types B-F)

Flame over circle

- Oxidizers

Exploding bomb



- Explosives
- Self-reactives (type A,B)
- Organic peroxides (type A,B)

Corrosion

- Skin corrosion / burns
- Eye damage
- Corrosive to metals

Exclamation mark

- Irritant (skin and eye)
- Skin sensitizer
- Acute toxicity (harmful)
- Narcotic effects
- Respiratory tract irritant
- Hazardous to ozone layer (non-mandatory)

Gas cylinder

- Gasses under pressure

Skull and crossbones

- Acute toxicity (fatal or toxic)

Health hazard

- Carcinogen
- Mutagenicity
- Reproductive toxicity
- Respirator sensitizer
- Target organ toxicity
- Aspiration toxicity

Environment (non-mandatory)

- Aquatic toxicity

FIG. 32. United Nations GHS standard pictograms.

TABLE 20. STANDARD CONTENT OF SAFETY DATA SHEETS ACCORDING TO THE GHS

Safety data sheet section	Comments
1. Identification	Identification of the substance or mixture (GHS identifier and other unique identifiers) Supplier's details (name, full address and phone numbers) Recommended use of the chemical and restrictions on use Emergency phone number
2. Hazard(s) identification	Classification of the substance or mixture GHS labels, including precautionary statements Other hazards which do not result in classification
3. Composition/information on ingredients	Substances — Chemical identity — Common name, synonym of the substance — CAS number and other unique identifiers — Impurities and stabilizing additives Mixtures (for all hazardous ingredients) — Chemical identity — Identification number — Concentration range
4. First aid measures	Description Most important symptoms/effects, acute and delayed If needed, indication of immediate medical attention and special treatment
5. Firefighting measures	Suitable extinguishing media Specific hazards arising from the chemical Special protective equipment and precautions for firefighters
6. Accidental release measures	Personal precautions, protective equipment and emergency procedures Environmental precautions Methods and materials for containment and cleaning up
7. Handling and storage	Precautions for safe handling Conditions for safe storage (including incompatibilities)
8. Exposure controls/personal protection	Control parameters Appropriate engineering controls Individual protection measures, including PPE
9. Physical and chemical properties	Appearance Odour and odour threshold pH Melting/freezing point Initial boiling point and range Flash point Evaporation rate Flammability (solid, gas) Upper/lower flammability or explosive limits Vapour pressure and density Relative density Solubility Partition coefficient n-octanol/water Auto-ignition temperature Viscosity

TABLE 20. STANDARD CONTENT OF SAFETY DATA SHEETS ACCORDING TO THE GHS (cont.)

Safety data sheet section	Comments
10. Stability and reactivity	Reactivity Chemical stability Possibility of hazardous reactions Conditions to avoid Incompatible materials Hazard decomposition products
11. Toxicological information	Provide data for all the health hazards covered by the GHS — if data for any of those hazards are not available, they should be listed on the safety data sheets with a statement that data are not available Information on the likely routes of exposure Symptoms related to the physical, chemical and toxicological characteristics Delayed and immediate effects and chronic effects from short or long term exposure Numerical measures of toxicity (i.e. acute toxicity estimate) Interactive effects Where specific chemical data are not available Mixtures Mixture versus ingredient information Other relevant information
12. Ecological information	Toxicity Persistence and degradability Bioaccumulative potential Mobility in soil Other adverse effects
13. Disposal considerations	Disposal methods
14. Transport information	UN Number UN Proper Shipping Name Transport hazard class Packing group, if applicable Environmental hazards Special precautions for user Transport in bulk according to Annex II of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and the IBC Code [150]
15. Regulatory information	Regulatory information not provided elsewhere in the safety data sheets Safety, health and environmental regulations specific for the chemical in question
16. Other information	Date of preparation of the latest version of the safety data sheets Clear indication of the changes made to the previous revision Key/legend to abbreviations and acronyms used in the safety data sheets Key literature references and sources for data used to compile the safety data sheets

Note: CAS — Chemical Abstracts Service; GHS — Globally Harmonized System of Classification and Labelling of Chemicals; PPE — personal protective equipment.

TABLE 21. SAMPLE OCCUPATIONAL SAFETY AND HEALTH SCOPING ASSESSMENT TABLE FOR MODIFICATIONS

Probability / Severity	High Worker exposed to multiple hazards over a wide variety of non-routine tasks	Medium Worker exposed to a single hazard over a wide variety of non-routine tasks or to multiple hazards for routine tasks	Low Worker exposed to a single hazard for routine tasks
Fatality or permanent injury			
Lost time accident or temporary disability			
Medically treated accident			

Source: Canadian Centre for Occupational Health and Safety, www.ccohs.ca/oshanswers/hsprograms/hazard_control.html

Risks identified during this scoping phase should be documented and addressed by the project team as part of the modification design. A design process to help do this, known as a COMS review, is discussed in the next section.

6.3.3.2. Constructability, operability, maintainability and safety reviews

Industrial safety reviews are often performed during the scoping or detailed design phases of a project to help address safety issues prior to them impacting on facility workers. Such reviews can be standalone reviews or be part of modification constructability or the COMS process. The concept is often referred to as 'safety by design', and encourages designers to 'design out' health and safety risks during early stages of design development. In EU Member States, construction designers are legally bound to design out risks during design development to reduce hazards in the construction and end use phases via the Mobile Worksite Directive [151] (also known as construction, design and management regulations [152] in the United Kingdom).

Design tools such as building information management systems can allow visualizations of key construction activities, and make planning for hazardous activities easier. They can also facilitate the early incorporation of safety elements, such as provisions for fall protection, lift/crane access, temporary access, confined space access and temporary structure planning into initial designs [5].

The CII defines constructability as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" [153]. It involves obtaining current construction expertise at early project stages and incorporating such expertise into the project planning and design stages. A constructability planning workshop is part of the process and attempts to fully exploit construction experience in a timely and structured fashion. Such a workshop covers the use of special construction methods, site logistics, equipment access, site security planning, industrial safety and other aspects.

A COMS workshop takes a similar approach and is used by numerous nuclear operating organizations to confirm that a modification is fit for its purpose. In such a workshop, construction, operations and maintenance expertise is sought for a particular project, which is incorporated into project planning and detailed designs. The project or modification manager typically leads the meeting. A follow-up meeting is typically held to confirm that the issues identified have been satisfactorily addressed. Technical specialists with knowledge of ergonomics, industrial hygiene, human factors, fire protection, chemistry, procurement, training or other areas might also attend the meetings. Of particular interest is to ensure that safety considerations are not compromised during the modification's construction, operation or maintenance. Such workshops typically follow a structured checklist, identify potential COMS issues and dispositions them as either fully addressed in the design, not relevant to the design, presenting negligible risk as assessed, can be addressed via administrative controls or soft solutions, or cannot be addressed in modification design and contingencies need to be in place. Appendix IV contains a list of sample industrial safety related questions that can be considered for a COMS meeting.

6.4. ELIMINATION OR SUBSTITUTION

Elimination removes a hazard from the workplace, while substitution replaces hazardous materials or machines with less hazardous ones. Elimination is the most effective way to control a risk because the hazard is no longer present. It is the preferred way to control a hazard and should be used whenever possible.

Hazardous chemicals can often be substituted with safer alternatives. Such an approach can often completely eliminate exposure to hazardous chemicals, reduce the potential for chemical accidents, reduce disposal costs and remove concerns regarding worker compliance and equipment maintenance. Eliminating or reducing chemical hazards at the source, when coupled with a thoughtful, systematic evaluation of alternatives and the adoption of safer chemicals, materials, products and processes, can provide substantial benefits to both workers and businesses.

Many jurisdictions mandate through legislation substitutions of materials with those that are less hazardous where feasible. The International Chemical Secretariat, in Sweden, maintains a ‘substitute it now’ list of chemicals[12] that are considered substances of very high concern. Such materials should be considered for substitution under current or potential future legislation.

Some examples of chemical substitutions from the Canadian Centre for Occupational Health and Safety are listed in Table 22. Potential substitutes should be evaluated based on their effectiveness, process compatibility, control measures required, waste disposal and hazard assessment. Some properties to consider during hazards assessment include the chemical’s vapour pressure, short and long term health effects, skin toxicity, respiratory sensitivity, cancer causing potential and reproductive effects, physical hazards (e.g. fire and explosion hazard) and whether an equivalent chemical is already in use at the location.

Another type of substitution is using the same chemical but it in a different form. For example, a dry, dusty powder could be an inhalation hazard; but as pellets or crystals, there may be less dust in the air and therefore less exposure.

A 2008 study by the American Industrial Hygiene Association demonstrated that making process improvements designed to reduce or eliminate worker exposures to hazardous chemicals resulted in greater savings and other benefits when compared to implementing controls further down the hierarchy (i.e. engineering controls, administrative and work practice controls and PPE) [154].

6.5. ENGINEERING CONTROLS

Engineering controls include designs or modifications to plants, equipment, ventilation systems and processes that reduce the source of exposure. They may include process controls, enclosure or isolation of emission sources, or ventilation (see Table 23).

TABLE 22. EXAMPLE CHEMICAL SUBSTITUTIONS

Chemical	Effect	Substitute
Carbon tetrachloride	Causes liver damage, cancer	1,1,1-trichloroethane, dichloromethane
Benzene	Causes cancer	Toluene, cyclohexane, ketones
Pesticides	Causes various effects on the body	‘Natural’ pesticides such as pyrethrins
Organic solvents	Causes various effects on the body	Water detergent solutions
Leaded glazes, paints, pigments	Causes various effects on the body	Versions that do not contain lead
Sandstone grinding wheels	Causes severe respiratory illness due to silica	Synthetic grinding wheels such as aluminium oxide

[12] Available at http://sinlist.chemsec.org

TABLE 23. EXAMPLE ENGINEERING CONTROLS TO ADDRESS HAZARDS

Type of control	Example
Process change	Use wet methods rather than dry when drilling or grinding. ‘Wet method’ means that water is sprayed over a dusty surface to keep dust levels down or material is mixed with water to prevent dust from being created.
	Use an appropriate vacuum or ‘wet method’ instead of dry sweeping (e.g. with a broom) to control dust and reduce the inhalation hazard.
	Use steam cleaning instead of solvent degreasing (but be sure to evaluate the potentially high temperature hazard being introduced such as heat stress).
	Use electric motors rather than diesel ones to eliminate diesel exhaust emissions.
	Float ‘balls’ on open surface tanks that contain solvents (e.g. degreasing operations) to reduce solvent surface area and to lower solvent loss.
	Instead of conventional spray painting, try to dip, paint with a brush, or use ‘airless’ spray paint methods. These methods will reduce the amount of paint that is released into the air.
	Decrease the temperature of a process so that less vapour is released.
	Use automation (e.g. carts, mechanical lifts, cranes) to handle materials and equipment — the les workers have to handle, the less potential there is for exposure.
	Use mechanical transportation rather than manual methods.
	Use prefabrication and modularization design and production processes to reduce clutter and activity on job sites and minimize material handling.
Enclosure and isolation	Specify or retrofit enclosed or otherwise designed equipment to keep hazards physically away from workers. Examples include machine guards, glove boxes, abrasive blasting cabinets or remote control devices.
	Create a contaminant free booth either around the equipment or around employee workstations.
	Specify physical equipment isolation means to be provided when ordering equipment (e.g. valves, breakers).
Ventilation	Remove or dilute an air contaminant using local exhaust ventilation (in accordance with local regulations surrounding environmental air regulations).

Personnel who design or plan construction or renovation projects, plant modifications or who impact on worker activities or tooling, should receive training in OSH, and should integrate worker safety and health into the design and planning process in accordance with national laws, regulations and practice. A process that involves reviews of a project’s COMS aspects (i.e. a COMS review) is described in Section 6.3.3.1. Such a process would help identify suitable engineering controls that would address identified hazards during project construction or during subsequent operations or maintenance activities.

The CII has developed a software based Design for Construction Safety Toolbox [155] and related training material [156] to assist designers and others to address construction worker safety in their designs. References [157, 158] address the application of safety instrumented systems for the process industries and require a process hazard and risk assessment to be carried out to enable the derivation of specifications for safety instrumented systems.

6.6. ADMINISTRATIVE CONTROLS

Administrative controls are non-physical processes or practices employed to reduce the potential for accidents. These control measures have many limitations because the hazard itself is not actually removed or reduced. They rely on human judgement, training and personal initiative. As such, they can be difficult to implement, maintain and are not always a reliable way to reduce exposure. Administrative controls, however, include many good safe work practices that are essential to any OSH programme. This section describes typical administrative controls in use at nuclear facilities.

6.6.1. Human performance event free tools

Personnel working at a nuclear facility are responsible for trying to anticipate situations that can lead to interference or faults and to use adequate work methods. The probability for faults or mistakes to happen in various activities can be reduced by using different human performance event free tools. These tools focus on anticipating, preventing and catching active errors before they become events. They help individuals and work teams to maintain control of the work situation [159]. Tools that should be used all the time (called fundamental tools) include [159]:

— Situational awareness;
— Task preview;
— Job site review;
— Questioning attitude;
— Self-checking (also known as STAR: stop, think, act, review), stop when unsure;
— Procedure use and adherence;
— Effective communication;
— Three-way communication;
— Phonetic alphabet.

Conditional or supplementary human performance tools are used depending on the work situation (see Table 24). These can include [159]:

— Pre-job briefing;
— Verification practices, including concurrent verification, independent verification and peer checking;
— Flagging;
— Keeping track in procedures step-by-step (place keeping);
— Shift turnover;
— Post-job review.

Each of these tools is described in detail in Refs [160, 161]. Training and indoctrination in the use of these tools is best practice for all nuclear facility staff, and leadership should encourage and champion their use. Industrial safety training should demonstrate the proper use of these tools in industrial safety. These tools can be applied to minimize industrial safety events and related injuries. Regardless of how conscientious personnel are, they can still make mistakes, sometimes at inopportune times. Errors can be made by omission or commission. Organizations can impact individual behaviour via production levels and pressures, quality management systems applied, workplace human factors and ergonomics, organizational development and learning processes in place, and human performance technology applied, among other things. In nuclear facilities, industrial safety related mistakes can include operating the wrong equipment, working on equipment that is not isolated, wearing the wrong PPE, taking shortcuts within procedures, working outside of procedures, performing unsafe acts and others.

Defences against human error can involve engineered, administrative, cultural and oversight controls. Ultimately, an individual's behaviour determines the level of safety and performance achieved. At high performing organizations, individuals on all levels take responsibility for their behaviour and are committed to improving themselves as well as the task and the work environment. Reference [159] covers managing human performance in nuclear facilities, and publications which address the improvement of human performance have been published by

TABLE 24. HUMAN PERFORMANCE EVENT FREE TOOLS AND EXAMPLE APPLICATIONS

Tool	Description	Industrial safety application examples
Situational awareness tools	Situational awareness can be defined as the accuracy of a person's current knowledge and understanding of actual conditions compared to expected conditions at a given time. It means the individual clearly understands the job requirements, the equipment condition, the work environment (including other workers in the area), and confirms the correct unit and equipment before acting.	Worker explicitly takes time prior to starting a task to look at the surrounding work environment and what hazards are present that could cause injury, as well as the potential for the work to damage equipment or harm personnel in the area. This may necessitate additional controls on the work or changes in work practices.
Task preview	Before starting work, individuals conduct a task preview, including reviewing procedures and other related documents to familiarize themselves with work scope, task sequences and critical steps; a conversation with those who performed the job in the past; and a walkdown of the job site. Critical steps, possible errors, and 'worst things that can happen' are identified, and controls evaluated. Can be part of a pre-job briefing.	Tasks reviewed in detail prior to commencement to ensure the work, its hazards and potential errors and consequences are understood.
Job site review	Taking the time necessary to get acquainted with the immediate work area, to develop an accurate understanding of critical indicators, system/equipment condition, work environment, hazards and team members at a job site.	Inspect work location for new or unanticipated hazardous conditions. A 'line of fire' review (see Section 6.3.2.1(c)) is a good practice at this stage.
Questioning attitude	Individuals stop and resolve hazards, warnings, error-likely situations or uncertainties before proceeding with the job. When doubt arises, follow up with the discovery of facts, not assumptions, to reveal more knowledge about the situation and eliminate the doubt.	If unclear with proper protective equipment to be worn obtain advice from an industrial safety professional.
Self-checking (also known as STAR: stop, think, act, review), stop when unsure	Individual focuses attention on appropriate component or activity; thinks about the intended action; understands the expected outcome before acting, and verifies the results after the action.	Prior to operating isolation devices, the individual confirms the correct device and what is expected upon operating the applicable device (e.g. pump flow stops, indicating lights change state, etc.).
Procedure use and adherence	Procedure adherence means understanding a procedure's intent and purpose, and following its direction. The user performs all actions as written in the sequence specified by the document. However, if it cannot be used safely and correctly as written, then the activity is stopped, and the procedure is revised before continuing.	Work procedure may specify required PPE, and when PPE is not available then the work is stopped until the desired PPE is available or alternate acceptable PPE is incorporated into the written procedure.
Effective communication	Effective communication is an important defence in the prevention of errors and events. Oral communication possesses a greater risk of misunderstanding compared to written forms of communication. Misunderstandings are most likely to occur when individuals have different understandings, or mental models, of the current work situation or use terms that are potentially confusing. Therefore, confirmation of verbal exchanges of operational information between individuals must occur to promote understanding and reliability of the communication.	

TABLE 24. HUMAN PERFORMANCE EVENT FREE TOOLS AND EXAMPLE APPLICATIONS (cont.)

Tool	Description	Industrial safety application examples
Three-way communication	Three-way or the 'repeat back' method is used to communicate changes to physical facility equipment during work activities via face to face, telephone, or radio and requires three verbal exchanges between a sender and a receiver to promote a reliable transfer of information and understanding. The person originating the communication is the sender and is responsible for verifying that the receiver understands the message as intended. The receiver makes sure he or she understands what the sender is saying.	Used when transferring instructions to another person verbally, for example: Sender: "Please close valve 3-3312–Valve 22." Receiver: "I understand that you want me to close valve 3-3312–Valve 22." Sender: "That is correct."
Phonetic alphabet	Several letters can sound alike when spoken and can be confused in stressful or noisy situations, for example, 'D' and 'B'. The phonetic alphabet specifies a common word for each letter of the alphabet. For example, 2UL-18L and 2UL-18F would be stated "two uniform Lima dash eighteen Lima" and "two uniform Lima dash eighteen Foxtrot".	When operating isolating devices or specifying information in a nuclear facility over phone, radio or face to face. Sender: "Please open circuit breaker 2-53300–circuit breaker 22 Charlie." Receiver: "I understand that you want me to open circuit breaker 2-53300–circuit breaker 22 Charlie." Sender: "That is correct."
Pre-job briefing	Meeting of individual performers and supervisors conducted before performing a job to discuss the tasks, critical steps, hazards and related safety precautions. This meeting helps individuals to better understand the task(s) to be accomplished, applicable operating experience, blackout conditions and associated hazards. Sometimes called a 'tailgate' or 'tailboard' meeting in construction environments.	Typically held at the start of a shift or a new work assignment (e.g. travel to a new site). Advanced techniques have the workers brief themselves on the work and hazards with supervisors taking more of an oversight role.
Verification practices, including concurrent verification, independent verification and peer checking	Refers broadly to four tools: peer checking (PC); concurrent verification (CV); independent verification (IV); and peer review (PR). These tools involve a second (or more) person to confirm actions and results achieved by a performer. While PC focuses on preventing a mistake by the performer, IV and CV focus more on confirming correct configuration or status of equipment or documents. PR is a defence to detect errors and defects before completion of documents by reading and checking the quality of another's work product (design, calculation, procedure, work package, etc.).	Second individual verifies the sequence and correctness of isolations proposed for work protection.
Flagging	If a component is physically near other similar looking components and is handled multiple times, flagging helps the user consistently touch the correct component. An individual distinctly marks the correct component with a flagging device that helps the performer visually return to the correct component during the activity or after a distraction or interruption. Individuals can also use flagging to identify similar components that are not to be touched or manipulated.	Physically marking work sites and equipment being worked on by ropes, tape or other means.

TABLE 24. HUMAN PERFORMANCE EVENT FREE TOOLS AND EXAMPLE APPLICATIONS (cont.)

Tool	Description	Industrial safety application examples
Keeping track in procedures step-by-step (place keeping)	Physically marking steps in a procedure that have been completed. Effective place keeping prevents omitting or duplicating steps. If the user is interrupted or delayed, this technique will help in returning to the last step performed.	Organizations typically have standards for procedures that require specific placekeeping methods (check boxes, signatures, etc.) in different circumstances. For complex work, a dedicated worker may be assigned to continually mark up a master procedure copy as work proceeds. Or workers themselves stop and mark procedures after each step.
Manager in field observation and coaching (behavioural observations)	Supervisors and managers observe field activities and provide immediate feedback on work activities. Observation goals can be established and measured for each team (e.g. ten per week). In an industrial safety context, these can include targeted observations of: — Management or worker involvement initiatives; — Work planning performance; — Line of fire; — PPE usage; — Fall protection; — Observation and intervention practices; — Barricading and signage; — Housekeeping; — Safe use of tools; — Confined space practices; — Work permits; — Others.	Typical observation and coaching programmes look at field safety practices as a common theme.
Shift turnover	Turnover is the orderly transfer of work related information, tasks and responsibilities between individuals or crews. A turnover provides time for the oncoming individual(s) to establish an accurate mental model of the work activity (situation awareness) before assuming responsibilities and commencing work.	Turnover is important not just for control room activities but for any job that transfers over a shift to a new crew. Known safety hazards and precautions in effect should be part of the turnover review.
Post-job review	A method of self-assessment conducted after a work activity to solicit feedback from the participants. Usually, the feedback involves a face to face meeting between the performer(s) and the supervisor(s).	A good method to incorporate lessons learned into work practices and procedures. Any additional safety hazards or difficulties encountered should be fed back to the assessors or procedure writers for incorporation into the next similar job.

Note: PPE — personal protective equipment.

the IAEA, INPO, the International Society for Performance Improvement, the United States Department of Energy and WANO.

6.6.2. Job observations

Management and supervisors are encouraged to spend time in the field, to observe and advise teams and workers. Such job observations are used to monitor and encourage compliance with applicable industrial safety and other requirements, and to facilitate measurement of leading performance measures on safety (see Section 7.1).

Many nuclear facilities have formal observation and coaching programmes that are designed to engage employees and reinforce behavioural expectations.

What leaders systematically pay attention to communicates their major beliefs. Attention to safety concerns during regular field observations can have a powerful influence on an organization's culture if the leaders are consistent in communicating the expected behaviours. Section 3A of Ref. [162] indicates that nuclear supervisor roles include maintaining standards (identifying when worker performance does not meet expectations and confronting performance shortfalls), and coaching workers in a positive manner (as opposed to criticizing).

In recent years, there has been a trend to expanding observation programmes to include all workers on a job site as safety observers. Workers would be expected to regularly report safety observations of their peers — both good and bad [5]. This can serve the dual purpose of getting more eyes focused on safety, and helping all workers better internalize lessons and recognize their own behaviours.

6.6.3. Job safety analysis

JSA is a procedure that helps integrate accepted safety and health principles and practices into a particular task or job operation. In a JSA, each basic step of the job is reviewed to identify potential hazards and to recommend the safest way to perform the step. A JSA can also be called a job hazard analysis or a job hazard breakdown.[13] Job assessors or workers perform JSAs prior to a task, and workers follow them during task execution. Workers involved in the job should be heavily involved in JSA preparation, even if they do not prepare them themselves. If conditions or the situation changes, the work should be paused until the JSA is revised and recommunicated to all involved in the task. The four basic stages in conducting a JSA are:

(a) Selecting the job to be analysed;
(b) Breaking the job down into a sequence of steps (making sure each step is not too general; a rule of thumb is that most jobs can be described in ten steps);
(c) Identifying potential hazards (based on job observations, knowledge of accident and injury causes, and experience);
(d) Determining measures to eliminate, control or mitigate the hazards.

An example of a completed JSA for the simple activity of changing a car tyre is given in Table 25.

Ideally, all jobs at a nuclear facility should be subjected to a JSA. In some cases, there are practical constraints posed by the time and effort required to do a JSA. Another consideration is that each JSA will require revision whenever equipment, raw materials, processes or environments change. For these reasons, it is usually necessary to identify the characteristics of which jobs are to be analysed, and include such requirements in site work planning and assessment processes. Even if analysis of all jobs is planned, this step ensures that the most critical jobs are examined first.

6.6.4. Pre-start health and safety reviews

Some jurisdictions have specific industrial safety regulations regarding the startup of new equipment or processes [163]. Such regulations often require what are called 'pre-start health and safety reviews' (PSRs). PSRs require written reports by qualified individuals (typically professional engineers) that detail the measures (steps, actions or engineering controls) necessary to bring the construction, addition, installation or modification into compliance with applicable industrial regulatory provisions surrounding exposure to chemicals, other designated substances and other hazards. The review would also confirm that these measures have been adequately put into place. Such controls might include physical protective elements such as machine guards and emergency stop devices, or the design of racks, stacking structures, hoists, spray booths or chemical process systems that are designed to certain published codes and standards. Where PSRs are required, they need to be completed prior to the final installation testing or commissioning steps at where the applicable hazard would become relevant.

[13] See www.ccohs.ca/oshanswers/hsprograms/job-haz.html

TABLE 25. SAMPLE JOB SAFETY ANALYSIS FOR CHANGING A CAR TYRE

Sequence of events	Potential accidents or hazards	Preventative measures
Park vehicle	Vehicle too close to passing traffic	Drive to an area well clear of traffic Turn on emergency flashers
	Vehicle on uneven, soft ground	Choose a firm, level parking area
	Vehicle may roll	Apply the parking brake Leave the transmission in PARK Place blocks in front and behind of the wheel diagonally opposite to the flat
Remove spare and tool kit	Strain from lifting spare	Turn spare into an upright position in the wheel well Using your legs and standing as close as possible, lift spare out of truck and roll to flat tire
Pry off hub cap and loosen lug bolts (nuts)	Hub cap may pop off and hit you Lug wrench may slip	Pry off hub cap using steady pressure Use proper lug wrench; apply steady pressure slowly
....	....	....

6.6.5. Housekeeping, cleanliness and material condition programmes

Most industrial safety regulations require that workplaces be kept clear of obstructions, debris and items likely to introduce a hazard (e.g. clause 11 of Ontario Regulation 851, Occupational Health and Safety Act 1990). Housekeeping, cleanliness and material condition programmes refer to processes that ensure facilities, equipment, work areas and access routes are kept in such an acceptable condition. Such a condition supports safe construction, safe and reliable operation and maintenance during normal plant operation, supports facility fire safety provisions, and ensures that emergency plant operations are not inhibited. The three elements are interrelated — reaching a good standard in one is difficult without reaching a good standard in them all. The degree to which they are effectively managed is an indicator of the safety culture at a nuclear facility [164].

Paragraphs 6.20–6.26 of NS-G-2.14 [19] cover housekeeping and material condition recommendations. Some examples of conditions which would exist at a plant which has good levels of housekeeping and cleanliness include [164]:

“— good physical characteristics and environmental conditions are present;
— cleanliness and order are evident throughout the plant;
— portable equipment, such as ladders, scaffolding, heavy maintenance equipment and fire extinguishers are stored in designated areas when not in use;
— work areas are tidy with equipment and materials neatly laid out;
— equipment and systems are free of significant amounts of dust and debris;
— access to equipment is not impeded by scaffolding or equipment laydown areas;
— trash containers are readily available and are not overflowing;
— parts and material are not laying about in inactive work areas after work is complete;
— incompatible chemicals are not stored in close proximity to each other;
— radioactive material storage areas are correctly identified and uncluttered;
— protective equipment storage areas are well stocked and tidy;
— pools of water or oil are not evident on the floor areas.”

Experience indicates that regular management attention to housekeeping is necessary to achieve and maintain desired standards. Elements of the management process to deal with this issue are [164]:

"— a clear indication of the desired standard. In addition to a documented standard, it is helpful to set up an area of the plant which has been brought to the desired standard and is maintained at that standard. This is an effective visual training aid. It should be set up in an area which is frequently seen by many personnel so they are reminded of the desired standard;
— a thoughtful training program, which helps people understand why housekeeping and cleanliness matter to them. This may include a discussion of people being injured as a consequence of poor housekeeping, for example;
— a sense of competition between the groups which have responsibility for various areas;
— provision of the necessary resources, both in people and equipment, to achieve the desired standard;
— monitoring of the status of housekeeping and cleanliness on a regular basis both by line management and quality assurance personnel. This can include dedication of one half day per week to a detailed area inspection by a senior manager with the group leader responsible for that area;
— reporting on and rewarding successes, and identifying areas of continuing challenge."

Paragraph 6.21 of NS-G-2.14 [19] recommends that:

"Administrative procedures should be put in place to establish and communicate clearly the roles and responsibilities for plant housekeeping in normal operating conditions, post-maintenance conditions and outage conditions. For all areas of the plant, it should be made clear who bears the responsibility for ensuring that an area is kept clean, tidy and secure. Operations personnel should periodically monitor housekeeping and material conditions[15] in all areas of the plant and should initiate corrective action when problems are identified.

"[15] The material condition concerns the degree to which structures and systems and equipment are kept in a well maintained state."

A process developed in Japan called '6S' (or '5S') [165] can help to create and maintain an organized, clean and high performance work place, which serves as a foundation for continual improvement activities. 'A place for everything, and everything in its place' is the mantra of the method (see Fig. 33). The Ss stand for the following:

— Seiri: Sort (housekeeping);
— Seiton: Set in order (workplace organization);
— Seiso: Shine (cleanup);
— Seiketsu: Standardize (maintain cleanliness);
— Shitsuke: Sustain (discipline);
— Safety: Number one throughout the process.

A typical 6S implementation results in reductions in the area needed for existing operations. It also results in the organization of tools and materials into labelled and colour coded storage locations, as well as 'kits' that contain just what is needed to perform a task. Nuclear work planning task kits prepared for a specific job are an example of this philosophy in action.

6.6.6. Work planning processes

Each task at a nuclear facility requires planning to ensure that work is performed safely through worker understanding of the work activity, the identified hazards, the safe work expectations and the mitigative efforts established to minimize risks. Low risk routine work may be planned and described verbally to workers via a pre-job briefing, while more complex or higher risk activities may require a written plan and reviews by subject matter experts and the potential workers prior to it being implemented. Standard job aids dealing with regularly encountered issues such as ergonomics, falling objects, rescue plans, situational awareness, field visits and others can assist in making this process more efficient. Outages or other periods of high activity need special attention to evaluate the potential safety impacts of doing multiple jobs at the same time (see Section 6.6.15).

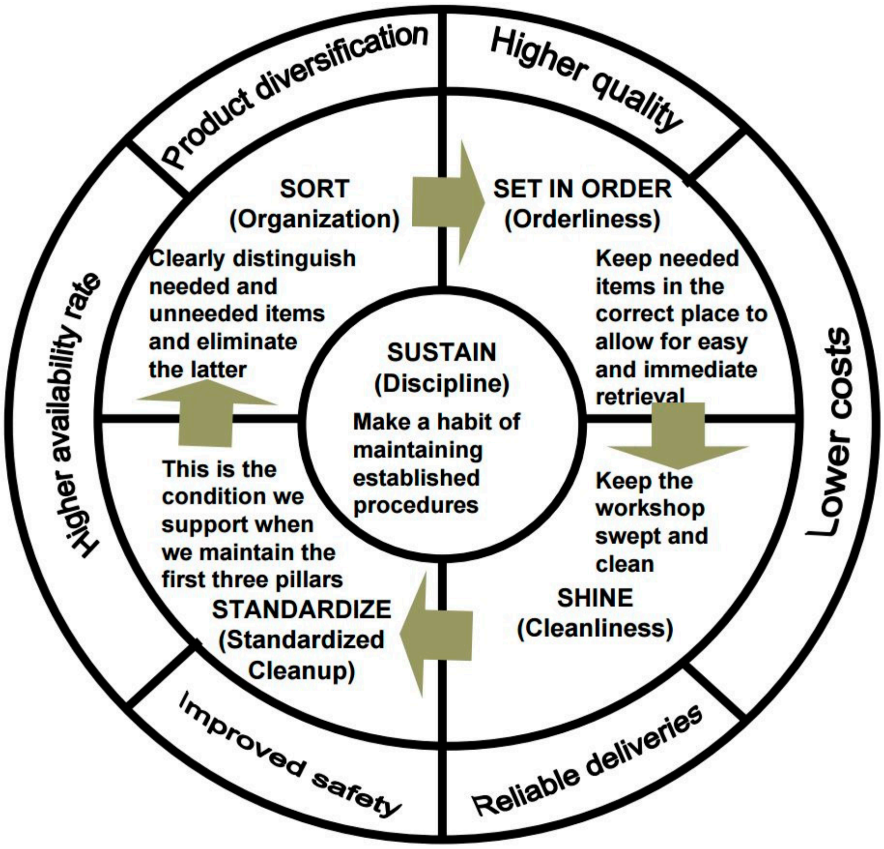


FIG. 33. 6S process wheel.

Organizations should identify the categories of work that require formal written industrial safety work planning. Such categories can include work:

— Using fall arrest systems;
— On or near live exposed electrical equipment (potential for body contact with electricity either directly or through handheld tools or where workers are situated at a distance less than the allowed limits of approach);
— In a confined space;
— Where there is exposure to designated substances;
— With radioactive sources (e.g. industrial radiography);
— In excessive heat and cold;
— Using breathing air systems;
— With diving operations;
— Where excavation, drilling, cutting surfaces or driving rods involves buried services;
— On or near open water where a significant risk of drowning exists;
— Involving helicopters;
— In potentially explosive atmospheres (e.g. gas, dust or vapour);
— Involving manual material handling, without mechanical assistance, of cumulative large loads (e.g. >1000 kg/shift/worker);
— With craning and rigging involving an engineering review for hoisting and rigging, non-routine lifts or lifts where other workers could be struck by the load or vehicle;
— Using unguarded rotating equipment;
— Using transport and work equipment without roll-over protection on any uneven surface;
— On live steam or pressurized systems that may expose a worker to the release of hazardous energy;
— Involving excavations requiring support systems (e.g. deep excavations) or the use of explosives.

Elements of a safe work plan can include the following:

(a) Determination of the type of plan required (i.e. verbal or written) based on the risks associated with the work performed;
(b) Hazard analysis of the work through hazard identification, evaluation and control including identification of specific radiation protection procedures and controls where required, necessary work protection (lockout/tagout);
(c) Discussion of physical requirements of the work and identification by the workers of any physical or other limitations that may reduce their ability to perform work safely;
(d) Identification of situations where a worker cannot work alone;
(e) Roles and responsibilities of each worker for the task and a check of workers' understanding of their role (three-way communication);
(f) Consideration of the need for coordination and communication where multiple work groups or public safety is involved;
(g) Feedback regarding the work activity to enable continual improvement;
(h) Review workers' understanding of the steps to take in the event of an emergency;
(i) After all work breaks, the requirement for workers to evaluate and review the pending work activity to help focus on the task and potential hazards;
(j) Communication of the work plan to workers;
(k) Work monitoring such as supervisory crew safety visits, observation and coaching.

An example of a safe work planning folder from an operating organization is included in Appendix III.

6.6.7. Work protection and lockout/tagout

Operating organizations put into place processes preventing the release of hazardous energy while employees perform servicing and maintenance activities. These processes are referred to as 'work protection' or 'lockout/tagout' (LOTO) depending on the jurisdiction. Such a programme is suited to the needs of the particular workplace and the types of machine and equipment being maintained or serviced. This is generally done by physically isolating machines and equipment (via protective energy isolating devices such as circuit breakers or valves), releasing any stored energy and affixing appropriate lockout or tagout devices to the energy isolating devices. Typically, a site or portion of a site is assigned a single individual known as the 'controlling authority' who is responsible for the administration of all work protection activities in that location.

Processes can be either operator administered, whereby operators (under the authority of the controlling authority) control the operation of the energy isolating devices and affix the tags, or trades administered, whereby the responsible maintenance group physically operates the energy isolating devices and affix the tags (with the permission of the controlling authority). Many nuclear facilities allow for both processes depending on the equipment involved and its safety functions.

Owing to the importance to personnel safety of keeping protective energy isolating devices in the correct state, all staff on a work site need a minimum amount of introductory training to ensure that they know, understand and follow the required work protection processes. Especially important is the need to not touch or operate energy isolating devices without proper approvals.

Designers have a role when specifying new equipment to ensure that it is capable of being locked out. For example, electrical panelboards can be purchased with or without the ability to lock out individual feeder breakers. If not specified as part of design, such a panelboard may arrive on-site without the ability to isolate the individual circuits (see Refs [109, 166–168] for example regulations and standards on lockout/tagout).

6.6.8. Work area control

Individuals need to have clear warnings and instructions not to enter potentially unsafe areas, including areas where work is under way and potential hazards may be exposed. During maintenance activities, for example, normal guards or enclosures around rotating equipment or live electrical equipment may be removed to allow for access by qualified staff.

Individuals responsible for such activities needs to ensure that temporary work areas are adequately controlled. This can include such measures as installing barricades (e.g. fences, walls or tape), installing warning signage with regard to hazards present and access restrictions, and communication via the public address system, email and verbally during the work authorization process when major changes occur. Orientation training should clearly cover the requirement for staff not to enter marked work areas without the permission of the responsible individual.

On a broader basis, vehicular traffic around and into a construction site needs to be carefully planned and controlled. A good traffic management plan includes "project site entry and egress arrangements (including security checks), time limitations for deliveries, use of temporary roads for public traffic, weight restrictions, traffic signals and channeling of vehicles to avoid construction works, access and egress for emergency vehicles, etc." [169]. Access control for facility visitors and the public is discussed in Section 6.6.16.2.

6.6.9. Procurement controls

Procedures should be established and maintained to ensure that:

— Compliance with OSH requirements for the organization is identified, evaluated and incorporated into purchasing specifications;
— PPE, other protective devices, and plant tools and equipment are purchased to required standards;
— National laws and regulations and the organization's own OSH requirements are identified prior to the procurement of goods and services;
— Arrangements are made to achieve conformance to the requirements prior to their use;
— Contractors and service providers maintain OSH standards equivalent to those of the nuclear facility owner;
— Methods to communicate changes in OSHMS requirements to contractors, and to coordinate relevant portions of the OSHMS on multi-employer or multi-contractor sites are in place.

Reference [170] includes a number of guidelines regarding incorporating industrial safety requirements into the procurement and contracting process:

(a) Developing standard procurement templates and clauses to identify owner industrial safety requirements (e.g. site safety procedures, supervisory training, and identification of and minimizing the use of hazardous chemicals);
(b) Conducting prequalification of contractors based on their historical safety performance;
(c) Thoroughly reviewing a contractor's planned OSH programme and historical track record as part of contract bid evaluation, including incentives and penalties into contracts based on industrial safety performance;
(d) Ensuring robust contractor oversight processes are in place that include OSH reporting and owner access rights for inspection activities;
(e) Providing supplier feedback on OSH performance (as discussed in Section 2.5.3, the owner's role in such procurement processes is seen as critical).

The UN Global Compact [171] is an international initiative relating to human rights, labour, environment and anti-corruption, in which companies formally commit to UN Global Compact's ten principles. The nuclear operating organization Vattenfall of Sweden, for example, commits to the principles as part of its supplier code of conduct [172], as well as meeting ILO–OSH guidelines. It also requires its suppliers to do the same. Within the Compact's guidance on labour is a commitment to examine the causes of industrial safety and health hazards, provide information on good practice observed in other countries, and effect necessary improvements.

6.6.10. Contractor safety programmes

Arrangements should be established and maintained for ensuring that the organization's safety and health requirements, or at least the equivalent, are applied to contractors and their workers. CII research [44] on the correlation between injury rates and whether subcontractors receive orientation training on construction sites finds reduction in injury rates for companies that extend training to subcontractor employees. Arrangements for contractors working on-site should:

(a) Include OSH criteria in procedures for evaluating and selecting contractors.
(b) Establish effective ongoing communication and coordination between appropriate levels of the organization and the contractor prior to commencing work. This should include provisions for communicating hazards and the measures to prevent and control them.
(c) Include arrangements for observation and coaching of contractor work activities, reporting of work related injuries, ill health, diseases and incidents among the contractors' workers while performing work for the organization.
(d) Provide relevant workplace safety and health hazard awareness and training to contractors or their workers prior to commencing work and as work progresses, as necessary.
(e) Regularly monitor OSH performance of contractor activities on-site and ensure that on-site OSH procedures and arrangements are followed by the contractors.
(f) Ensure that the contactor implements an improvement/corrective action programme to address any identified deficiencies.

Contracts for construction, installation, maintenance or other support services should reflect the operating organization's high safety priority and proactive approach to industrial safety. Prior to selection of a contractor a prequalification step should be performed that reviews the contractor's industrial safety performance and disqualifies those with poor records. Some information to be reviewed can include a three to five year history for total recordable incident rates, lost time incident rates, days away restricted or transferred rate, and number of fatalities. There are commercial service providers that can provide such independent data on specific companies.[14] Additional documentation to be submitted and reviewed includes:

— Information on the contractor's organization structure supporting OSH (organizational chart highlighting safety responsibility, safety qualifications of safety representatives, site management and field supervision);
— Contractor's written OSH plan (including safety training processes);
— Substance abuse programme;
— Contractor's risk identification and mitigation process;
— Project site specific OSH plan;
— Pre-JSA or task hazard analysis process;
— Contractor's incident investigation process and forms;
— Key safety performance indicators to be monitored;
— Insurance and workplace compensation information;
— References from previous recent projects.

When any contractor fails to meet all of the requirements for prequalification, the owner should either seek additional qualified bidders or request that the bidders closest to meeting the requirements submit a formal mitigation plan for evaluation by the prequalification team.

Contract terms and conditions are an important industrial safety tool. They should consistently require contractor conformance to the operating organization's safety expectations and requirements, and identify incentives and/or penalties based on safety performance. Some descriptions of site or project industrial safety requirements that might be detailed in contracts include those surrounding safety orientations (see Ref. [173]).

— Site safety committee;
— Safety meetings;
— Fall prevention;
— Trenching and excavating;
— Hot work;
— Confined space;
— Cranes and lifts;
— Critical lifts;
— Pre-task/pre-job plans;

[14] See www.isnetworld.com

— Housekeeping;
— Waste management;
— Material control;
— Utilities;
— Work permits;
— Work coordination;
— Use of facilities;
— Site rules (e.g. work hours, alcohol, firearms, prohibited substances, food and hygiene, parking, site access, security and badging).

Construction activities pose a unique set of industrial safety challenges. Hazards and risks present regularly change, large numbers of workers, including temporary workers from different companies and countries can be on-site, and significant infrequently performed operations such as heavy lift craning take place. Significant attention needs to be taken to establish an appropriate safety culture within the various workers and companies involved, and to ensure that processes that address fall protection, confined spaces, electrical hazards, craning, rigging, scaffolding, ladders, pinch points, PPE and others are in place and are followed. Significant owner or general contractor OSH oversight, surveillance programmes and monitoring is recommended. Hundreds of procedures, forms and work instructions are typically required in this process within the owner's OSHMS and in that of the contractors or constructors. As shown in Fig. 34, a formal review of a company's OSHMS plans should be done prior to starting work.

The provision of site specific orientation and indoctrination information and training is an important first step. Some organizations implement 'gap training' that aims to ensure new contractors who enter nuclear sites understand the expectations for working on the site, and have the required knowledge regarding how to do so safely in accordance with site procedures. This may include providing information on the organization's safety policy, PPE requirements, foreign material exclusion, human performance event free tools, emergency response and showing examples of well maintained worksites in accordance with site standards.

Once site work has commenced, a key activity is to provide proactive project and industrial safety oversight and support of contractors. Such activities can include the identification of a specific contract owner and contract monitors, observing training, pre-job briefings and work execution, monitoring adherence to contact provisions, identifying non-conformances and requiring correction and follow-up on hazards and unsafe conditions (see Ref. [170] for further details on procurement and oversight of services).

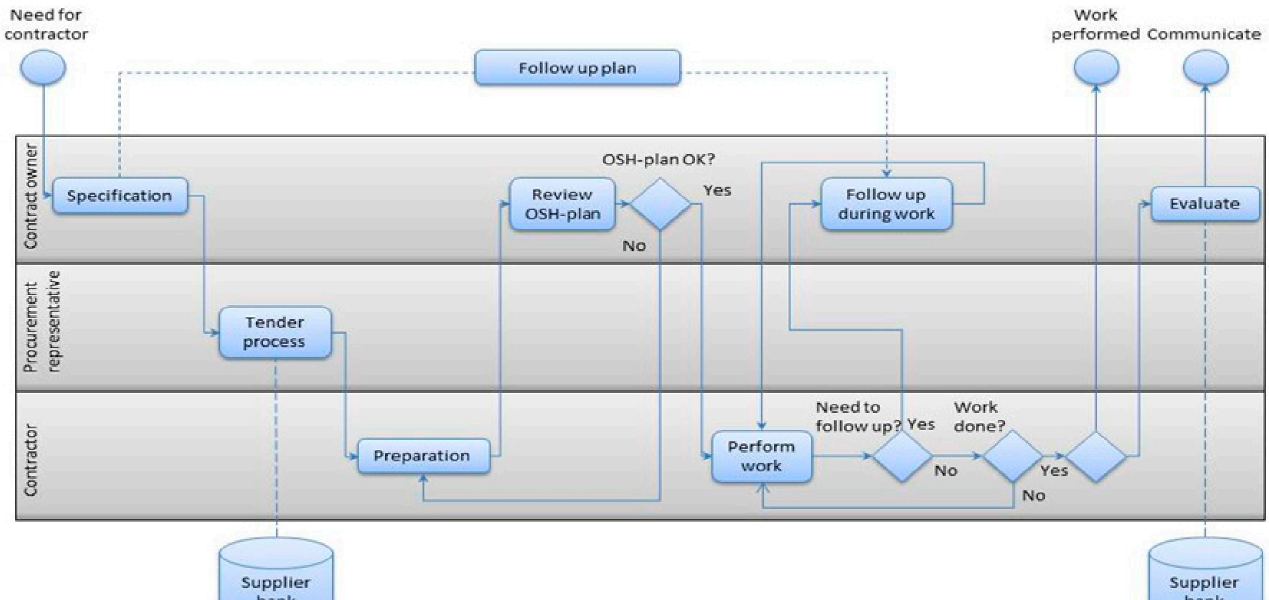


FIG. 34. Example contract management process.

6.6.11. Fire safety programmes

Nuclear facilities have extensive programmes to address fire safety. Such programmes ensure that safety related systems are available to operate when required, and help to ensure personnel/life safety by preventing and mitigating the impacts of any fires. Numerous IAEA safety standards apply to these fire programmes (see Table 1), including requirements surrounding design and analysis of fire protection systems, fire barriers, maintenance and testing of fixed and portable firefighting equipment, control of combustible materials, training, drills and exercises.

NS-G-2.1 [21], on fire safety in the operation of nuclear power plants, details in section 6 necessary controls on combustible materials and ignition sources in a facility. Specific controls for any ‘hot work’ (typically, special hot work permits) are recommended. NS-G-2.1 [21] defines hot work as “Work having the potential for causing fire, particularly work involving the use of open flames, soldering, welding, flame cutting, grinding or disk cutting” (see also Refs [174–177]).

Plant housekeeping programme inspections (see Section 6.6.5) should confirm that fire safety related housekeeping controls, such as limits on temporary combustible materials in the facility, are in place. Permanently installed and portable fire related safety equipment should be regularly maintained, inspected and tested periodically. Fire and emergency response planning is an essential part of a facility’s fire protection programme. Planning for both on-site and off-site responders (e.g. civil firefighting groups) is required. This is discussed more thoroughly in Section 6.8.

6.6.12. Tool and equipment control

Improper control of tools and equipment can lead to industrial safety hazards. Safety related equipment (e.g. PPE, test and measurement equipment, and hoisting and lifting apparatus) can require calibration or inspection, or they may have a defined acceptable maximum service life, before they need to be replaced. Inadequate control around tool purchases can permit uncertified tools (e.g. those not meeting required national safety standards) to be brought onto site through operating organizations or contractors. Site procedures surrounding such issues need to be developed and implemented. Figure 35 shows an example of tagging done at Électricité de France for a sling and a lifting lug with yellow tags showing the next needed inspection date.

6.6.13. Drug and alcohol screening

Some jurisdictions have implemented mandatory drug and alcohol screening for nuclear employees or construction workers, as substance abusers are more likely to be unsafe on a job site. Regimes can include pre-employment screening, random testing and post-accident testing. An ILO code of practice on the management of alcohol and drug related issues in the workplace is available [178].

FIG. 35. Tool expiry date labelling (courtesy of Électricité de France).

6.6.14. Targeted safety programmes

A targeted safety programme is one that is designed to prevent specific types of injuries, such as hand injuries, trips, slips, and falls, arc flash injuries, impact injuries, driving accidents and trench cave ins. Where trending shows a high prevalence of incidents in a specific area, a targeted safety programme can be implemented to drive improvements in this area across the organization. A 'terms of reference' is typically prepared to define the scope of the project, and a project plan is developed identifying the tasks, accountabilities and timeframe to complete each action. Resources are then allocated. An integrated improvement plan can be developed with actions at the corporate level for company wide rollout, as well as business unit specific actions. Corporate wide actions include IT system changes, governance changes, communications and other actions which can be developed and implemented centrally for use across the organization. Each business unit develops action plans specific to their business to drive local improvements in areas that are unique to their business. Actions are documented, with regular monitoring and progress reports. Some examples of targeted safety programmes are provided in Appendix VII.

CII research on implementing targeted programmes [179, 180] finds that most successful implementations follow a similar process of establishing a programme target or benchmark, appointing a programme champion to drive programme implementation, developing, communicating and implementing the programme, monitoring results and correcting as required, and measuring and celebrating success. Successful programmes focus on hazard recognition/awareness and protective measures, and not on the injuries received. They are found to be effective for all sizes and type of projects [179].

6.6.15. Outage safety programmes

Outages at nuclear facilities are unique periods of increased activity with the increased possibility of industrial safety accidents. In some aspects, they are similar to initial facility construction (e.g. large workforces, many heavy lifts, a large number of field activities, and movement of equipment and materials), but have additional complications of a large number of staff new to a facility, and for work scheduling and integration of facility operating and maintenance staff with large numbers of external contractors. During non-outage periods work sites might only have one job ongoing at a given time, but during outage multiple work groups can be present — this increases the potential for work from one area to impact on another (e.g. workers dropping an item from one elevation to another and hitting another workforce).

Organizations often increase the numbers of dedicated safety personnel and safety oversight activities during such periods. This can include drawing on all departments for support to focus on health and safety through enhanced observations and coaching programmes, trending programmes to increase 'eyes in the field' and focusing on known/predicted risks at specific times in the outage. A sample outage observation and coaching card for rapid trending is provided in Appendix VIII.

Organizations often prepare specific outage industrial safety plans to help to coordinate such initiatives, review past performance (performance metrics, specific events and trends), set performance targets, review specific outage hazards, review external operating experience and plan proactive activities to address the hazards such as pre-outage communications and training plans. Planning for a given work area (e.g. inside the reactor building, and all work on the turbine generator) should consider the impact of multiple work groups being present at the same time. During the outage, timed communications and daily field walkdowns can be directed and focused on specific hazards coinciding with applicable work activities. By daily/weekly trending of observations from the field walkdowns and adverse condition records, adverse performance trends can be identified and potential emerging trends caught early. Then the attention of the organization can be drawn to these activities before an incident occurs.

Best practices for indicators for planned outage management include tracking industrial safety events and near misses, and fire hazard events as part of overall outage performance indicators [181]. Best practices for a power outage optimization at a nuclear plant include providing contractors with a considerable amount of training to introduce them to industrial safety aspects, that attention be given during the outage to good housekeeping, and that a rapid feedback system should be established to monitor the personnel performance with respect to industrial and radiological safety [182, 183].

The CII performed research into implementing successful outage safety programmes [184, 185]. The research was for general industry and was not specific to nuclear. It found that outages were most successful from a safety perspective when attention was paid to transferring temporary workers from other sites with similar projects (as opposed to hiring new local staff unfamiliar with the needed work), when temporary workers were brought on-site at least two weeks before the outage for orientation training, when work was well planned and tightly scheduled (by the hour), when outage durations were shorter, when work crews were smaller, and when contracts had incentive clauses based on safe work practices and behaviours (not just injury performance). Additional CII guidance on general management and planning of outages is available in Refs [186–189]. Of major importance is the degree of pre-planning (front end planning using CII terminology) for all aspects of the outage.

6.6.16. Home and public safety programmes

6.6.16.1. Home and total worker safety

Recognizing that workers are their most important asset, organizations in many jurisdictions have extended their workplace industrial safety programmes to include elements relating to off the job and family safety. Workers injured anywhere, on the job or off, are unavailable to work and to apply their unique skills and experience to the nuclear facility. Workers caring for, or concerned about, injured family members are similarly less available and less productive. Focusing on the total safety of the employee and their family can thus provide organizations with tangible benefits.

Such programmes need not be costly, and can consist simply of safety messages surrounding good safety practices while at home, while engaging in recreational activities, while driving or while performing other non-work-related activities. Repair, renovation, gardening, similar work around the home, or sporting activities can be of particular concern, as workers may not routinely be exposed to such activities, their associated hazards and proper safety precautions. Reminders just prior to significant holidays or festivals, where workers or their families might be exposed to additional risks, are seen as good practice. Communication methods can include safety notes, flyers or videos included with items sent to the home, monthly letters or offering safety training to family members.

The Rovno nuclear power plant, in Ukraine, was recognized in 2003 with an OSART good practice in this area.[15] Every week, the labour protection division conducted a training workshop with safety industrial specialists relating to events analyses as well as injuries that have occurred to personnel during sports activities, hobbies and everyday work at home. On the basis of the analyses, corrective measures to improve the work of the social facilities in the town were elaborated.

6.6.16.2. Visitors, security and publicly accessible areas

The safety and security of visitors and temporary personnel at a nuclear site is of particular concern. Such individuals have not been trained in recognizing or protecting against the hazards found at the site, and thus can be at increased risk of injury. Processes regarding the care and control of plant visitors are necessary. These can include requirements surrounding access control (approvals needed, processing, sponsorship and badging), pre-entry briefings, escorting, permitted tour routes and prohibited areas, and basic safety precautions, including PPE.

Nuclear operating organizations often have care and custody over a large area of land as part of their sites, not all of which is within the site security boundary. Injuries to the general public in these areas would reflect badly on the nuclear operation as a whole. A review of potential safety concerns within these areas, and addressing the concerns via physical means or via warning signage, is seen as good corporate citizenship.

Security measures contribute to reducing risks to the general public. The site security boundary provides an obvious deterrent to public individuals exposing themselves to risks within the operating island. Other areas outside the formal nuclear security perimeter can also be of concern. For example, copper is a valuable metal that has increasingly been the target of thieves hoping to profit by selling it to scrapyards. Such actions are potentially fatal for the thieves involved. Non-radioactive copper wire also has been stolen from, or close to, switchyards located near several nuclear power plants.[16] Some nuclear power plants are bolstering security measures at substations and notifying scrapyard owners to be on the lookout for large quantities of copper wire that could have been taken from switchyards. FirstEnergy and Ohio Edison, for example, indicated in 2014 that they planned to install security fencing and monitoring systems at some of their substations in an effort to deter metal thieves.

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[15] See www-ns.iaea.org/downloads/ni/s-reviews/gp-2009/1.5.pdf

[16] See https://public-blog.nrc-gateway.gov/2015/01/14/pursuit-of-metal-can-be-costly-if-not-deadly

6.7. PERSONAL PROTECTIVE EQUIPMENT

Personal protective devices are needed if engineering or administrative controls cannot eliminate or adequately control a hazard. Once it has been determined that PPE may be necessary, a process needs to be followed to ensure that it is selected and used properly. Such a process should include:

— Hazard assessments to determine work activities that may require PPE;
— Selection and assignment of appropriate PPE to personnel;
— Training of affected employees in proper use and care of the PPE;
— Worker consultation and feedback regarding ease of use or other issues with the PPE;
— Ongoing communication regarding any changes in PPE requirements (e.g. new procedures, processes requiring PPE, different or more stringent requirements, and new available options).

Certain PPE has specific importance with respect to facility nuclear safety considerations. Self-contained breathing apparatus (SCBAs), for example, is an integral piece of emergency response equipment for radiological and oxygen deficient atmospheres. As such, they are an integral piece of safety equipment for fire protection and emergency response plans. They are used extensively by on-site fire brigades for immediate firefighting response and emergency workers for radiological protection. When they cannot provide adequate personal protection, a degradation of emergency response is likely to occur and the consequences can be life threatening. The Nuclear Regulatory Commission [190] provides information on some operating experience surrounding controls on SCBA and respirator use:

> "It is important that licensees maintain current and comprehensive oversight. A strong oversight program would ensure not only that each worker is appropriately fit tested, trained, and qualified, but also that respirator mask sizes are staged and available to meet any potential demand, and that corrective lens kits are available at all times to all users who require them. A strong oversight program would also ensure that each piece of equipment is systematically tested and maintained in accordance with guidelines agreed to by the manufacturer and licensee."

Across the world, work equipment, tools and PPE, have been traditionally designed for the male body size and shape. Moreover, most PPE designs are based on the sizes and characteristics of male populations from certain countries in Europe, Canada and the United States. As a result, women and many men experience problems finding suitable and comfortable PPE because they do not conform to this standard male worker model. Poor fit to work equipment and tools can lead to poor working posture, leading to an increased risk of material safety data sheets. Poor fit to PPE will lead to reduced protection. Organizations should take care to ensure that designers of work equipment, tools and PPE develop or use anthropometric data that reflect the characteristics of the actual working population thereby ensuring equipment, tools and PPE are suitable for both sexes and for the expected worker population [191].

6.7.1. Hazard assessment and selection of personal protective equipment

Each task or job needs assessing to determine what hazards are present to each individual body part and what proper PPE should be worn to protect against the hazards. This is normally done via completion of a hazard assessment form. Increasingly, electronic tools are available to assist with PPE selection, such as the US Occupational Safety and Health Administration (OSHA) tool for selecting eye and face protection.[17] These assessments should be finalized or reviewed just prior to the jobs being started to ensure that current workplace conditions are incorporated into the assessment. They should also be updated or re-evaluated whenever conditions or procedures change. Table 26 provides a listing of various body parts, hazards and typical basic PPE used to protect those body parts.

Standards for PPE have evolved over time. Traditionally most PPE was tested and evaluated by suppliers to the requirements of voluntary product standards, with the supplier attesting to the product's conformance to the

[17] See www.osha.gov/SLTC/etools/eyeandface/index.html

TABLE 26. BASIC PERSONAL PROTECTIVE EQUIPMENT

Body part	Hazards	Personal protective equipment
Eyes	Chemical or metal splash, dust, projectiles, radiation, gas and vapour	Safety glasses, goggles, face screens, face shields and visors
Head and neck	Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery, chemical drips or splash, climate or temperature	Industrial safety helmets, bump caps, hairnets and firefighter helmets
Ears	Noise	Earplugs, earmuffs and semi-insert/canal caps
Hands and arms	Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, vibration, biological agents and prolonged immersion in water	Gloves, gloves with a cuff, gauntlets and sleeving that covers part or the entire arm
Feet and legs	Wet, hot and cold conditions, electrostatic buildup, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, and vehicles	Safety boots and shoes with protective toecaps and penetration resistant, mid-sole rubber boots and job specific footwear
Lungs	Oxygen deficient atmospheres, dusts, radioactive particles, gases and vapour	Respiratory protective equipment of many types (cartridges, full face respirators, plastic suits)
Whole body	Heat, chemical or metal splash, spray from pressure leaks or spray guns, contaminated dust, impact or penetration, excessive wear or entanglement of own clothing, electrical arc flash, and falls	Conventional or disposable overalls/coveralls, aprons, chemical suits, cooling jackets, arc flash ensembles, fall arrest equipment Choice of clothing materials includes flame-retardant, anti-static, chain mail, chemically impermeable and high visibility

standard by marking or labelling. In the United States of America, for example, only respiratory PPE was subject to a conformity assessment through the National Institute for Occupational Safety and Health. More recently, however, there has been a trend to more uniform standards and independent conformity testing. In the United States of America, for example, there are three levels of conformity assessment [192]. For each level, there are requirements for initial and ongoing testing, quality management, corrective and preventive action, recordkeeping and declaration of conformity. The standard provides the option to select a method of conformity assessment that provides a suitable level of assurance of conformity for any product or application. For the most stringent level (level 3), an accredited third party certification body must certify and apply its mark to the products.

European standards for PPE demonstrate their conformity with the basic health and safety requirements of EU regulations [193]. Only equipment meeting these requirements is entitled to carry a Conformité Européene (CE, European Conformity) marking and be sold for use in the European Union (see Appendix VI for a selection of PPE clothing standards from various jurisdictions).

6.7.2. Personal protective equipment training

PPE will not provide adequate protection if worn incorrectly. Affected employees should receive training on:

- What PPE is necessary and why;
- How to wear PPE properly;
- PPE limitations and capabilities;
- PPE inspection, cleaning, maintenance, and replacement (e.g. manufacturer’s instructions for use, expiry time frames or other replacement criteria);
- Expectations regarding not using damaged or defective equipment.

Respirators and similar equipment typically need to be fit tested for specific workers to ensure that they can provide the necessary protection (given the individual's specific facial features). During fit testing, the workers are typically qualified to certify that they can properly use the PPE. Fit test records are often kept to document such qualifications. Training should be repeated if there are changes in the workplace that makes previous training obsolete, for example, when new PPE is introduced, when employees receive new job assignments, or when employees are observed wearing or using PPE incorrectly.

6.7.3. Standard personal protective equipment within construction and operating islands

Organizations typically require standard PPE to be worn or be available to all workers within industrial areas (i.e. non-office and non-changing rooms areas) of construction or operating islands. This PPE typically includes hard hats, safety shoes, safety glasses, ear protection, high visibility vests and gloves. Specific areas where such PPE should be worn or be readily available should be clearly marked at all entrance points and be the subject of worker orientation training.

CII research [44] into the correlation between injury rates and requirements for compulsory wearing of PPE on construction sites finds a reduction in injury rates for companies that, for example, mandate in all circumstances the wearing of steel-toed safety boots and hard hats.

6.8. MINIMIZING SEVERITY OF INJURIES (INCIDENT RESPONSE AND MEDICAL TREATMENT)

Systems should be in place for identifying and reviewing potential accident situations, and for planning for the prompt and effective mitigation and control of incidents. Emergency response plans should be developed and maintained that address potential situations that would require emergency action. These can include escape routes, assembly areas, emergency contact phone numbers, first aid, resuscitation, on- and off-site medical treatment, fire and rescue crew responses (include summoning off-site civil firefighters), and spill recovery cleanup measures. Arrangements should be made with a local hospital for the treatment of injuries and contaminated casualties.

Portable tools and fixed equipment such as fire extinguishers, first aid kits, eyewash stations, emergency showers, automated external defibrillators (AEDs) and electrical rescue equipment (e.g. high voltage gloves and retrieval hooks) should be readily available and installed per national regulations, codes and standards. To improve likely response times, many operating organizations provide first aid kits, fire extinguishers and AEDs in company vehicles that travel on- or off-site, and train additional staff in fire extinguisher use, first aid, AED use and cardiopulmonary resuscitation.

Periodic drills and exercises should validate emergency response plan adequacy and effectiveness. These exercises should include dealing with injuries caused by hazardous materials, and treatment of contaminated casualties (see Ref. [64] for emergency procedures for construction and demolition sites).

7. PROGRAMME EVALUATION

7.1. PERFORMANCE MONITORING AND MEASUREMENT

7.1.1. Key performance indicators

The OSHMS should have annual and long term objectives, with pertinent and representative key performance indicators. Senior management should monitor these indicators regularly and take corrective actions as required to address adverse trends. Metrics should cover the range of actual events (e.g. accidents with work interruption and lost time accidents) and leading indicators of behavioural observations for industrial safety. Data should be compared with groups outside of the organization (e.g. other nuclear facilities, general industry and other construction projects) to benchmark good performance and to challenge objectives and results over time.

Results should be shared with the applicable workers and supervisors to celebrate successes and to improve their performance (see in Figs 36 and 37). Individual work groups should have personalized metrics that can point to different or unique issues that might need addressing within each team.

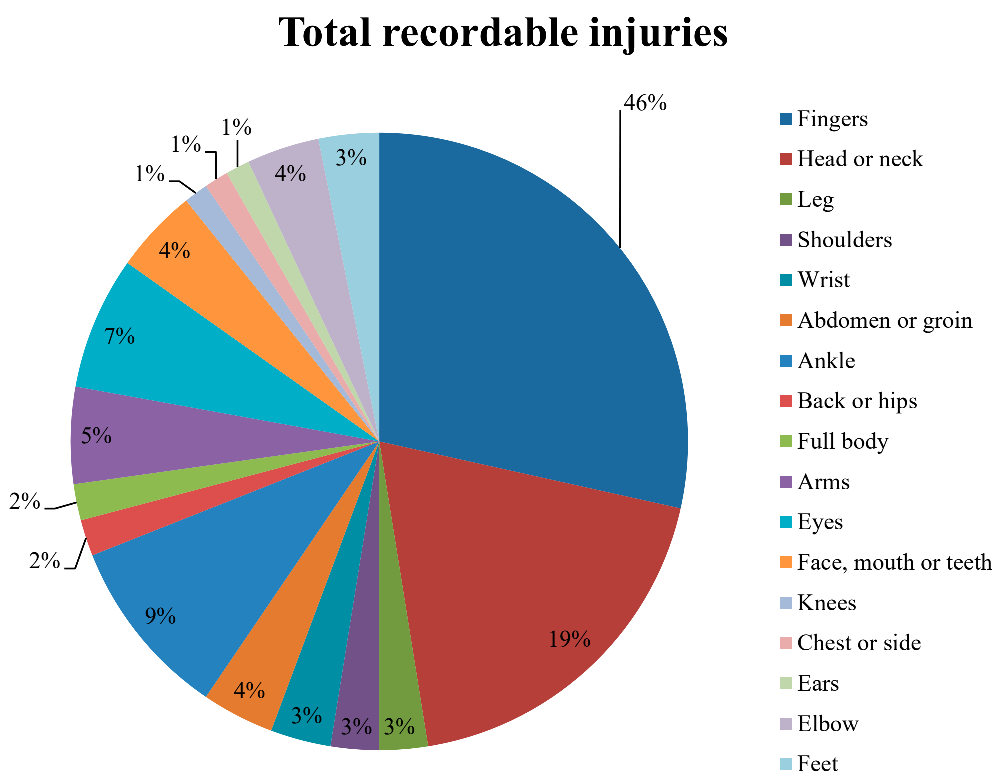

FIG. 36. Recorded injuries report.

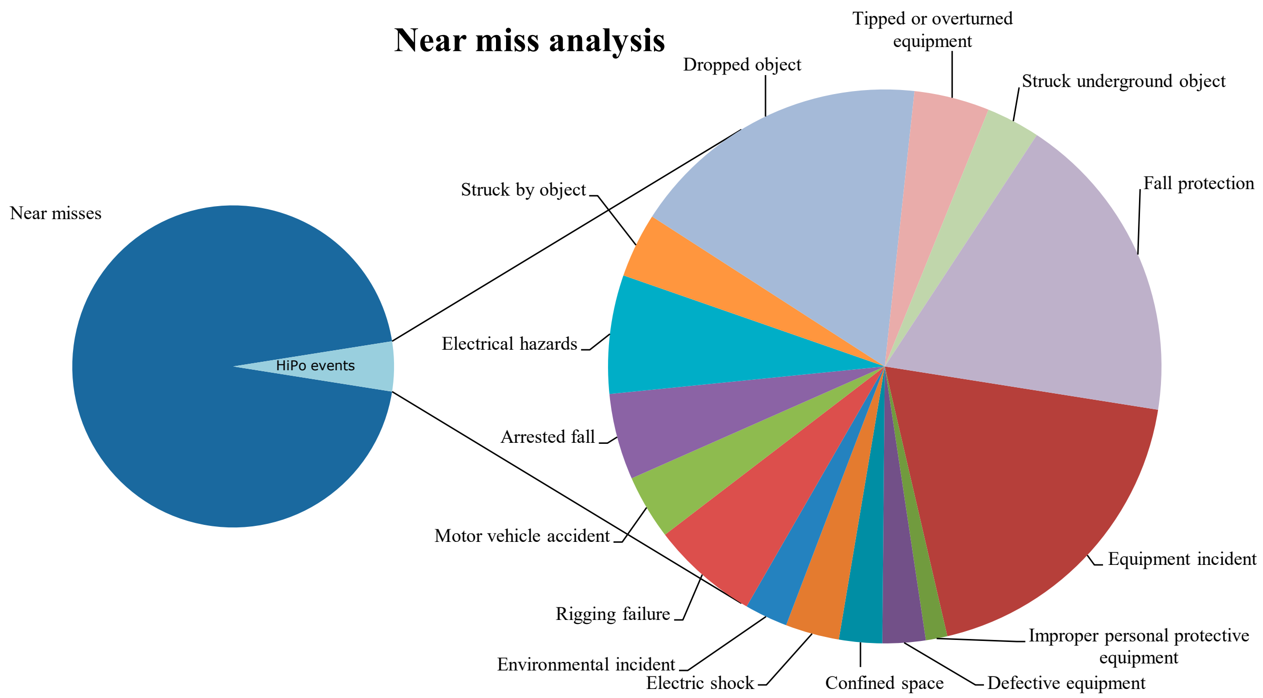

FIG. 37. Near miss report with high potential for harm (HiPo) events highlighted.

OSH software described in Section 4.8.2 often has integrated reporting capability that can make this task easier. An easily remembered acronym for setting targets is SMART — specific, measurable, agreed, realistic and time limited. Safety indicators can be divided into the categories of lagging, passive leading and active leading. Each of these is useful in monitoring an organization's OSH performance, and is described in subsequent sections. Recent CII research has focused on active leading indicators, as the CII finds them to be better predictors of future performance.

It should be noted that when indicators are first set up and active participation increases, any increases in the number of reports of items such as near misses might not be reflective of actual increases in number, but rather an increased awareness of their occurrence and of their reporting. Such an increase can reflect a desired improvement in reporting culture.

The Organisation for Economic Co-operation and Development (OECD) has developed guidance on developing safety performance indicators (SPI) for chemical accident prevention, preparedness and response [194]. It is useful in both identifying some specific indicators for chemical process safety, but also in its recommended approach to implementing a programme for establishing indicators of any type. The OECD recommends that such a programme follow a seven step process:

(1) Establish the SPI team;
(2) Identify the key issues of concern;
(3) Define outcome indicators and related metrics;
(4) Define activities indicators and related metrics;
(5) Collect the data and reporting indicator results;
(6) Act on findings from the SPIs;
(7) Evaluate and refine the SPIs.

CII research on implementing similar active leader performance indicators for construction safety also emphasizes the need to publicize performance related to the chosen indicators with others on a job site, including supervisors and workers and to celebrate successes [195, 196].

7.1.2. Lagging indicators

Lagging or reactive indicators are measurements of previous safety performance (see Fig. 38). They measure things that have already happened such as accident rates or first aid treatments.

A commonly used high level industry safety related performance indicator (e.g. tracked by WANO [38]) is the industrial safety accident rate (ISAR or ISA), which is defined as the number of accidents resulting in lost work, restricted work or fatalities for a defined number of worker hours:

$$\text{ISAR} = \frac{N}{H_{\text{E}}} \times 200\,000$$

where

N is the number of injuries and/or illnesses (i.e. lost time accidents + restricted time accidents + fatalities);
H_{E} is the employee hours (total hours worked by all employees during the calendar year);

and 200 000 is the base for 100 full time equivalent workers (working 40 hours per week, 50 weeks per year).[18]

As an industry, country or organization, the ISAR N term is calculated as the sum for all stations, and H_{E} as the sum of hours worked at all stations. Station rather than unit values are used for this indicator because accident records are not normally maintained separately for each unit. However, since the station values are normalized by the number of hours worked, valid comparisons among single and multi-unit stations can still be made.

[18] Some jurisdictions track results per 1 000 000 person hours.

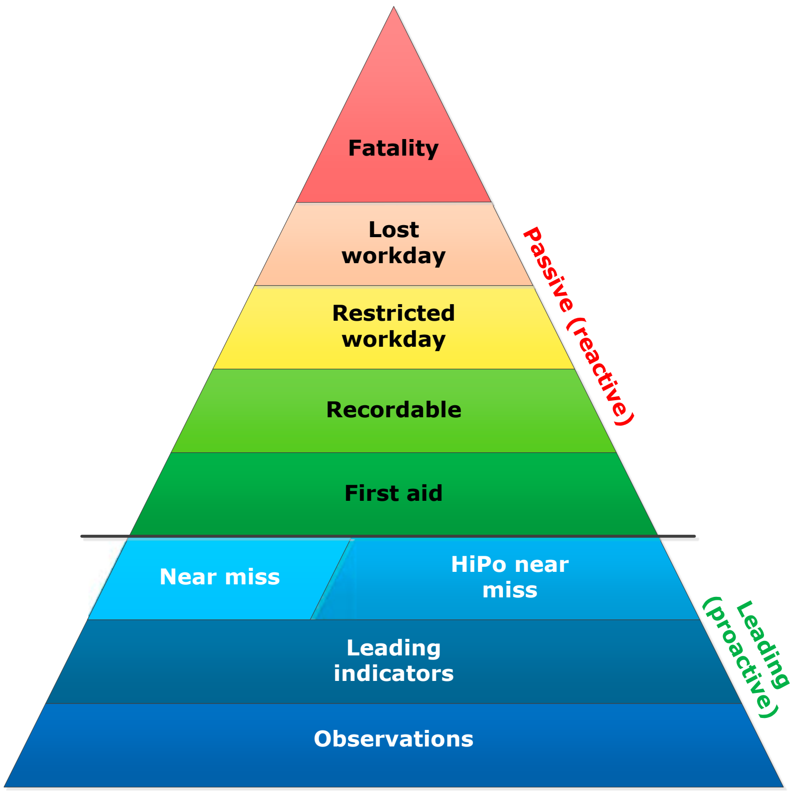

FIG. 38. Leading (proactive) and lagging (passive/reactive) indicators.

Industry trends of ISAR performance for WANO members are shown in Fig. 39. For this industry calculation, the N term is the sum of accidents and fatalities of reported staff for all stations, and the H_E term is the sum of hours worked for all stations by staff.

WANO also tracks an ISAR rate for contactors separately — the contractor industrial safety accident rate (CISA) performance indicator is similar to the ISAR except that it only tracks contractor injuries, illnesses and associated work hours. WANO targets as of 2014 for the ISAR are for it to be less than 0.50 for any given station and less than 0.20 for the industry (75% of stations meeting that target) [38].

Some other common lagging high level indicators used (e.g. nuclear power plants in France) are the number of incidents with medical work interruption (lost time accidents) per 1 000 000 hours and the number of incidents without medical work interruption (lost time and other accidents) per 1 000 000 hours.

7.1.3. Passive leading indicators

Passive leading indicators are safety strategies that may be implemented to set up a project or organization for success, and may serve as predictors of future safety performance. They can include the following (see appendix B of Ref. [198] for a comprehensive list):

— Contract prequalification based on safety;
— Specific contract language surrounding safety;
— Health and safety policy;
— Earplug policy;
— Stop work policy;
— Safety reward programmes;
— Constructability reviews;
— Drug and alcohol policy;
— On-site medical facility.

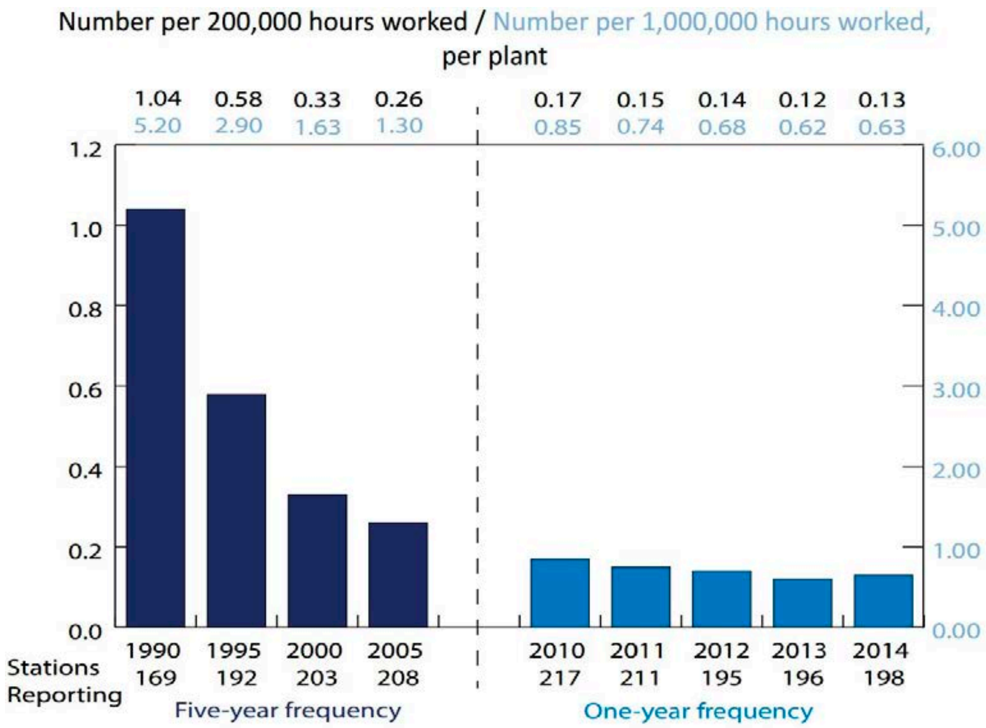

FIG. 39. WANO ISAR trend (courtesy of World Association of Nuclear Operators) [197].

7.1.4. Active leading indicators

In recent years, there has been increased emphasis on the establishment and tracking of active leading indicators for industrial safety performance. Such indicators are those that track precursors to actual incidents or accidents, and are practices or observations that can be made in the field during work activities. Today's near miss, unsafe condition or unsafe behaviour is possibly tomorrow's accident. Active leading indicators can include the following:

— Observed behavioural non-compliances;
— Observed poor housekeeping during audits or field observations;
— Participation of project management team members in the daily field safety activities;
— Quality of pre-task plans;
— Incidences of stop work authority being exercised;
— Owner–project manager participation in contractor orientation training;
— Owner–project manager meetings with the contractor foreman;
— Owner performed safety walkdowns;
— Contractor safety audits and/or exit meetings conducted;
— Vendor designs received with no identified safety concerns;
— Near miss reports.

Appendix C of Ref. [198] provides a comprehensive list of indicators, measurement methods, potential thresholds, resources and a draft action plan for each indicator. For example, an indicator to measure the worker observation process could be set up. A definition used to measure the indicator could be a three month moving average of the number of safety observations made per 200 000 worker hours of exposure. The initial threshold for the indicator would be 250 observations per 200 000 worker hours of exposure. For resources, all workers would be educated on the programme and a standard observation form used. The action plan would consist of the safety manager and project management team taking various steps to confirm that the programme is being properly managed.

The intent of active leading indicators is to gather data on field activities that occur before there is an accident (see blue section of Fig. 42), and to address the underlying issue prior to any accident occurring. A key part of utilizing active leading indicators is often the establishment of a system of performing field observations of work activities. Often termed behaviour based safety programmes [199–201] or safety observation programmes, these initiatives include observations of all activities from the start of job planning, work assessment, pre-job briefings, field work execution, post-job debriefings and closeouts. Reinforcement and feedback, both positive and constructive, is given to the individuals observed and corrective actions are taken when programmatic issues are discovered. When implementing such programmes, it is important to understand that worker actions are not always the problem and that their unsafe acts do not cause all accidents. That is, these programmes complement other safety initiatives such as hazard identification and elimination.

Active leading indicators can also include observations of general plant material condition, the condition of infrequently used safety equipment, observations of engineering meetings for adequate discussion of safety issues, or facility housekeeping. As part of such observation programmes supervisors and managers typically receive training in how to properly conduct observations. Defined targets for the number of observations to make during a particular week or month are often set, especially during early stages, and an observation theme (e.g. PPE compliance, hand safety, work protection and proper use of ladders) might be set for the entire organization to focus on during that particular timeframe. Such themes would be chosen based on frequencies of observed issues and events. Figures 40 and 41 show typical reports of some active leading indicators for a construction project. In these examples, the indicators are observations of proper use of hand tools (by type of tool), and observations relating to the facility housekeeping programme (see Refs [195, 196, 198, 202–204] for CII research on methods of implementing active leading indicators and the related topic of near miss reporting).

Category	Sub-Category	Observations	Conditions		% Safe	At Risk Conditions - Severity			
			At Risk Conditions	Safe Conditions		Low	Medium	High	Life Threat
Hand Tools	Summary	4872	117	4755	97.60%	28	45	41	3
	Proper tool being used for job	992	6	986	99.40%	3	2	1	0
	Tools properly stored/carried	698	34	664	95.10%	7	9	17	1
	Inspection and maintenance	615	15	600	97.60%	5	7	1	2
	Damaged tools not in use	322	5	317	98.40%	0	2	3	0
	Cords free of damage	564	29	535	94.90%	6	6	17	0
	Elec cont color coding uptodate	544	21	523	96.10%	6	14	1	0
	Guards in place	476	3	473	99.40%	0	2	1	0
	No mushroom heads	334	4	330	98.80%	1	3	0	0
	No homemade tools	327	0	327	100.00%	0	0	0	0

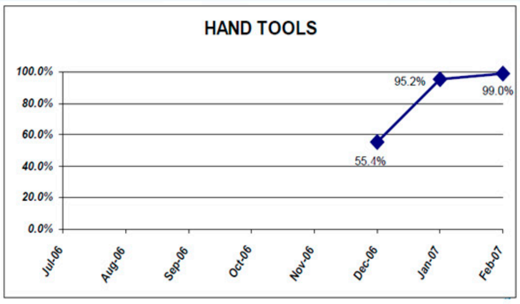

FIG. 40. Hand tool leading indicator tracking.

Category	Sub-Category	Observations	Conditions		% Safe	At Risk Conditions - Severity			
			At Risk Conditions	Safe Conditions		Low	Medium	High	Life Threat
Housekeeping	Summary	5679	366	5313	93.60%	268	81	16	1
	Work area clean and orderly	837	90	747	89.20%	61	26	3	0
	Regular disp of waste & trash	721	31	690	95.70%	20	11	0	0
	Passageways & walkways clear	601	41	560	93.20%	28	8	5	0
	Exits clrly mark&illum as req	297	2	295	99.30%	1	1	0	0
	Adequate drinking water supply	82	1	81	98.80%	1	0	0	0
	Adequate lighting outside work area	420	5	415	98.80%	2	0	2	1
	Projecting nails removed	435	31	404	92.90%	20	10	1	0
	Oil and grease removed	419	3	416	99.30%	3	0	0	0
	Waste cont provided and used	586	14	572	97.60%	13	1	0	0
	Sanit facilities adeq & clean	593	31	562	94.80%	21	9	1	0
	Area free from trip/slip haz	688	117	571	83.00%	98	15	4	0

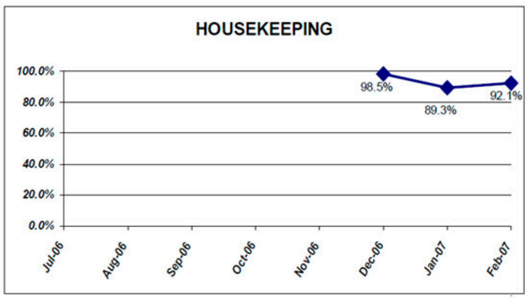

FIG. 41. Housekeeping leading indicator tracking.

7.1.5. Comparison issues

Even when similar organizations utilize the same indicator to measure an aspect of industrial safety performance, differences in national practices and influencers such as the availability of free or subsidized health care, available days of paid sick leave and any waiting periods, cultural norms, employment insurance practices, unemployment rates and others, can make direct comparisons between jurisdictions challenging. Workers in some jurisdictions may experience little or no penalty (e.g. from a lost day of work following an accident), while others may experience an immediate loss in wages. This may directly influence lost time accident rates in those jurisdictions, as workers may decide to return to work earlier than might otherwise be the case.

Similarly, national laws and regulations on worker rights and working conditions, or requirements on employers with regard to accident reporting, compensation insurance schemes and other areas can impact on reporting rates and on the metrics adopted. This does not mean that comparisons between jurisdictions are not possible, but rather that any conclusions drawn should be backed by knowledge of the impact of the applicable jurisdiction's labour environment.

7.2. INVESTIGATION

A key to reducing injuries and improving OSH is a 'just culture'. That is, a culture in which an atmosphere of trust pervades, in which people are encouraged, even rewarded, for providing safety related information, but at the same time are clear about what is unacceptable versus acceptable safety behaviour (i.e. there are consequences for unacceptable behaviour) [205]. Part of such a culture is an environment for reporting events, injuries and near misses and for learning from them.

7.2.1. Injury pyramid

A sample injury pyramid is provided in Fig. 42. It demonstrates that small numbers of fatalities or serious injures can be preceded by hundreds or thousands of lower level events such as first aid treatments, near misses or at risk behaviours. At risk behaviours are activities that are not consistent with safety programmes, training and components on machinery, and may include bypassing safety components on machinery or eliminating a safety step in the production process that slows down the operator. Effective machine safeguarding and training, for example, can reduce risk behaviours and near misses, but factors such as organizational weaknesses and behavioural drivers can increase them. Accidents often occur because individuals made choices that in retrospect were poor, but at the time made sense to the individuals involved [206]. Understanding these choices and how they influenced individual behaviours can help organizations put in place steps to reduce the frequency of any at risk behaviour, and thus reduce the chance of a serious injury or fatality occurring.

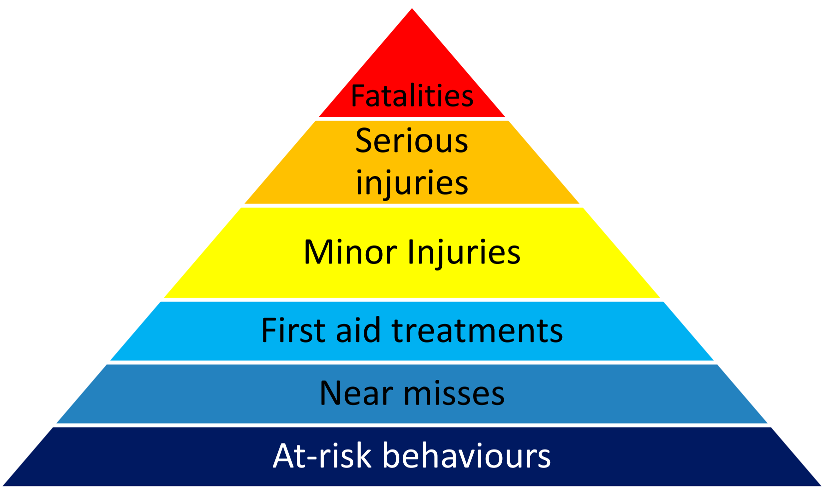

FIG. 42. Injury pyramid.

In addition to the severity of an injury, there are a number of factors that vary by country and that determine its ‘shape’. These can include access to health care services, days an injured worker goes without pay before compensation is received, the quality of the data collected, or the classifications used for events between ‘near miss’ and ‘fatality’. In any event, if organizations only document and investigate the most serious events, then many opportunities for learning and improvement are lost. A 1992 study [207] shows that there are at least 60 near misses for every event classified as a first aid treatment through to fatality. A ratio of 1:10:30:600 for fatalities to serious accidents to accidents to incidents summarizes this research. Unfortunately, in many organizations the reported numbers do not reflect this ratio, as lower level events can often be under-reported. A similar study in 2003 by the petrochemical company ConocoPhillips Marine concludes that for every fatality there are at least 300 000 at risk behaviours (see Fig. 43) [208].

Barriers to reporting can include a fear of blame, incoherent difference, and lack of supervisor support [209]. Fear of blame involves the individual not wanting to be accused of doing something wrong that precipitated the accident. Incoherent difference is a belief that the incident was not significant enough to be reported. Lack of supervisor support is the belief that supervisors will not treat the incident as a priority item to be investigated. All three of these can be detrimental to an effective near miss reporting programme, and can be counteracted by a truly supportive work environment, clear definitions of the types of incident to report and active supervisor support for reporting.

Other studies have shown that organizations that document and trend lower level events have better safety records. The CII finds, for example, that documentation of near misses is “one of more influential factors in reducing accidents/incidents” [44], with over 45% fewer injuries reported for companies that do so. In all cases, organizations should enter data for every incident, as well as any analysis, root or apparent causes, and corrective actions, into a common database, typically the same database used for the site’s overall corrective action programme. Such a database would ideally cover all workgroups on a site, whether direct employees or contactors. Coding schemes should be developed that can assist in future analysis, for example, to distinguish different types of incident, types of injury sustained, work groups involved, locations and so on. This allows for future trending and sharing of information within and outside of the organization. Corrective action programmes are further discussed in Section 8.2.1.

Paragraph 4.3 of IAEA Safety Standards Series No. NS-G-2.11, A System for the Feedback of Experience from Events in Nuclear Installations [210], identifies significant factors that would influence the magnitude of an event investigation at a nuclear installation, of which an injury to on-site personnel is one.

7.2.2. Reporting and documentation of incidents

Reporting consists of two steps, the initial recording and reporting of an industrial safety related event, and its subsequent reporting to the appropriate authorities. Initial recording of events is obvious for events that have a consequence such as a seriously injured worker. Where workers are not seriously injured and quickly return to work,

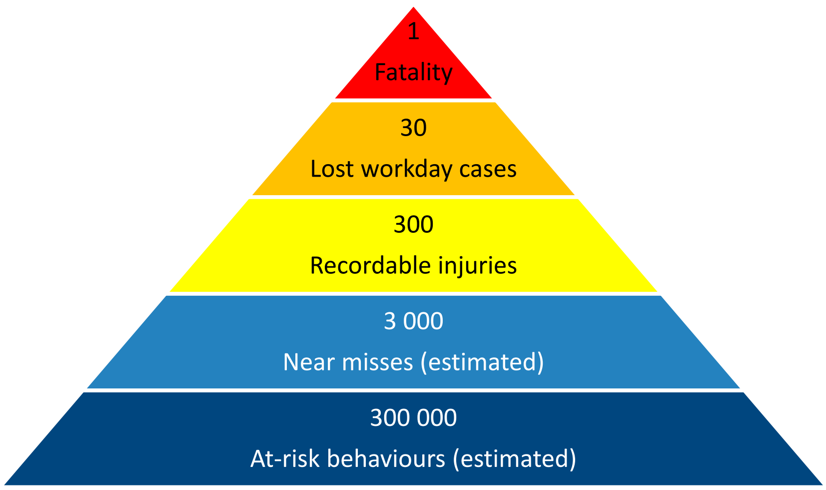

FIG. 43. 2003 ConocoPhillips Marine study.

or if they are not injured at all, then reporting can unfortunately be more variable. As discussed in Section 7.2.1, well performing organizations with a ‘no-blame’ and learning safety culture encourage and achieve reporting of large numbers of low levels events so that lessons can be learned. In the early stages, near miss reporting standards for each worker (e.g. each field worker and supervisor to report two per year) may be useful in increasing reports of near misses.

It is important that initial reporting occur as soon as practical following an incident. This helps to ensure that key facts are not forgotten by the individuals involved. For serious events involving injuries or death, it is also important to secure the incident location so that a full investigation by the appropriate authorities is possible. Incident investigation is more fully covered in Section 7.2.3 and Appendix V. An example of a simple initial accident report is shown in Fig. 44. Modern systems, such as those described in Section 4.8.2, record similar information in electronic databases.

Incident Reporting Form

Use this form to report any workplace accident, injury, incident, near miss or illness.

Return completed form to XXXXX.

This is documenting an:

☐ Lost Time/Injury ☐ First aid incident ☐ Near miss ☐ Observation

Details of person injured or involved (to be filled in by person injured/involved if possible)

Person completing report: ____________________________

Date:____________________

Person(s) involved: ____________________________

Equipment ID (if applicable):____________________________

Event Details

Date of event:_____________________ Location of event:______________________

Time of event:_____________________ Eyewitnesses:_________________________

Description of events (Describe tasks being performed, hazards present and sequence of events):

____

____

____

____

Was event/injury caused by an unsafe act (activity or movement) or an unsafe condition (machinery or weather)? Please explain:

____

____

INCIDENT DETAILS

Nature of injury sustained/body parts affected:_______________________

Cause of lost time/injury or first aid:_____________________________

Was medical treatment necessary? Yes ☐ No ☐

If yes indicate hospital and/or physician:___________________________

PPE that was in use:____

Signature of Employee:__________________________ Date:__________________

Signature of Supervisor:_________________________ Date:_________________

FIG. 44. Typical initial incident report.

Certain categories of events require reporting to local or national labour authorities. Specific maximum timeframes might be allowed for such reporting. Such reporting is often tied to worker insurance compensation schemes that pay part of all of a worker's wages following a work related injury and an associated absence from work. Increases in accident rates cause premiums paid by companies associated with such insurance to increase. Low level events such as near misses are typically not part of such mandatory reporting schemes. It is important however that organizations document and trend low level events beyond strict regulatory requirements. If regulatory reporting of such events becomes the de facto minimum standard for an organization to analyse events, then safety is unlikely to improve.

For regulatory reporting purposes, it is important that jurisdictions have clear definitions surrounding what organizations must specifically report. OSHA, in the United States of America, for example, uses the following[19]:

(a) All work related injuries and illnesses that result in days away from work, restricted work or transfer to another job, loss of consciousness or medical treatment beyond first aid (see OSHA definition of first aid below).
(b) Significant work related injuries or illnesses diagnoses by a physician or other licensed health care professional, even if it does not result in death, days away from work, restricted work or job transfer, medical treatment beyond first aid, or loss of consciousness.
(c) Injuries include cases such as, but not limited to, a cut, fracture, sprain or amputation.
(d) Illnesses include both acute and chronic illnesses, such as, but not limited to, a skin disease (i.e. contact dermatitis), respiratory disorder (i.e. occupational asthma and pneumoconiosis) or poisoning (i.e. lead poisoning and solvent intoxication).
(e) The OSHA definition of work related injuries, illnesses and fatalities are those in which an event or exposure in the work environment either caused or contributed to the condition. In addition, if an event or exposure in the work environment significantly aggravated a pre-existing injury or illness, this is also considered work related.

7.2.3. Classification, analysis and investigation of incidents

Operating organizations typically categorize events according to their significance and consequence. This categorization determines the extent of investigation and analysis to be performed, and the level of oversight around any related corrective actions. Often certain types of near miss incidents are classified as 'high potential for harm' (HiPo) and treated similarly to the most serious events. An HiPo incident is a potential incident, which were it to have occurred, would have led to major loss. An example of an HiPo event would be a toxic gas leak from a flange into the atmosphere with no one present. No one was present or injured, but the potential for a fatality existed.

Industrial safety related events of sufficient importance typically are investigated via a team that is designed to uncover their root causes, with significant follow-up attention given to implementing appropriate mitigative and corrective actions. Lesser impact events may be investigated by the work groups involved, and may use less advanced techniques such as apparent cause analysis, which does yield formal corrective actions but may not address root causes. Events such as low impact (not HiPo) near misses may not only be documented near the time of occurrence, but be used as part of later trend analysis to help determine trends in type of safety issues (e.g. increases in small events due to gloves not being worn).

The IAEA has published a reference manual on conducting root cause investigations following events at nuclear installations [211], and information on effective corrective actions [212]. Such a process can be useful in investigating serious industrial safety events. For such investigations a pre-prepared checklist specific to industrial safety can be a useful tool. Appendix V provides more detail on performing an incident investigation, including advanced methods of accident analysis. A sample table of contents for an accident investigation report is provided in Box 2.

7.2.4. Self-assessments

Self-assessments are structured, objective and visible and are done by a work group to look within its own performance, and seek ways to improve it. They are a useful tool for any learning organization seeking to improve.

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[19] Adapted from www.osha.gov/recordkeeping/index.html

BOX 2. SAMPLE TABLE OF CONTENTS OF AN ACCIDENT INVESTIGATION REPORT (*adapted from Ref.* [213])

CONTENTS

ACRONYMS AND ABBREVIATIONS

EXECUTIVE SUMMARY

1. INTRODUCTION

   1.1. Background
   1.2. Facility description
   1.3. Scope, conduct and methodology

2. THE ACCIDENT

   2.1. Background
   2.2. Accident description
   2.3. Accident response
   2.4. Medical report summary
   2.5. Event chronology

3. FACTS AND ANALYSIS

   3.1. Emergency response
   3.2. Post-event accident scene preservation and management response
   3.3. Conduct of operations, work planning and controls
   3.4. Supervision and oversight of work
   3.5. Worker safety and health programme
   3.6. Assessment of prior events and event precursors
   3.7. Integrated safety management analysis
   3.8. Human performance analysis
   3.9. Corporate programmes and oversight
   3.10. Summary of causal factors analysis
   3.11. Barrier analysis
   3.12. Change analysis
   3.13. Events and causal factors analysis

4. CONCLUSIONS AND JUDGEMENTS OF NEED

5. SIGNATURES

APPENDICES WITH DETAILED ANALYSES ATTACHED

They are based on the principle that those personnel who actually perform a task on a regular basis are often best placed to understand potential weaknesses and how the process might be improved.

Processes of self-assessment have been continually developed at nuclear facilities. Although the primary beneficiary of a self-assessment process is the organization performing the assessment, the result of the self-assessment is also used, for example, to increase the confidence of the regulator. Figure 45 shows the various levels of an assessment process, of which levels 1–3 are part of the self-assessment. General steps for a typical process are shown in Table 27 [214].

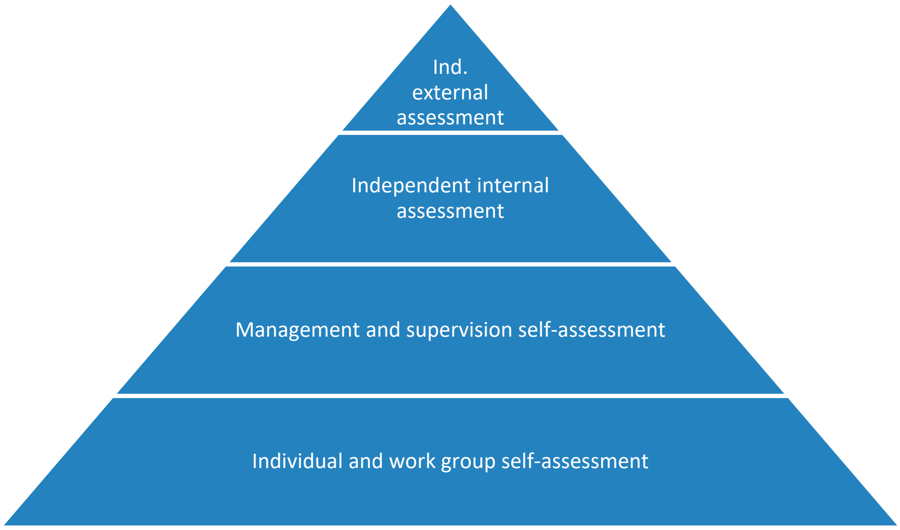

FIG. 45. Assessment process triangle.

TABLE 27. GENERAL SELF-ASSESSMENT PROCESS

Step	Objective
1. Define the areas to be covered by the self-assessment	Define the scope and objectives to be included in an overall self-assessment programme or to be applied to a specific self-assessment activity
2. Define the performance expectation	Define the expected level of performance to fully accomplish the desired safety goals
3. Identify assessment process and schedule	Provide plans, resources and schedules for completing the self-assessment
4. Conduct performance comparison	Compare the actual performance to the established performance expectations to identify differences
5. Conduct performance assessment	Determine the significance of observed differences between performance and expectations necessary to identify the extent and priority of needed corrective actions
6. Implement corrective actions	Implement actions to correct significant identified deficiencies
7. Monitor effectiveness of corrective actions	Monitor performance indication to verify that the actions are effective in resolving performance discrepancy

7.3. AUDIT

7.3.1. Programme audits

Auditing is one of the key steps in both implementing an OSHMS and evaluating its performance. The ILO [215] has developed an audit matrix based on its guidelines on OSHMS [35]. This guide helps to identify the strengths and weaknesses in an organization's OSHMS, and highlights opportunities for improvement.

Audits can be performed by an organization's internal audit department or by external parties. It is useful to use both methods on occasion as they can provide different and unique perspectives. Audit topics can include subjects related to an organization's industrial safety performance, methods, results, work environment and field practices. Outside organizations or agencies provide an opportunity to reveal 'blind spots' within an OSH programme that otherwise might have remained hidden.

7.3.2. Subject specific assessments and audits

OSH assessments or audits on specific projects, construction sites or with a particular safety focus can be conducted periodically. Observations and results can be both qualitative and quantitative measures of performance. Assessment findings and corrective actions are typically documented and presented to senior management to allow for continued evaluation of the organization's performance. Sample safety focus subjects for assessment can include the following:

— PPE use and compliance;
— Hazard communication ('right to know' programmes);
— Sanitation and health;
— Control of hot work (welding, cutting and burning) and flammable materials;
— Use of power or air tools and related equipment;
— Electrical work safety;
— Scaffolding and ladder safety (including rolling and swing scaffolds);
— Control of floor and wall openings;
— Material handling methods;
— Craning and rigging;
— Excavations, trenching and shoring;
— Roofing;
— Concrete forming and pouring;
— Steel erection;
— Demolition;
— Radiation protection (ionizing and non-ionizing).

Regular overall site safety audits are considered good practice. They are typically conducted by a small, interdisciplinary team that is not directly connected with the location, with a senior manager leading the team. The audit is carried out first during the plant commissioning, but audits are also repeated later at regular intervals. Typical intervals are a year after initial startup and every five years thereafter. A standard audit checklist, such as the one in Ref. [116], can assist the team in ensuring that it reviews all necessary areas.

7.4. MANAGEMENT REVIEW

Management review involves senior managers evaluating industrial safety performance and seeking to improve it, through appropriate corrective measures and continual improvement activities. It helps to ensure that expectations are being performed to standards, that performance gaps are identified and closed, and that corrective actions are completed effectively. The oversight structure described in Section 5.3.1 is one way to achieve this. Such a group establishes the overall station vision, strategy and processes for managing OSH within the applicable organization.

8. ACTION FOR IMPROVEMENT

A key part of any management system, including an OSHMS, is the process of taking corrective actions and improving the programme. It is the 'act' part of the Deming circle that was described in Section 2.3. This section describes some typical actions that are taken in the context of industrial safety.

8.1. PREVENTIVE AND CORRECTIVE ACTION

Preventive actions are those that detect, preclude or mitigate the degradation of a situation. They can be conducted regularly or periodically, one time in a planned manner, or in a predictive manner based on an observed condition. Corrective actions are those that restore a failed or degraded condition to its desired state based on observation of the failure or degradation.

In industrial safety, the situations or conditions of interest are those observed via the performance monitoring, investigations, audits and management reviews that were described in Section 6. Preventive and corrective actions are those designed to place or return the system to its desired state. Preventive actions where possible are preferred as they eliminate the adverse condition prior to it occurring.

8.2. CONTINUAL IMPROVEMENT

Continual improvement of OSH measurably enhances industrial safety performance. Many nuclear operating organizations have been able to improve their industrial safety performance over time. For example, the WANO ISAR chart in Fig. 43 shows continual improvement in industrial accident severity rates over time at world nuclear plants [197].

The nuclear industry has recently undertaken the goal and challenge of how to get to 'zero injuries'. As discussed in Section 7.1.4, a focus on what active leading safety indicators reveal with respect to worker behaviours is thought to be the best way to get there. Using the organization's corrective action programme, benchmarking, gathering and using operating experience, adopting proven industry best practices and implementing a formal lessons learned programme can enhance organizational knowledge and thus further drive OSH improvements. Individual work units can also prepare and implement an OSH improvement plan applicable to their work. Each of these is discussed in turn below.

As changes are made to the programme a formal change management process should be followed. Aspects of such a process would ensure that changes are made in a timely manner, written documentation is formally revised, people are adequately trained in what the change is, and that the change's effectiveness is verified.

8.2.1. Corrective action programmes

Corrective action programmes provide benefits in correcting known problems and preventing their reoccurrence. Successful programmes can alter the internal culture of an organization and drive its continual improvement. They are an important part of any nuclear facility's management system, in both industrial safety and non-industrial safety related areas. Requirement 13 of GSR Part 2 [12], paras 6.50–6.75 of GS-G-3.1 [13] and paras 6.42–6.69 of GS-G-3.5 [14] lay out corrective actions (see Ref. [159] on corrective actions on human performance and behaviours important for industrial safety).

Various organizations and individuals have published information on the elements of a typical corrective action programme (see Refs [3, 216–219]). Reference [212] lists the following as the key elements:

— Addressing root causes;
— Selecting corrective actions;
— Conservative decision making;
— Prioritization and implementation of corrective actions;
— Tracking effectiveness of corrective actions;
— Preventing repetition;
— Rally commitments;
— Indicators;
— Self-assessment;
— Peer reviews;
— Benchmarking.

8.2.2. Benchmarking and industry best practices

OSH benchmarking compares current practices with those elsewhere to identify vulnerabilities, performance gaps and opportunities for improvement. Identifying target organizations that are ‘best in class’ is a key prerequisite for such activities. Target organizations can be derived from studying OSH statistics (e.g. accident rates), from discussions with industry peers, from reviews of industry journals, or other sources. As lessons learned can be derived from both nuclear and non-nuclear organizations, consideration should be given for occasional benchmarking outside of nuclear facilities. Any lessons learned and associated corrective actions should be incorporated into an organization’s standard corrective action programme.

A best practice specifically is a process or method that, when executed effectively, leads to enhanced performance. They are typically proven through extensive industry use or validation. Various safety organizations, described in Section 4.6.7, publish guidebooks of recommended safety best practices. The American Society of Safety Engineers, for example, publishes best practices in safety, industrial hygiene and environmental management [220]. Organizations are recommended to research such practices from a wide variety of sources, and incorporate them into their OSH programmes.

The CII maintains a set of best practices for the construction industry [221]. ‘Zero accident techniques’ is the practice most relevant to industrial safety. Other practices, however, have supportive roles that can enhance industrial safety (see Table 28).

8.2.3. Gathering operating experience

Gathering lessons learned and experience data from internal and external sources is a key part of an OSH programme. Internal data can include records of incidents, performance indicators and worker health monitoring. External sources can be similar information from other plants within an organization’s fleet, from other nuclear facilities (e.g. IAEA, WANO, INPO, owner group data and regulator reports), and from non-nuclear heavy industry (e.g. construction and petrochemicals). The follow subsections detail some recently published significant operating experience on nuclear and non-nuclear facilities.

8.2.3.1. OSART findings and trends

The IAEA routinely publishes results and lessons learned from OSART missions on its Operational Safety Services web site.[20] Known as OSART Mission Results (OSMIR), these reports highlight the most significant findings of OSART missions, while retaining as much of the vital background information as possible. Table 29 provides some recent OSMIR report findings on industrial safety, which indicate that the industry has further to go to meet excellent performance in this area. Industrial safety indicators in these reports (in management, organization and administration) were classified as ‘red’ (poor) for the first two time periods evaluated, and for the third time period the report did not use the same methodology but instead indicated that the number of industrial safety recommendations greatly exceeded the number of identified good practices.

8.2.3.2. Baker Report on process safety (non-nuclear example)

An explosion that resulted in 15 deaths and 170 injuries at a BP chemical refinery in 2005 in Texas focused attention on the issue of process safety and its relationship to industrial safety and safety culture. Process safety accidents such as fires, chemical leaks or explosions at petrochemical facilities have the potential to cause multiple injuries and fatalities, and negatively impact on the environment. Industrial safety accidents on the other hand primarily affect one worker or a small group of workers. The report of the safety review panel (Baker Report) that was convened to investigate the accident concluded that many of the characteristics discussed in this publication that are needed for strong industrial safety programmes, and indeed for strong nuclear safety programmes, were lacking at BP and thus contributed to a poor process safety programme [225]. Nuclear facilities with inherent hazards (e.g. radiation hazards and those inherent with chemical and fuel handling systems) can gain from such a perspective. The ten main recommendations are in Box 3.

[20] See www-ns.iaea.org/reviews/op-safety-reviews.asp

TABLE 28. SELECTED CONSTRUCTION INDUSTRY INSTITUTE BEST PRACTICES AND THEIR ROLE IN ENHANCING OCCUPATIONAL SAFETY AND HEALTH

Best practice	Description	Example role in enhancing OSH
Zero accident techniques	Site specific safety programmes and implementation, auditing, and incentive efforts to create a project environment and a level of training that embraces the mindset that all accidents are preventable and that zero accidents is an obtainable goal.	Enhances hazard recognition, near miss reporting, use of leading safety indicators, and the owner's role in project safety.
Front end planning	The essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project.	Enhances predictability of job execution and consideration of industrial safety aspects early in the project when they can more effectively be addressed.
Constructability	The effective and timely integration of construction knowledge into the conceptual planning, design, construction and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost effective levels.	Incorporates construction knowledge regarding work methods and hazards into the project design and execution plans (see Section 6.3.3.2).
Change management	The process of incorporating a balanced change culture of recognition, planning and evaluation of project changes in an organization to effectively manage project changes.	Enhances the organization's ability to recognize and address changes before they occur, including potential changes in OSH hazards and risks.
Benchmarking and metrics	The systematic process of measuring an organization's performance against recognized leaders for the purpose of determining best practices that lead to superior performance when adapted and utilized.	OSH metrics would be included in an organization's performance metrics. Comparison to other organizations via benchmarking activities would be encouraged (see Section 8.2.2).
Lessons learned	A critical element in the management of institutional knowledge, an effective lessons learned programme will facilitate the continuous improvement of processes and procedures and provide a direct advantage in an increasingly competitive industry.	Sharing of lessons learned regarding OSH issues would help continually to improve performance (see Section 8.2.3).
Planning for startup	Startup is defined as the transitional phase between plant construction completion and commercial operations, that encompasses all activities that bridge these two phases, including systems turnover, check-out of systems, commissioning of systems, introduction of feedstocks and performance testing.	Startup activities are high activity phases and occur at the end of each outage. Proper planning can help minimize unplanned changes and OSH risks (see Section 6.6.15).
Project risk assessment	The process to identify, assess and manage risk. The project team evaluates risk exposure for potential project impact to provide focus for mitigation strategies.	OSH risks are part of this process.
Team building	A project focused process that builds and develops shared goals, interdependence, trust and commitment and accountability among team members and that seeks to improve team members' problem solving skills.	Well functioning teams are more likely to raise/identify OSH hazards and risks and work together on improvement strategies.

TABLE 29. OSMIR REPORT FINDINGS ON INDUSTRIAL SAFETY

Time frame	Finding	Ref.
2003–2006	“• *Trend: There are some indications the local industrial safety policy is not sufficiently clear, or sufficiently well developed to ensure that hazards are minimized (7/21)*. “This was manifested in a variety of ways, from lack of control of temporary storage areas (with associated hazards – notably fire) to unidentified/unrecognized hazards in the field. “• *Trend: There are many indications that employees fail to follow the requirements of their local safety rules and management fails to adequately enforce them (13/21)*. “This was particularly evident in the failure to comply with the wearing of personal protective equipment and in the adherence to rules prohibiting smoking in inappropriate areas. Failure to require contractors to comply with safety rules was also identified during the missions (5/21).”	[222]
2007–2009	“• Trend: In some plants, there are indications that the industrial safety policies or programmes are established but they are not fully implemented in the field. (7/17). “there are strong indications that behaviour in the field did not fully comply with the policies and programmes. It was found that communication and reinforcement of expectations, as well as supervision and co[a]ching, were not properly used by the management to achieve significant improvements in this area. Managers do not always identify and correct inadequate industrial safety practices and eliminate hazardous behaviour of own staff or contractors. “In particular cases, development, implementation and follow-up of corrective actions are not sufficiently considered.”	[223]
2010–2012	“• Trend: In many plants, there are indications that the industrial safety policies or programmes are established, but they are not fully implemented/followed in the field. (10/19). “Examples show that; — Plant personnel [do] not always wearing safety protective means (goggles, hard-hats, gloves, ear-protection tools etc.). — Some plant equipment is missing or has disconnected grounding cables. — Lighting defects are not always eliminated in timely manner. — Electrical and other cabinets have no safety hazard warning labels. — There are number of unlocked electric/I&C [instrumentation and control] cabinets. — Escape routes are not appropriately marked. “Though plants have established policies, standards and expectations on industrial safety that employees are required to meet, there are strong indications that behaviour in the field did not fully comply with these policies, standards and programmes. Management must put additional efforts to recover the situation and to ensure that expectations are communicated and reinforced repeatedly to make plant staff and contractors understand the industrial safety policies and strictly follow them in the field. This trend requires thorough analysis of the situation at the plants where the deficiencies were found and development of the respective corrective actions — training, posters, industrial safety days etc.”	[224]

BOX 3. RECOMMENDATIONS OF THE BP US REFINERIES INDEPENDENT SAFETY REVIEW PANEL [225]

RECOMMENDATION #1 — PROCESS SAFETY LEADERSHIP

The Board of Directors..., BP's executive management..., and other members of BP's corporate management must provide effective leadership on and establish appropriate goals for process safety. Those individuals must demonstrate their commitment to process safety by articulating a clear message on the importance of process safety and matching that message both with the policies they adopt and the actions they take.

....

RECOMMENDATION #2 — INTEGRATED AND COMPREHENSIVE PROCESS SAFETY MANAGEMENT SYSTEM

BP should establish and implement an integrated and comprehensive management system that systematically and continuously identifies, reduces, and manages process safety risks at its U.S. refineries.

....

...a management system for process safety must be comprehensive; a weak or fragmented system will not address all of the numerous safety risks that exist in BP's U.S. refineries.

....

RECOMMENDATION #3 — PROCESS SAFETY KNOWLEDGE AND EXPERTISE

BP should develop and implement a system to ensure that its executive management, its refining line management above the refinery level, and all U.S. refining personnel, including managers, supervisors, workers, and contractors, possess an appropriate level of process safety knowledge and expertise.

....

...BP should also seek input and advice from external groups with appropriate process safety expertise to help design, develop and implement this system.

....

RECOMMENDATION #4 — PROCESS SAFETY CULTURE

BP should involve the relevant stakeholders to develop a positive, trusting, and open process safety culture within each U.S. refinery.

....

...BP should ensure that mechanisms exist that effectively promote and facilitate two-way communication between BP managers and all relevant stakeholders.

....

RECOMMENDATION #5 — CLEARLY DEFINED EXPECTATIONS AND ACCOUNTABILITY FOR PROCESS SAFETY

BP should clearly define expectations and strengthen accountability for process safety performance at all levels in executive management and in the refining managerial and supervisory reporting line.

....

...Ultimate accountability and responsibility cannot be delegated and rests at the top of the organization. BP must strengthen accountability and responsibility for process safety performance in executive management...

....

RECOMMENDATION #6 — SUPPORT FOR LINE MANAGEMENT

BP should provide more effective and better coordinated process safety support for the U.S. refining line organization.

....

...BP should designate and establish a full-time leader for process safety who reports to a refining line manager above the refinery level.

....

RECOMMENDATION #7 — LEADING AND LAGGING PERFORMANCE INDICATORS FOR PROCESS SAFETY

BP should develop, implement, maintain, and periodically update an integrated set of leading and lagging performance indicators for more effectively monitoring the process safety performance of the U.S. refineries...

....

...BP should develop and implement within six months from the date this report is issued a reasonable set of integrated performance indicators....

....

RECOMMENDATION #8 — PROCESS SAFETY AUDITING

BP should establish and implement an effective system to audit the process safety performance at its U.S. refineries.

....

RECOMMENDATION #9 — BOARD MONITORING

...**The Board should, for a period of at least five calendar years, engage an independent monitor to report annually to the board on BP's progress in implementing the Panel's recommendations**....

....

RECOMMENDATION #10 — INDUSTRY LEADER

BP should use the lessons learned from the Texas City tragedy and from the Panel's report to transform the company into a recognized industry leader in process safety management.

8.2.3.3. Root cause report on Arkansas Nuclear One stator drop event

In 2013, during movement of the Unit 1 main turbine generator stator (ca. 475 t), a temporary lift assembly failed resulting in loss of life, loss of off-site power to Unit 1, structural damage to the turbine building and physical injuries. The root cause report into the accident identified that the design of the lift assembly could not support the loads anticipated, calculations to ensure that the assembly was designed to support the projected load had not been reviewed, and load testing of the modified temporary lift assembly had not been performed according to OSHA regulations [226]. World Nuclear News reported that the Nuclear Regulatory Commission found that Entergy "did not ensure adequate supervisory and management oversight of the contractors and other supplemental personnel involved with the stator lift, and this contributed to the event" [227]. The event emphasizes the need for careful oversight of contract work for industrial safety concerns.

8.2.3.4. Tokyo Electric Power Company 2015 press conference handout on safety measure improvements after accidents

The Tokyo Electric Power Company (TEPCO) released press conference handouts [228] on the causes of several accidents resulting in death and injury that occurred at its nuclear power plants, and on its measures to improve safety. The handout emphasizes the important role for supervisors and lessons learned programmes in preventing industrial safety accidents. The events were in 2015 during recovery efforts following the 2011 earthquake and accident and included the following:

(a) A worker installing a water tank at Fukushima Daiichi nuclear power plant fell 10 m from the top of the tank (empty at the time) into it and died.
(b) A worker inspecting equipment at a Fukushima Daini nuclear power plant waste treatment facility had his head caught between a piece of scaffolding and a 700 kg piece of moving equipment and died.
(c) A worker received an injury at Kashiwazaki Kariwa that needed three months to heal.

The main issues relating to these accidents were seen to be:

— Lack of efforts to eradicate human accidents due to strong schedule pressure;
— Weakness in using lessons learned from past troubles and accidents and rolling out information;
— Lack of management skill in accident prevention (e.g. supervisors spending too much time on desk work and not being sufficiently trained for on-site supervision, and operational procedures not being sufficiently detailed).

Corrective measures included increased training on accident prevention, increased emphasis on the priority of safety over schedules, and a commitment to have senior executives patrol the facilities to identify risks and personally convey the 'safety first' message [229].

8.2.4. Implementing lessons learned programmes

Lessons learned programmes are a necessary part of improving OSH performance. Such programmes require as inputs a process to identify and analyse safety events and lessons learned from internal and external sources. External sources can include the IAEA, the ILO, INPO, WANO, labour ministries and various other industrial safety related organizations throughout the world. Information should be input into a software platform that allows for searching and analysing of data. Data collected can be used in the development of project plans, readiness reviews, work packages, pre-job briefing material and training.

Operating organizations typically use their site corrective action programme software to manage OSH lessons. Construction companies will typically have their own software programmes that they use on multiple projects or job sites. It is important that for joint projects (e.g. a new build nuclear power plant or a major nuclear facility outage or refurbishment) that all workers on a job site employ a common system and that lessons learned be shared between the operating and construction programmes. Typical lessons learned software should include the capability to:

(a) Enter data/events into the software in an easy manner, such as one step (see Fig. 46);
(b) Easily search and retrieve lessons learned information;
(c) Apply coding to events and lessons to facilitate trending (e.g. event, causes and significance coding);
(d) Have library of operating experience/lessons learned and related photographs sorted by topic area, project, and/or applicable milestone (e.g. lessons on plant start-ups, all lessons on a particular project etc.);
(e) Links to other industry sources of lessons learned.

CII research [44] on the correlation between injury rates and the sharing of accident reports to other projects or job sites within a company finds over 40% fewer injuries for companies that have a policy of sharing accident reports among projects. Similarly, the documentation of near misses is “one of more influential factors in reducing accidents/incidents” (over 45% fewer injuries reported) [44].

8.2.5. Occupational safety and health improvement plans

Some organizations mandate the preparation of annual OSH improvement plans for all work groups within the organization. Preparation and review of such plans regularly focuses attention on health and safety topics, and where improvement efforts can be focused in the near future. Improvement actions should be focused on proactive indicators and behavioural observations made of that group’s activities. Table 30 shows a small portion of an example of such a plan.

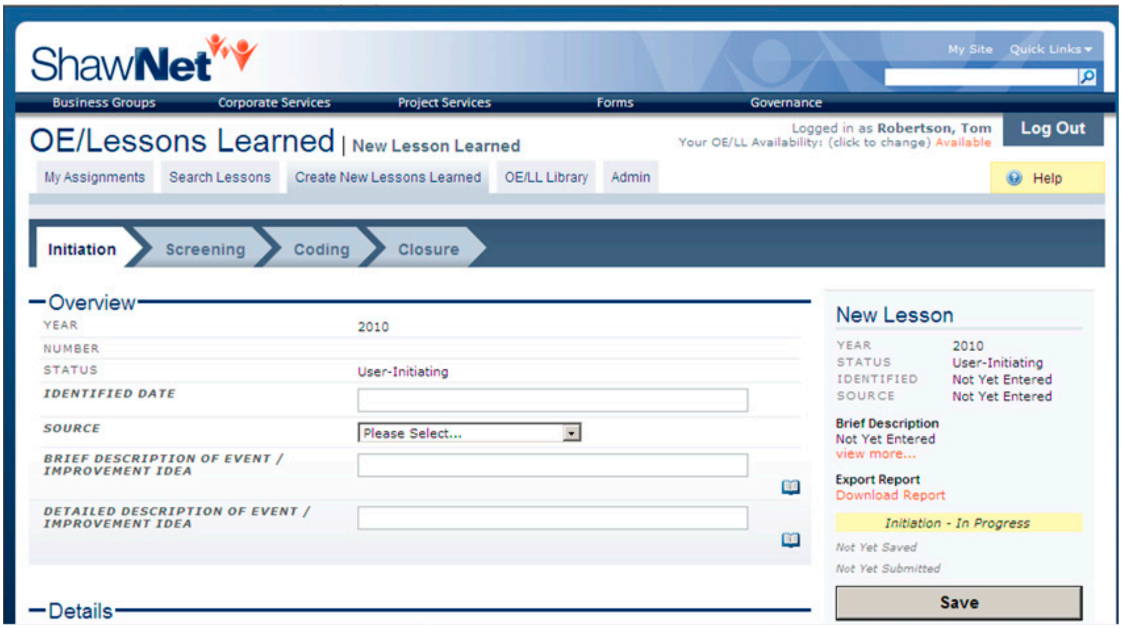

FIG. 46. Lessons learned computer program initiation screen (courtesy of Chicago Bridge and Iron Company).

TABLE 30. SAMPLE OCCUPATIONAL SAFETY AND HEALTH IMPROVEMENT PLAN

Action	Category	Improvement opportunity	Plan forward	Responsible party	Target date	Status			
						Q1	Q2	Q3	Q4
1001	Leadership and commitment	Create formal OSH improvement plan	Created, reviewed and updated quarterly	XXX, YYY	2016-02-17				
Additional actions									

9. CONCLUSION

This publication outlines good practices and elements of an OSH programme for a nuclear facility. Although national regulatory standards for OSH can vary throughout the world, there are both business and safety drivers in all countries for ensuring a high level of safety in these areas. Keeping staff and the public safe is consistent with the basic principles developed for nuclear energy [10], and the behaviour and practices needed to ensure excellence in industrial safety are the same as those required for excellence in nuclear safety and security, and for safe, economic electricity production. If a facility is missing any of the elements described in this publication, it should consider adding them.

Appendix I

NUCLEAR FACILITY HAZARDS

I.1. MECHANICAL HAZARDS

Mechanical hazards are those that can occur when the body comes into contact with machinery, tools or other common items. The applied power may be electrical, hydraulic, mechanical or human. Hazards can exist at the point of operation, the point of power transmission, or in the area of moving parts. Injuries can occur due to striking, crushing, shearing, cutting, severing, stabbing, puncture, entanglement, drawing in or trapping, impact, friction or abrasion.[21] Driving on public roads and on-site is a special case where mechanical hazards are commonly and routinely encountered.

Protection against mechanical hazards involves a combination of design features (e.g. elimination of hazard via machine design), guards and protective devices (fixed guards and interlocking devices, protective guards), warnings, work methods, PPE and associated training.

I.1.1. Striking, crushing or shearing

Crush points exist when two objects move towards each other, or when one object moves towards a stationary object. Protection against crushing hazards can be ensured by either leaving a minimum distance between moving components (to avoid all contact between the moving components and body), or by reducing the force of the moving components to limit the consequences of contact. The first of these approaches is an inherently safe design measure because the hazard is eliminated, while the second reduces the risk to an acceptable level.

I.1.2. Cutting, severing, stabbing or puncture

Cutting, stabbing or puncture hazards can result from machinery or more commonly from portable hand tools. Protection is often in the form of PPE such as gloves. Dangers from flying objects exist when power tools or activities like pushing, pulling or prying, may cause objects to become airborne. Eyes are especially vulnerable to flying objects. Standard eye protection PPE is typically made mandatory on nuclear sites, and job specific PPE is often necessary for specific tasks (e.g. full face shields and welding shields).

I.1.3. Entanglement, drawing in or trapping

Moving or rotating parts on common pumps, fans, motors, maintenance shop equipment and power tools found at nuclear power plants have the potential to cause severe workplace injuries. These can include crushed fingers or hands, amputations, burns or blindness. Rotating apparatus or tools can be dangerous because they can catch and twist a worker's clothing, hair or jewellery. Even slowly rotating objects can snag something and force an arm or hand into a precarious position. For these reasons operating organizations often place restrictions on the wearing of jewellery (e.g. rings, bracelets and necklaces) or potential long clothing (e.g. scarves and ties) within the operating island.

Operator error in failing to disconnect power before making machine adjustments, lubricating, or clearing blockages can also contribute to such hazards, and so training in proper work protection procedures is important (see Section 6.6.6). Safeguards are essential for protecting workers from these preventable injuries. Increasingly national regulations and industry standards (e.g. Refs [230–237]) have been developed for machine guarding. Such standards typically establish a 'maximum permissible opening' size that is designed to eliminate the potential for entry of a body part such as a finger or hand with the device operating. In some cases, machine guards are connected to interlock systems that stop the applicable machinery if the guard is removed or defeated. An ILO

[21] See www.hse.gov.uk/agriculture/topics/machinery/mechanical.htm

publication [80] on the safety and health in the use of machinery is available that contains information on machine guarding.

Of particular application to nuclear facilities are the areas where motor shafts are coupled to pumps or fans (see Fig. 47), which in earlier designs were not always fully guarded. Many operating organizations have implemented programmes to assess older installed equipment and have retrofitted them with guards that meet modern standards.

I.1.4. Impact

Machines can have fast moving parts that can strike a person, or eject machine parts and material with considerable force. Failing to fit or maintain protection against ejected material can contribute to such hazards, as can operator error in placing body parts in the danger zone or 'line of fire'. If it is not possible to guard a machine, additional operator protection might include fitting of mesh guards or impact resistant glazing to cabs and specifying safe working zones.

I.1.5 Friction or abrasion

Rough or moving surfaces adjacent to work stations can cause burns or removal of skin and muscle. Equipment incorporating conveyors, webs or rollers are especially vulnerable, as are portable hand tools.

I.1.6 Driving

I.1.6.1. Public roads

Many operating organizations develop corporate safe driving programmes into their industrial safety framework. Such programmes can cover company drivers, employees in general and their families, and contractors. Subjects to be covered can include seat belt use, safety equipment to be carried, driving while talking or texting, driving while fatigued, dealing with taxi or limousine drivers, drinking and driving, defensive driving techniques, adverse weather (see Section 4.1.3), collision hazards with animals, and advanced driver training for certain individuals.

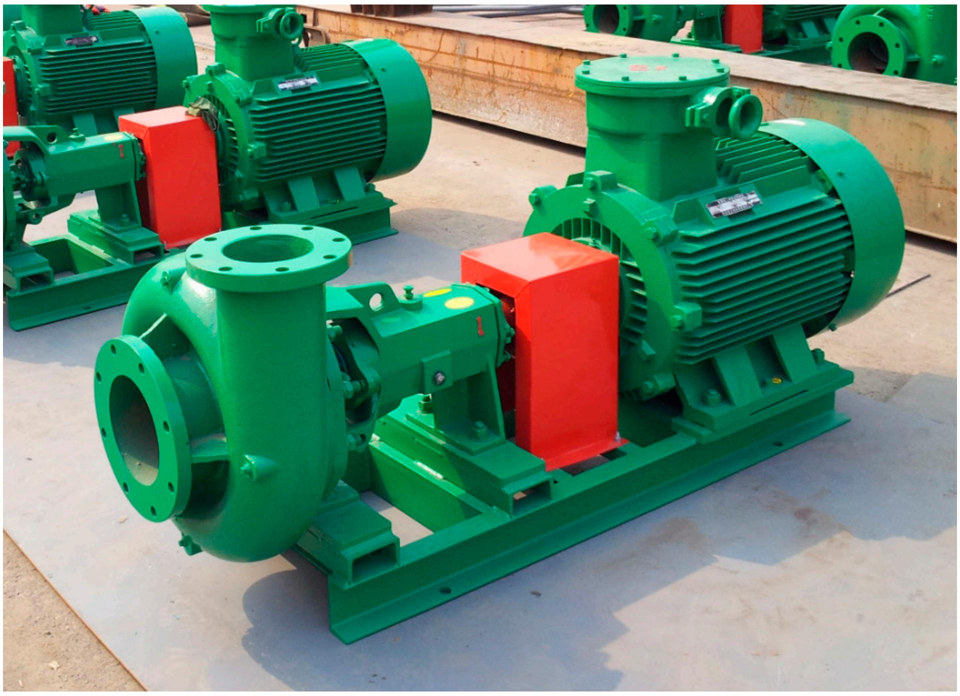

FIG. 47. Pump and motor with machine guard (red) covering coupling area (courtesy of GN Solids Control).

With respect to the use of mobile devices while driving, the Network of Employers for Traffic Safety[22] recommends that employers:

(a) Do not create or imply a culture where employees feel that they need to make or take calls or read or reply to emails while driving;
(b) Get buy-in and commitment from management at all levels that they will not contact employees' mobile phones during times they know to be their drive times;
(c) Prohibit any employees from participating on conference calls while driving;
(d) Provide ongoing education and awareness messaging about the dangers of using a mobile device while driving.

I.1.6.2. On-site vehicles

On-site vehicles such as trucks, forklifts, delivery carts, fuel transporters and others can be hazardous to personnel driving the vehicles and those in the immediate area. Workplace vehicles should be assessed to ensure that[23]:

(a) Drivers have good all round visibility;
(b) Appropriate warning systems (such as horns and lights) are fitted;
(c) Seat belts and restraints are safe and comfortable;
(d) Safeguards prevent people from coming into contact with dangerous parts of the vehicle;
(e) Drivers get in and out of the vehicle safely and easily;
(f) There is protection for bad weather and extremes of temperature, dirt, dust and fumes;
(g) There a way to prevent injury if the vehicle overturns (e.g. roll protection, operator restraints or falling object protection);
(h) There a way to prevent the vehicle from moving;
(i) The vehicle is bright enough to be seen;
(j) The vehicle lights provide enough light for the driver to work.

Depending on the vehicle, specific precautions regarding the loads carried and usage should be taken. Forklifts, for example, should only be driven with their loads lowered, the load raised or lowered only when stopped, and the forks lowered with controls off and brakes on whenever the vehicle is left by the operator. Many jurisdictions have specific standards for lift trucks and require specific training for their operators (see Refs [238–240]).

I.2. GRAVITATIONAL HAZARDS

I.2.1. Falling objects

Individuals are at risk from falling objects when they are beneath cranes, scaffolds, ladders, work platforms or where overhead work is being performed. Injuries can range from minor abrasions to concussions, blindness or death. Even a small object falling from a height can cause serious or fatal injuries. Figure 48 shows a calculator[24] that is endorsed by the Dropped Objects Prevention Scheme (DROPS) workgroup. It plots the mass of a dropped object against the distance it falls to determine its possible consequences on individuals.

I.2.2. Work at heights and falling hazards

Working at height remains one of the biggest causes of fatalities and major injuries in industry. Common cases include falls from ladders, elevated work platforms and through fragile surfaces. Working at heights means work in any place where, if there were no precautions in place, a person could fall a distance liable to cause

[22] See https://trafficsafety.org
[23] See www.hse.gov.uk/workplacetransport/vehicles/safevehicles.htm
[24] Imperial and metric versions are available at www.dropsonline.org/resources-and-guidance/drops-calculator

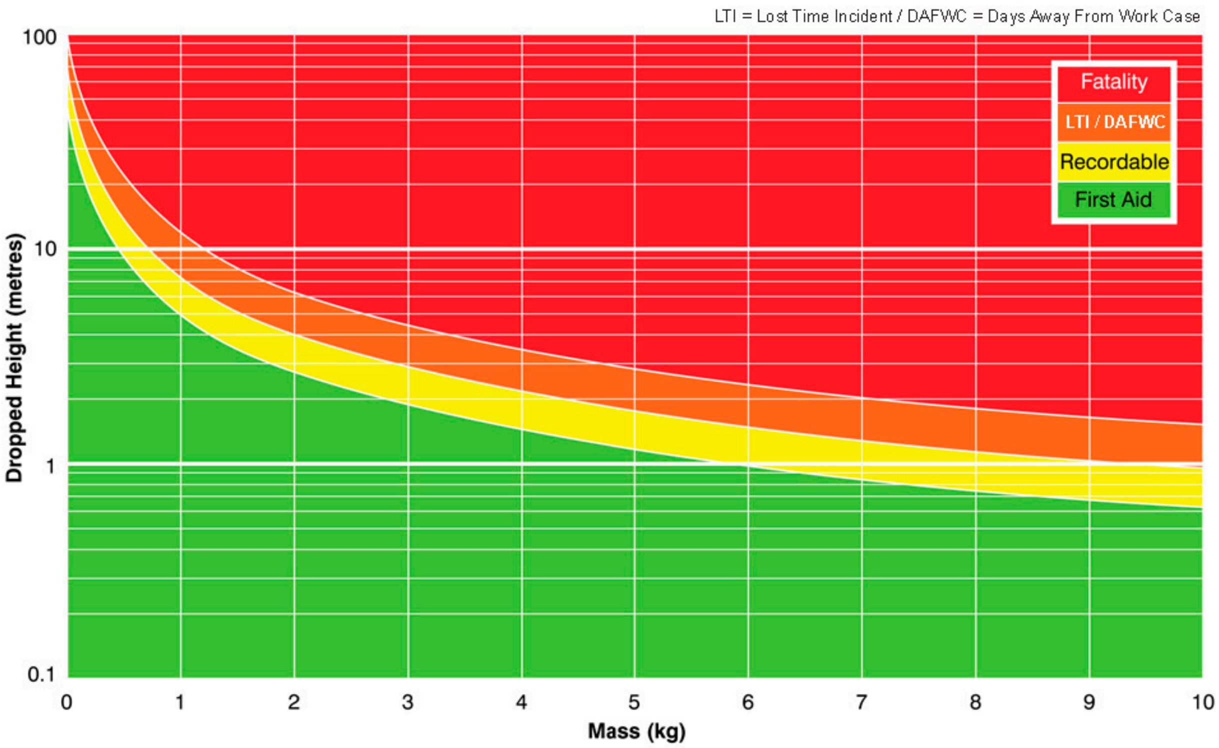

FIG. 48. DROPS calculator (courtesy of DROPS).

personal injury (e.g. a fall through a fragile roof or a floor opening). Common heights used in many jurisdictions to invoke additional work at height precautions are either 3 m or 10 ft. Such work can also induce falling object hazards (tools or equipment falling from an elevated location) as described above.

Even work below the 3 m height level or on a level surface can be subjected to falling related hazards. Given the right circumstances, serious injury can still take place. Reference [241] describes fall energy measured in joules for given weights and fall distances (see Fig. 49). The curves are derived from the simple formula of energy (in J) of a dropped object equalling the mass of the object (in kg) times the distance fallen (in m) times the gravitational constant (9.8 m/s^2). Fall energy is used in connection with the risk of personal injury, and a limit of 40 J has been defined in some jurisdictions as the criterion for serious personal injury.

Specific controls surrounding overhead work are important in nuclear facilities, as they are constructed with multiple floors and elevations, and work activities can often be planned in such a manner that individuals have the potential to work above or below each other. Operating experience from the oil and gas industry is particularly relevant due to the nature of oil derricks, platforms and refineries in that industry (see Refs [242, 243]).

Managing work at height follows a hierarchy of controls — avoid, prevent and arrest. ‘Avoid’ addresses whether the work can be safely done on the ground or whether alternate methods can be used (e.g. use of unmanned aerial vehicles or drones) as opposed to working at heights. ‘Prevention’ mechanisms include various systems designed to prevent individuals from getting into a position where they can fall or drop material, and include guardrails, toe boards, tethers, travel restraint systems, fencing and scaffolding. Floors or stairwells constructed with gratings can have the gratings covered to eliminate small objects dropping through. ‘Arrest’ mechanisms include various types of fall restraint system and safety netting, which should only be considered as a last resort if other safety equipment cannot be used. Some typical actions to address the hazards that work at height might entail are listed in Table 31 and some good examples of such actions are shown in Figs 50–52 (see Refs [244–247] and The Work at Height Regulations 2005 (United Kingdom) for national regulations specific to work at height).

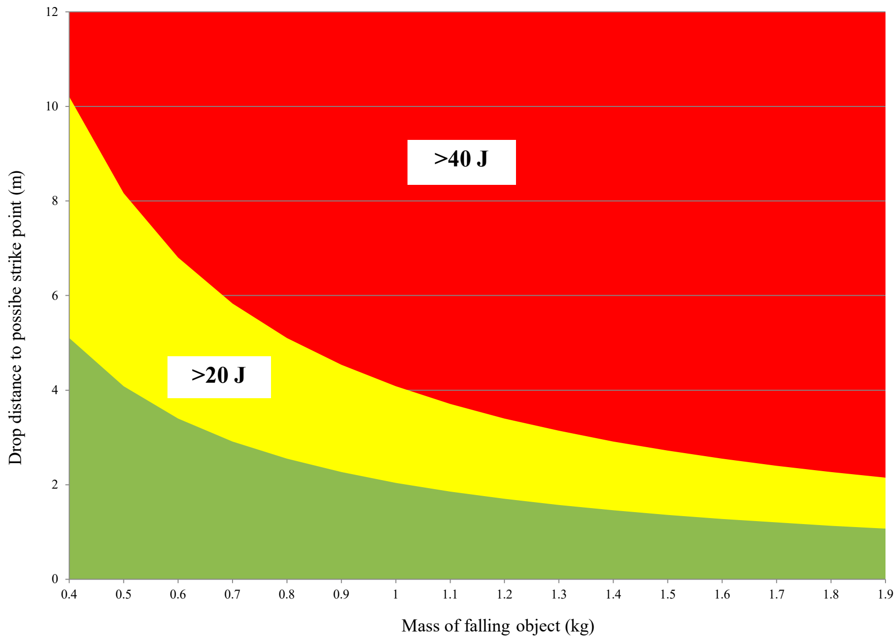

FIG. 49. Fall energy (adapted from Ref. [241] with permission courtesy of Samarbeid for Sikkerhet).

I.2.3. Craning and hoisting

Significant injuries, near misses and deaths have occurred at nuclear sites during craning and hoisting operations [227, 248, 249].[25] Construction, operations and maintenance activities all routinely require the use of cranes and hoists, as well as similar equipment with extendable booms such as concrete pumpers. Recent trends such as modularization have increased the mass and frequency of heavy lifts. Heavy loads can include turbine spindles and rotors, radioactive material flasks and transport containers, steam generators, new nuclear power plant components such as reactor pressure vessels, pressurizers, modules and other large components, and other equipment. Nuclear related cranes often have special requirements to withstand seismic loads, and dropping of heavy loads onto plant equipment or spent fuel can have nuclear safety implications. Transport of heavy components typically requires special rigging and handling arrangements to move the components on and off rail transport, port facilities, large trucks, barges or ships.

Analysis[26] of overhead crane accidents reveals three common safety hazards:

(a) Electrical hazards: Contact with a power source during operation, typically high voltage power lines. Usually, the electrocuted person is touching the crane when it comes into contact with the power line. Danger is not limited to the operator, but extends to all personnel in the vicinity. Power line contacts most often occur due to a lack of safety planning and preventive measures to avoid hazards.
(b) Overloading: According to the OSHA, 80% of all crane upsets and structural failures can be attributed to exceeding the crane's operational capacity. When a crane is overloaded, it is subject to structural stresses that may cause irreversible damage. Swinging or sudden dropping of the load, using defective components, hoisting a load beyond capacity, dragging a load and side-loading a boom can all cause overloading. Overloading most often occurs when poorly trained personnel are allowed to operate cranes.
(c) Material falling: Visual impairment, two-blocking, slipping, mechanical failure or operator incompetency can all result in serious injuries or fatalities. If materials are not properly secured, loads can slip and land on workers or cause major property damage. For larger or mobile cranes, undesired movement of material can pinch or crush workers involved in the rigging process. Regular maintenance, inspections, PPE and worker training can help reduce this risk.

[25] Incident Reports 7870, 8053, 8402, 8504 and 8564 are available from https://nucleus.iaea.org/Pages/irs1.aspx

[26] See www.spanco.com/overhead-crane-safety-three-major-hazards-preventative-measures

TABLE 31. ACTIONS FOR WORK AT HEIGHT

Subject area	Action
Tools and equipment	Consider alternate methods to access/view the high location (e.g. use of unmanned aerial vehicles/drones).
	Secure tools, portable equipment and materials used at height to either the user or the workplace to prevent them from falling on people below.
	Ensure tools used at height have a lanyard attachment point that does not compromise the tool's effectiveness.
	Inspect all tools, lanyards and attachment points prior to use and prior to their return storage, to ensure they are fit for purpose.
	Minimize amount of materials at height.
	Store materials at height in secure, enclosed boxes or containers.
	Use pails or bags to lift tools/equipment.
	Pre-fabricate small components on the ground prior to using at height.
	Inspect all overhead equipment and locations for loose items that may present a hazard during maintenance activities.
	Do not modify any tools or securing equipment.
	Use only tools reviewed and approved for use at height.
	Inspect PPE prior to use (e.g. safety harness, lanyard and chin straps).
	Review handling and securing procedures for tubular or other difficult to secure components. Use 'grab and twist' method for handoff of tubes.
	Consider allocating specific toolkits for working at height, with processes to account for such tools.
	Apply additional controls if specialized PPE, such as radiological clothing, may reduce dexterity and increase risk of falling objects.
Work area	Barricade 'drop zone' hazard areas and post warning signs to restrict access before work is conducted overhead. Use a spotter where necessary. Use a drop cone calculator tool[a] to determine how far a barrier should be placed from a 'straight down' position (objects do not necessarily drop straight down).
	Use toeboards, screens, or guardrails on scaffolds to prevent falling objects. Minimize use of open gratings in facility design.
	Add secondary retention, and consider safety systems, such as safety nets debris nets, catch platforms or canopies to catch or deflect falling objects.
	Consider installing ladder braces and backrests and permanently installing fall arrest safety blocks in the plant to ensure safety further and prevent accidents in areas where ladders are routinely used.
	Consider installing permanent platforms for areas routinely necessary to access via ladders or scaffolding.
	Develop standard practices for protecting holes or other open floor penetrations.

TABLE 31. ACTIONS FOR WORK AT HEIGHT (cont.)

Subject area	Action
	Consider the impact of weather on outdoor work. Wind may blow objects off platforms and in winter falling ice, slipping and cold temperatures can pose hazards.
Personnel	Train and qualify personnel working at height and/or using ‘at height’ compliant tools. Ensure training for personnel includes methods to identify and mitigate dropped objects and proper use of PPE (e.g. travel restraint, fall restrict, fall arrest, safety net, work belts and/or safety belts).
Procedures	Introduce working at height procedures. Properly review and approve any deviations to approved best practices and procedures for working at heights.
	Coordinate work schedules with other work groups working above or below.
	Use a job safety analysis to plan work at heights and to reduce dropped object potential.
	Ensure rigging risk assessments require consideration of the risk involved in moving equipment at height.
	Report any dropped tool or equipment, or any failures of a retention system such that there was potential for the tool or equipment to drop. Record and track specific dropped objects and address any identified trends.
	Appoint area owners to consider/ensure safety of at height work within their area.
	Develop an inspection programme related to work at heights.
	Consider a dropped object campaign and/or hazard hunt.

[a] Available from http://dropsonline.org/resources-and-guidance/presentations/general-interest/drop-cone-calculations

Note: PPE — personal protective equipment.

FIG. 50. Travel restraint system for use on a roof (courtesy of Électricité de France).

FIG. 51. Workers tied when dismantling scaffolding (courtesy of Électricité de France).

FIG. 52. Hole protection standards from the occupational safety and health manual (courtesy of the China National Nuclear Corporation).

Groups such as the American Society of Civil Engineers (ASCE) indicate that construction crane safety plans including both production and critical lifts should incorporate crane erection and dismantling, and that national crane operator certification programmes that cover operators, riggers, lift directors, spotters, and other crane personnel are recommended [250]. The ASCE reports that for construction activities electrocution via contact with electrical power lines is the number one cause of crane related fatalities.

An IAEA publication provides experience of heavy component replacement at nuclear power plants [251]. The Nuclear Regulatory Commission has developed a number of guideline documents specific to craning at nuclear power plants, primarily addressing nuclear safety issues (see Table 32).

Industrial safety control for craning and rigging typically incorporates many of the same practices as utilized to address nuclear safety concerns. Permanently mounted cranes and hoists should be marked with their rated capacity.

A usual aspect of a crane safety programme is the requirement for lift plans. Lift plans may be for general lifts (i.e. non-production or non-critical lifts), production lifts (repetitive, non-critical lifts), or for critical lifts (lifts using multiple cranes, helicopters or where other criteria involving the weight of the equipment, swing area, overall risk, difficulty or complexity of the lift, toxicity of the product being lifted or other considerations are met). General lift plans should:

TABLE 32. NUCLEAR REGULATORY COMMISSION HEAVY LIFT CRANE DOCUMENTS

Document	Summary
NUREG-0554, Single Failure-proof Cranes for Nuclear Power Plants [252]	Identifies features of the design, fabrication, installation, inspection, testing and operation of single failure-proof overhead crane handling systems that are used to handle critical loads.
NUREG-0612, Control of Heavy Loads at Nuclear Power Plants [253]	Provides alternative criteria for upgrading the reliability of existing cranes to single failure-proof standards.
NUREG-0933: Main Report with Supplements 1–34, Resolution of Generic Safety Issues, Issue 186: Potential Risk and Consequences of Heavy Load Drops in Nuclear Power Plants [254]	Endorses ASME NOG-1 for Type I cranes as an acceptable method of qualifying new or upgraded cranes as single failure-proof and issue guidance endorsing the standard, as appropriate.
NUREG-1774, A Survey of Crane Operating Experience at US Nuclear Power Plants from 1968 through 2002 [255]	Provides a detailed review of crane operating experience at US nuclear power plants from 1968 to 2002. Information was obtained from several sources including licensee event reports (10 CFR 50, sections 50.72 [256] and 50.73 [257]), NRC inspection reports, licensee correspondence and crane vendor reports.
NRC Regulatory Issue Summary 2005-25, Clarification of NRC Guidelines for Control of Heavy Loads [258]	Clarifies guidance related to control of heavy loads, as a result of recommendations developed through Generic Issue 186 [254] and findings developed through the NRC inspection programme.
NRC Regulatory Issue Summary 2005-25 (Supplement 1), Clarification of NRC Guidelines for Control of Heavy Loads [259]	Announced availability of guidance on handling systems, single failure-proof cranes and methods for heavy load analyses, and communicates regulatory expectations associated with 10 CFR 50, sections 50.59 [260] and 50.71(e)[261], as these requirements relate to the safe handling of heavy loads and load drop analyses.
NRC Information Notice 2014-12, Crane and Heavy Lift Issues Identified during NRC Inspections [262]	Provides examples of issues identified by NRC inspectors during crane and heavy lift inspections.

(a) List any restrictions due to weather limitations, time of day and temperature;
(b) Require that the weight of the load be known;
(c) Require barricading of hazard areas and posting of warning signs;
(d) Give a description of the general arrangement and use of rigging equipment such as ‘no chains allowed’ or ‘no slings made with cable clamps’ or any other general admonition that is appropriate to site conditions;
(e) Outline procedures used to ensure that rigging equipment has been inspected properly;
(f) Require a lift director to be in charge of each lift;
(g) Require a signal person be assigned and clearly identified as such to the operator.

Production lifts may all be covered by one lift plan that outlines the procedures, parameters and equipment to be used. They are an extension of general lift plans and should:

(a) Contain a description of items to be repetitively lifted including worst-case size, shape, weight and centre of gravity.
(b) List operational factors such as lifting and swing speeds, and the travel path.
(c) Address hazards from failure of the rigging and/or collision. A hazard evaluation should be performed to identify and eliminate these potential hazards. Hazards associated with lifting over personnel and congested areas should be eliminated by either controlling access to the area or by changing the path of the lifting operation. Staff training should ensure people know to avoid working underneath loads being moved.
(d) List specific restrictions over and above those for the general lift plan that are necessary because of weather, time of day and temperature.

(e) Identify the type and minimum capacity of the lifting equipment required.
(f) Identify specific arrangements of rigging equipment.
(g) Identify special rigging fixtures which might be required. Fixtures should be designed in accordance with applicable regulations and standards.
(h) Require rigging and lifting equipment to be inspected regularly and a documented record of inspection and/or certification history be maintained.
(i) Require a designated leader of the rigging crew be appointed.

Critical lifts are similar to production lifts but require individual lift plans covering the specifics of the particular lift. Communication around the hazards involved with craning and lifting is important. The Gravelines nuclear power plant was recognized with an OSART good practice in 2012 on account of the various awareness tools used for lifting.[27] These included an awareness booklet on the essentials of lifting, a sextant on which safety points are labelled, and a graduated rule for calculation of the maximum weight according to the slinging mode used. A sample crane safety poster used in Ontario, Canada is provided in Fig. 53.

FIG. 53. Crane safety poster (courtesy of the Government of Ontario).

[27] See www-ns.iaea.org/downloads/ni/s-reviews/gp-2009/1.5.pdf

1.2.4. Stairwell related hazards

The vast majority of stairway and ramp related falls result from a loss of balance, just as falls are on level surfaces. Common contributing factors are neglecting to use handrails, inattention and unsafe behaviours. The American National Council on Compensation Insurance estimated that the cost of such fall injuries in 2001–2002 was second only to those caused by motor vehicles.[28]

Because stairway accidents can cause severe injury and even death, building codes for stairs and ramps are normally very rigorous. Good design (good handrails, appropriate and uniform steepness, uniform tread, good visibility, and methods to keep snow or ice clear) can substantially reduce the potential for missteps, but even the best design cannot completely eliminate falling hazards.

The best approach to minimize the hazard of falling down stairs is to encourage the building of well designed stairways, combined with training focused on raising our awareness of the potential for hazards. Training should focus on persuading people to grasp handrails while ascending or descending stairs, avoid carrying objects with both hands, and not carry bulky objects that block vision. Care needs to be taken during construction to ensure personnel are protected from falling thorough openings for future stairwells or guardrails.

I.2.5. Slips and trips

Slips and trips can be the most common causes of injury at work.[29] Most slips occur when floors or outside walking surfaces become wet, icy or contaminated. Many trips are due to poor housekeeping or inattention. Solutions are often simple and cost effective and a basic risk assessment should help to identify any slip or trip hazards in your workplace. Some methods to be considered include the following:

(a) Prevent walking surfaces from becoming wet or contaminated in the first place;
(b) Clean up spills quickly and have cleanup and warning equipment (e.g. pylons and signs) readily available;
(c) Create awareness surrounding tripping hazards such as uneven floors or trailing cables (including in meeting rooms), and encourage good housekeeping and attention while walking;
(d) Ensure workers wear suitable footwear;
(e) Allocate sufficient resources to winter snow clearing and de-icing;
(f) Keep related winter supplies (e.g. sand, salt and shovels) near potential problem areas for easy access when needed;
(g) Ensure flooring is suitable.

I.3. ELECTRICAL HAZARDS

I.3.1. Physical impacts

Electricity can cause direct injury, including electrocution and death, due to electric shocks and burns, and indirect injuries or death from falls and fire. The severity of shocks depends on the path of current through the body, the amount of current flowing, and the duration of the shocking current. Voltages above 600 V can cause dielectric breakdown at the skin, thus lowering skin resistance and allowing further increased current flow. Figure 54 shows the effect of alternating current passing from the left hand to the feet on a human body, with.

Reference [264] provides a table of nominal system voltages, with low voltages defined as anything 600 V and below, medium as between 2400 V and 69 kV, and high as 115 kV and above. In a typical nuclear facility, the voltage ranges may be considered more from an equipment perspective or be defined per national electrical safety codes. Care should thus be taken in using the terms low, medium or high voltage. Steady state voltages up to 42.4 Vac peak, or 60 Vdc, are not generally regarded as hazardous under dry conditions for an area of contact equivalent to a human hand. Bare parts that have to be touched or handled should be at earth potential or properly insulated [265]. Above these levels voltage is considered hazardous.

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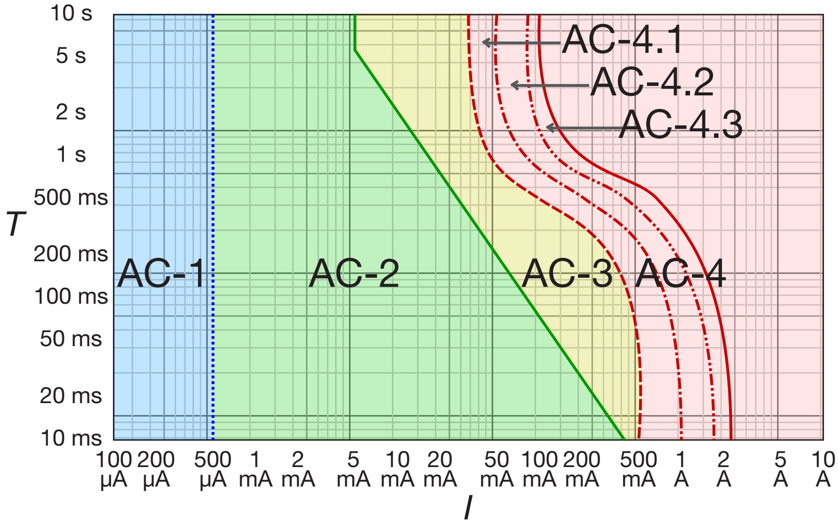
[28] See www.ccohs.ca/oshanswers/safety_haz/stairs_fallprevention.html

[29] See www.hse.gov.uk/toolbox/slips.htm



Source: Cmglee: Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=35414234

Note: AC-1 is imperceptible. AC-2 is perceptible but no muscle reaction. AC-3 induces muscle contraction with reversible effects. AC-4 has possible irreversible effects (AC-4.1: up to 5% probability of heart fibrillation, AC-4.2: 5–50% probability of fibrillation, AC-4.3: over 50% probability of fibrillation).

FIG. 54. Log-log graph of the effect of alternating current I of duration T passing from the left hand to the feet as defined in Ref. [263].

I.3.2. Arc flash

Energized electrical equipment presents the risk of arc flash — the energy release that occurs during an electrical fault when current flows through the air between two live conductors, causing a short circuit. Arc flash can be spontaneous or can result from inadvertently bridging electrical contacts with a conducting object such as a potential tester. Other causes may include dropped tools or the buildups of conductive dust or corrosion.

In a residential setting, arc flashes usually produce little more than a brief flash of light before extinguishing themselves harmlessly. In a commercial or industrial setting, however, voltages and current are much higher, so arc flashes routinely produce powerful explosions marked by searing heat, toxic fumes, blinding light, deafening noise, flying shrapnel, and massive pressure waves (see Fig. 55). Arc flash temperatures can reach or exceed 19 400°C at the arc terminals [266].

According to Electrical Safety Foundation International, 2000 workers in the United States of America are admitted to burn centres each year for treatment of severe arc flash burns.[30] Électricité de France reports that electrical arc injuries account for 77% of all recorded electrical injuries.[31]

Properly protecting workers from arc flash involves additional PPE than was previously considered adequate for electrical workers (see Fig. 56). Materials used for such PPE are tested for their arc rating, which is the maximum incident energy resistance (expressed in cal/cm) demonstrated by a material prior to breakopen (a hole in the material) or necessary to pass through and cause with 50% probability of a second or third degree burn [267]. A standard test for arc rating is Ref. [268]. Good fabrics for protection against electric arc flash are modacrylic-cotton blends.

Methods for selection of arc flash PPE include consulting a hazard category classification table (e.g. Ref. [267]), which will yield a necessary protective clothing system category, or to perform a detailed arc flash calculation following a process such as that shown in Ref. [269] to determine the available incident arc energy, and then selecting appropriate PPE to offer protection against that energy level. CSA Z462 [75] is another source of arc flash and worker electrical safety protection information that incorporates the approach of the National Fire Protection Association [267].

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[30] See http://esfi.org/index.cfm/page/Arc-Flash-Awareness/pid/10862

[31] See https://standards.ieee.org/about/arcflash/prospectus.pdf

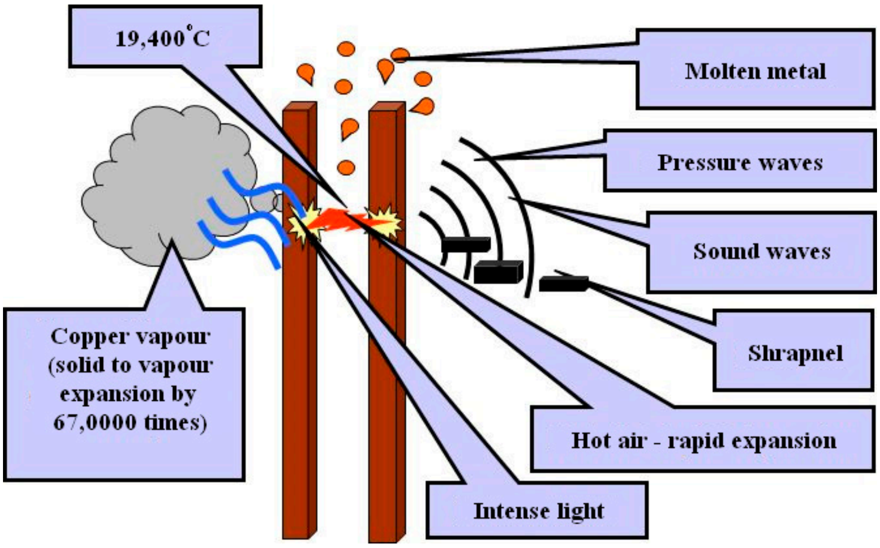

FIG. 55. Arc flash hazards (courtesy of Ontario Power Generation).

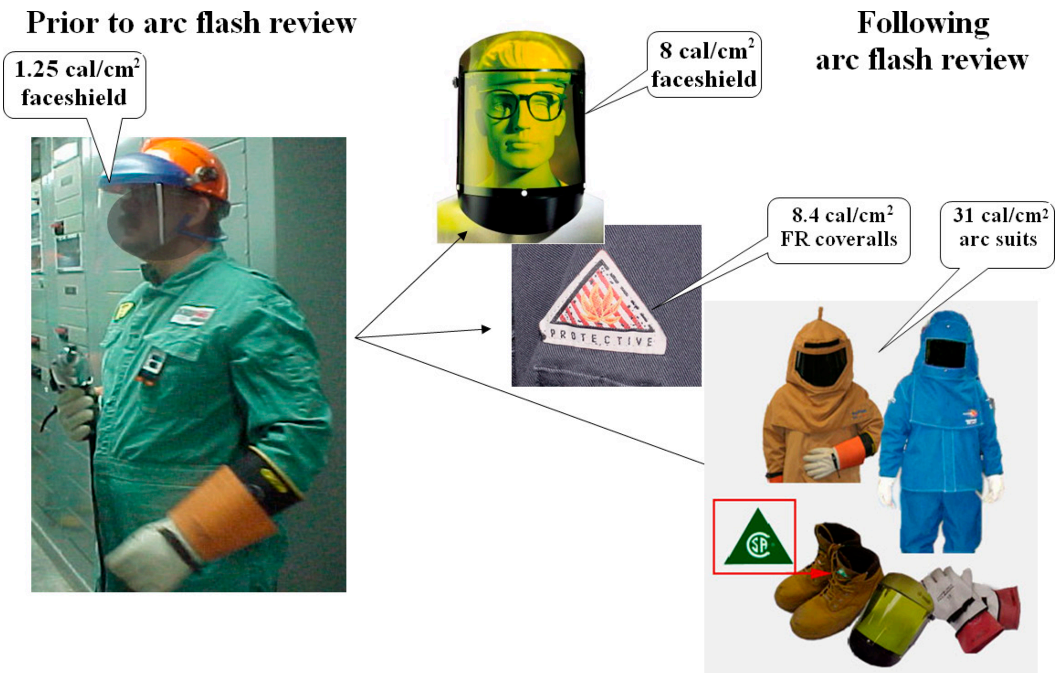

FIG. 56. Typical electrician clothing prior to (left) and following (right) a review of arc flash potential (courtesy of Ontario Power Generation).

New tooling and work practices can also contribute to protection from arc flash. Longer handled remote breaker racking tools can increase the distance of workers from potential faults, using only test equipment that is certified to international standards can reduce the risk of contacts being inadvertently bridged, implementation of a 'no jewellery' policy can reduce the severity of any electrical burns to the hands, and shielding for bystanders can increase their safety. A list of routinely encountered electrical work and the required PPE to adequately protect against arc flash can make work planning easier. Some sample improvements done by Ontario Power Generation are shown in Fig. 57.

FIG. 57. Arc flash related improvements at Ontario Power Generation, including changes in manual switching practices, new remote racking tools and exclusion boundary shields (courtesy of Ontario Power Generation).

I.3.3. Live line work

Live line work is the maintenance of electrical equipment, often operating at high voltage, while the equipment is energized. It is generally accepted that live line work should be avoided where practical, and in nuclear facilities, the amount of live line work has been generally declining over time. Where necessary, requirements should be established, which allow qualified individuals to work on energized equipment. They should address the following topics:

— Work limits/approach boundaries for workers and bystanders;
— Clearances for live line work (distance between live apparatus and a ground source);
— Appropriate PPE for live line work (including arc flash protection);
— Special tools for live line work;
— Special work equipment for live line work;
— Qualification of employees for live line work;
— Recommended live line work practices.

I.3.4. Protection considerations

PPE provides protection after electrical incidents have occurred and should be viewed as the last line of protection. Reducing the frequency and severity of incidents should be the first option and this can be achieved through a complete arc flash hazard assessment and through the application of technology such as high-resistance grounding which can reduce the frequency and severity of incidents. Equipment design can include measures to shield or separate hazardous voltages from normally accessible areas, provide safety interlocks, select appropriate (non-flammable/ignitable) materials, provide overcurrent protection, use of ground fault circuit interrupters (GFCIs) or arc fault circuit interrupters (AFCIs).

Most electrical safety regulations include a concept of ‘limits of approach’. Such a concept defines the minimum distances that must be maintained between an electrical hazard (such as overhead transmission lines) and qualified workers or the general public (see Table 33).

Permanent and portable equipment should be confirmed to be in accordance with national electrical safety codes. Often local authorities will provide special inspections and approvals for the use of customized equipment.

TABLE 33. EXAMPLE LIMITS OF APPROACH REGULATION

Nominal phase-to-phase voltage rating (V)	Minimum distance (m)
750 or more, but no more than 150 000	3.0
More than 150 000, but no more than 250 000	4.5
More than 250 000	6.0

Source: Occupational Health and Safety Act, Ontario Regulation 213/91 Construction Projects.
Note: No object to be brought closer to energized overhead conductor by qualified workers).

I.3.5. Temporary installations

Construction sites usually require installation of temporary electrical supplies. These supplies are often exposed to weather, frequently relocated and experience rough use and other conditions not normally encountered by conventional wiring systems. A shock or arc fault from a temporary installation can, however, be just as deadly as one from a permanent installation, and either type of installation is capable of igniting a fire if the conductors overheat or an arc is produced by faulty wiring. The same rules concerning workmanship, conductor ampacity limits and overcurrent protection apply to both kinds of installations. Typical electrical codes do allow for some changes in wiring methods and materials for temporary installations. Of particular concern is that the materials used (e.g. cabling and lamps) are sufficiently robust or otherwise protected from accidental damage such as that that can occur on a construction site, and that personnel are protected via GFCI devices. Lighting and receptacle power supply circuits are generally kept separate so that a fault caused, for example, by a power tool does not initiate a tripping of lighting circuits (and thus the introduction of another hazard).

I.4. THERMAL HAZARDS

Thermal hazards stem from extremes of low or high temperature. The hazards can be because of direct contact with hot or cold material, or indirectly during work in a hot or cold environment.

I.4.1. Contact with hot objects

Nuclear power plants contain many hot objects, primarily as a cause of heat generated or found in the reactor and turbine steam cycle. Proper maintenance practices for the restoration of thermal insulation, and standard protective clothing such as gloves and coveralls can help minimize the potential for inadvertent contact. Non-ionizing thermal radiation (not associated with direct contact) is discussed in Section I.11.2.

I.4.2. Cryogenic hazards

Cryogenic hazards, typically through the use of liquid nitrogen helium, or oxygen, are present at most nuclear power plants. Cryogenic liquids are typically odourless and colourless when vaporized to the gaseous state. Most have no colour as a liquid, although liquid oxygen is light blue. Extremely cold liquid and vapours are associated with highly visible fogs that occur when the cold boil off gases condense into moisture in the air. Cryogenic liquids and their cold boil off vapours are extremely cold and can rapidly freeze human tissue and cause frostbite or flesh sticking to cold materials. Even a brief contact with a cryogenic liquid is capable of causing tissue damage similar to that of thermal burns. Prolonged contact may result in blood clots. Other hazards can include pressure build ups or explosions due to expansions that occur on temperature rises, accelerating combustion effects (for liquid oxygen), and material embrittlement. PPE typically includes eye protection, hand protection and protective clothing that covers all skin surfaces.

I.4.3. Extreme heat

Exposure to excessive heat can lead to heat stress that could lead to heat exhaustion, fainting, heat stroke and other conditions. As temperature or heat burden increases, people may feel increased irritability and lose concentration and the ability to do mental or skilled tasks. Power plants are especially susceptible to high temperature conditions due to the presence of large heat sources such as steam and hot water piping. Areas near the tops of buildings where heat will rise, or around secondary system equipment such as the turbine generator, are especially vulnerable.

Occupational exposure limits or guidelines for exposure to high temperatures depend on a number of factors, not just the temperature. These other factors include relative humidity, exposure to sun or other heat sources, amount of air movement, physical work demands, worker acclimatization, clothing — including protective clothing, included related protection from ultraviolet light for outdoor workers (see Section I.11.2), and the work to rest regimen (% time work vs % time rest break).

Threshold limit values for heat stress are published by the American Conference of Governmental Industrial Hygienists [270]. Heat stress exposure is expressed as wet bulb globe temperature (WBGT) values in degrees Celsius. Direct reading WBGT meters or 'heat stress indicators' are commercially available. Their measurements can depend on the physical demands of the job. The ISO [271] specifies a method for analytical evaluation and interpretation of thermal stress experienced by a subject in a hot environment. It describes a method for predicting the sweat rate and internal core temperature that the human body will develop in response to working conditions.

A variety of specialized PPE exists for work in extremely hot environments. These include reflective aluminized or Kevlar protective clothing, cooling jackets and others. Frequent breaks in a cool environment with plenty of water, and the use of methods to help to minimize local temperatures (e.g. fans) are also encouraged.

I.4.4. Extreme cold

Workers in cold environments can experience thermal discomfort, increased strain, decreased performance and cold related diseases and injuries. Cold can also modify or aggravate the risk of common hazards and increase the risk of cold associated injuries. When the body is exposed to cold temperatures, the negative effects can include dehydration, numbness, shivering, frostbite, immersion foot and hypothermia. These effects are experienced first by the peripheral parts of the body and gradually progress to deep body tissues and the body core. When the body's core temperature drops below 35°C, it is defined as hypothermia, which along with frostbite is one of the more extreme dangers of prolonged work in cold environments.

Frostbite freezes and crystallizes fluids in body tissues. This can cause blood clotting and lack of oxygen to the affected area and deeper tissues. In severe cases, frostbite can kill and damage tissue to the extent that an amputation may be required. Frostbite can occur in just a few minutes if conditions are cold enough with a high wind chill factor on unprotected body parts, for example, the ears.

Protection from cold requires the wearing of proper warm clothing that ensures all skin is protected, eating and drinking properly (ensuring plenty of carbohydrates for energy and plenty of fluids), and removing any wet clothing promptly (see Ref. [272] for practical instructions for risk analysis and management in cold working conditions).

I.5. NOISE HAZARDS

Noise exposure can cause both non-auditory effects and auditory effects. Non-auditory effects include stress, related physiological and behavioural effects, and safety concerns. Auditory effects include acoustic trauma (sudden hearing damage caused by short burst of extremely loud noise), tinnitus (ringing or buzzing in the ear), temporary hearing loss or permanent hearing loss. Permanent hearing loss progresses constantly as noise exposure continues year after year. The impairment is noticeable only when it is substantial enough to interfere with routine activities. Once this has occurred, there is irreversible hearing damage, which cannot be cured by medical treatment and worsens with continued noise exposure. Some individuals are more susceptible to noise induced hearing loss than others.

Occupational exposure limits for noise are typically given as the maximum duration of exposure permitted for various noise levels. They are often displayed in exposure duration tables (see Table 34). The occupational exposure limits depend on two key factors: the criterion level and the exchange rate. The criterion level is the steady noise level permitted for a full eight hour work shift, while the exchange rate is the amount by which the permitted sound level may increase if the exposure time is halved.

Standard measures taken by operating organizations to address noise include signage and warnings in noisy areas indicating hazard levels and necessary PPE required (typically earplugs), design standards surrounding acceptable or targeted noise levels (that influence equipment purchases), installation of noisy equipment in low traffic or segregated areas, and installation of noise baffles or noise absorbing panels around or as part of noisy equipment. Addressing noise issues can often have other benefits; such as in reducing vibration levels that might be causing other industrial safety hazards (see Section I.8.1) or be associated with equipment damage.

Many operating organizations include hearing level screening and testing ('audiometry' programmes) as part of their OSH programmes. Such testing can provide indications as to the effectiveness of noise control and hearing programmes, and provide individuals with early detection of hearing loss from occupation or non-occupational sources. In a group of exposed persons, the percentage of population with hearing loss depends on the level of noise exposure and the duration of exposure. For higher noise exposure levels, and longer durations of exposures, a larger percentage of exposed persons acquire hearing loss. This observation forms the basis for calculating noise induced hearing loss as outlined in Refs [273, 274].

An ILO code of practice [81] is available which covers the protection of workers against noise and vibration in the working environment, and the American Society of Safety Engineers has produced a guide [275] on hearing loss prevention for construction and demolition workers. The Canadian Standards Association has produced a standard [276] for hearing loss prevention programme management.

I.6. CHEMICAL HAZARDS

Many chemicals are present at a typical nuclear facility. Common items include chemicals used in water treatment, cleaning and decontamination and laboratory equipment, chemicals used for laboratory analysis, battery electrolytes, refrigerants, lubricants, in deuterium oxide upgrading facilities, and for yard maintenance (pesticides and fertilizers).

Nuclear fuel cycle facilities utilize a number of chemicals in their processes such as hydrogen fluoride, ammonia, tributyl phosphate and nitric acid. In such facilities, the industrial safety and chemical hazards to workers and the public can be greater than the radiological hazards (Requirement 70 of SSR-4 [25]). Exposure to humans can occur during product transport, use or disposal, and be via methods such as ingestion, inhalation or absorption through skin.

TABLE 34. SAMPLE NOISE EXPOSURE LIMITS

Permissible level (dB(A))	Max. permitted daily duration (hours)
85	8
88	4
91	2
94	1
97	0.5
100	0.25

Source: Canadian Centre for Occupational Health and Safety
www.ccohs.ca/oshanswers/phys_agents/exposure_can.html
Note: Criterion level = 85 dB(A) and exchange rate = 3 dB(A).

Appropriate chemical control regimes play a part in maintaining equipment reliability (via minimizing corrosion), in the reduction of occupational radiation does rates, and in minimizing environmental radiological releases. Each chemical has its own properties and hazards as described in safety data sheets (see Section 6.3.2.5). Beyond these hazards, the inadvertent mixing of chemicals or their improper use can introduce new hazards via chemical reactions, uncontrolled releases, and/or fires or explosions. The World Health Organization (WHO) maintains web based health and safety guides[32] that provide concise information on risks from exposure to chemicals, together with practical advice on medical and administrative issues. The ILO maintains a database of International Chemical Safety Cards (see Fig. 58).[33]

IAEA Safety Standards Series No. SSG-13, Chemistry Programme for Water Cooled Nuclear Power Plants [277], includes necessary items for chemical safety:

(a) A list of approved chemicals and other substances for use in the facility is maintained.
(b) Procedures are available for procurement, storage, replacement and ordering of chemicals and other substances, including hazardous chemicals.
(c) Chemical containers, including smaller containers into which chemicals are decanted, are properly labelled.
(d) Harmful chemicals are encouraged to be substituted with less harmful substances.
(e) Applicable staff are adequately trained to understand storage compatibility, labelling requirements, handling, safety and impacts on structures, systems and components at the plant.
(f) Managers perform walkdowns to check (among other things) for uncontrolled storage of chemicals.
(g) Safety data sheets for all approved chemicals and substances are available and easily accessible.
(h) Chemicals are stored properly:
    — Fire protected, with spill containment;
    — Emergency showers equipped as necessary;
    — Oxidizing and reducing chemicals, flammable solvents and concentrated acid and alkali solutions stored separately.
(i) Tanks containing chemicals are appropriately labelled.

HYDRAZINE	**ICSC:** 0281 Peer-Review Status: 25.11.2009 Validated
Diamide Diamine Nitrogen hydride (anhydrous)	
CAS #: 302-01-2 RTECS #: MU7175000 UN #: 2029 EC #: 007-008-00-3 EINECS #: 206-114-9	Formula: N_2H_4 / H_2N-NH_2 Molecular mass: 32.1

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRE-FIGHTING
FIRE	Flammable.	NO open flames, NO sparks and NO smoking.	Use alcohol-resistant foam, foam, water spray, dry powder, carbon dioxide.
EXPLOSION	Above 40°C explosive vapour/air mixtures may be formed. Risk of fire and explosion on contact with many materials.	Above 40°C use a closed system, ventilation and explosion-proof electrical equipment.	In case of fire: keep drums, etc., cool by spraying with water. Combat fire from a sheltered position.
EXPOSURE		**AVOID ALL CONTACT!**	**IN ALL CASES CONSULT A DOCTOR!**
Inhalation	Cough. Burning sensation. Headache. Confusion. Drowsiness. Nausea. Shortness of breath. Convulsions. Unconsciousness.	Use closed system and ventilation.	Fresh air, rest. Half-upright position. Refer immediately for medical attention.
Skin	MAY BE ABSORBED! Redness. Pain. Skin burns.	Protective gloves. Protective clothing.	First rinse with plenty of water for at least 15 minutes, then remove contaminated clothes and rinse again. See Notes. Refer immediately for medical attention.
Eyes	Redness. Pain. Blurred vision. Severe burns.	Wear face shield or eye protection in combination with breathing protection.	Rinse with plenty of water (remove contact lenses if easily possible). Refer immediately for medical attention.
Ingestion	Burns in mouth and throat. Abdominal pain. Diarrhoea. Vomiting. Shock or collapse. Further see Inhalation.	Do not eat, drink, or smoke during work. Wash hands before eating.	Rinse mouth. Give nothing to drink. Do NOT induce vomiting. Refer immediately for medical attention.

SPILLAGE DISPOSAL	PACKAGING & LABELLING
Evacuate danger area! Consult an expert! Personal protection: complete protective clothing including self-contained breathing apparatus. Do NOT let this chemical enter the environment. Collect leaking liquid in sealable non-metallic containers. Absorb remaining liquid in sand or inert absorbent. Then store and dispose of according to local regulations. Do NOT absorb in saw-dust or other combustible absorbents.	Special material. Unbreakable packaging. Put breakable packaging into closed unbreakable container. Do not transport with food and feedstuffs. **EC Classification** Symbol: T, N; R: 45-10-23/24/25-34-43-50/53; S: 53-45-60-61; Note: E **UN Classification**

FIG. 58. International Chemical Safety Card for hydrazine (courtesy of the International Labour Organization).

[32] See www.inchem.org/pages/hsg.html
[33] See www.ilo.org/dyn/icsc/showcard.home

(j) Workers:
- Understand the need for proper laboratory hygiene and conduct, such as never eating, drinking or chewing gum in a laboratory, confining loose hair and clothing, and avoiding horseplay and practical jokes;
- Use a 'buddy system' to avoid working alone when using chemicals;
- Know how to evaluate the procedure or process so that they take only the amount of chemicals necessary for the job;
- Know how to handle waste materials.

In addition, it should be ensured that systems are designed to control airborne chemical hazards such as fume hoods and exhaust systems.

I.7. HAZARDOUS MATERIALS

I.7.1. Exposure to designated substances

Exposure by inhalation, ingestion, skin absorption or skin contact of certain substances can be hazardous in the short term or long term. Certain chemical agents in most jurisdictions are designated as posing special hazards, and thus require special industrial safety treatment. Legal workplace exposure limits can set the permissible amounts present in workplace air. Typical designated substances include:

- Acrylonitrile;
- Arsenic;
- Asbestos;
- Benzene;
- Coke oven emissions;
- Ethylene oxide;
- Isocyanates;
- Lead;
- Mercury;
- Silica;
- Vinyl chloride.

Some typical regulations on designated substances are given in Ontario Regulation 490/09 Designated Substances of the Occupational Health and Safety Act and Refs [278, 279]. Such regulations typically require that employers adequately control exposure to materials in the workplace that cause ill health, and includes:

- Identifying harmful substances present in the workplace and how workers might be exposed to them;
- Developing measures to prevent this harm (considering such approaches as substance substitution, process changes, containment, ventilation, changes in work methods, cleaning to reduce hazard levels, and PPE);
- Providing information, instruction and training on safe handling of the substances;
- Performing long term health surveillance when appropriate.

Access to experts in OSH and industrial hygiene is typically necessary to ensure organizational approaches and controls are appropriate for such substances.

I.8. BODY MECHANICS

I.8.1. Industrial related musculoskeletal disorders

I.8.1.1. Manual material handling

The Canadian Centre for Occupational Health and Safety report that manual material handling is a common cause of occupational fatigue and low back pain.[34] Many workers whose job includes manual material handling suffer pain due to back injury at some time. Immediate and short term effects include accidental injuries and fatigue. Sharp or rough surfaces, and falling and flying objects are common causes of wounds, lacerations or bruises during manual material handling. The worker can also suffer these injuries by falling or by colliding with objects.

Workplace design, work assessment, ensuring equipment and tools packed in cases have limited weight, providing manual lifting assist tools (e.g. mechanical aids such as small hoists, lifts, levers, carts or platforms), and frequent breaks can reduce the potential for injury. Screening methods used during job planning can help to identify when workers are most at risk and whether a planned load and frequency of its handling is acceptable. Industrial related material safety data sheets from material handling result from the application of high forces to the body, awkward postures, or prolonged or repetitive exertions.

High forces can occur when heavy objects are moved manually (e.g. two or more people lifting an object, objects have poor grips, multiple objects are carried in the hands, equipment used is not the regular or prescribed equipment for the task), when forceful pushing, pulling or sliding of items or equipment is required (e.g. equipment normally used is unavailable or broken, cart wheels are in poor condition, carts are wheeled over rough/uneven surfaces), when high forces are exerted with, or on, the hands (e.g. hand tools are old or steel casings instead of plastic, manual tools used instead of power tools, or carts are overloaded).

Awkward postures can occur when work is positioned below waist level (e.g. kneeling or squatting required, overhead obstructions are below heights of employees, no knee pads/stools for low level work, or bending is required to reach heavy items), when work is positioned above shoulder level (e.g. heavy items are stored overhead, valves are located above shoulder level), when extended reaching is required (e.g. elevated work platforms are not as close as possible to the work), when bending, leaning or twisting is required (e.g. obstructions are present between the employee and work), or when viewing the work area is difficult (e.g. poor lighting, or obstacles are present between the employee and work).

Prolonged or repetitive exertions can occur when workers cannot rotate tasks or take rest breaks when needed (e.g. only one person in the group is qualified to perform a job), when standing is required for long periods of time (e.g. no anti-fatigue mats available around work benches or machine equipment), when sitting is required for long periods of time (e.g. seat heights are non-adjustable, not enough clearance for knees or legs), when material is carried long distances without a cart or lifting device (e.g. narrow walkways and/or obstructions on the path to the job), or for repetitive manual lifting activities (e.g. battery cell installations). A sample guide for doing manual lifting calculations is available in Ref. [280].

It should be noted that national standards for manual handling are moving away from regulating weight limits that differ between women and men workers, and are increasingly adopting a non-discriminatory approach based on individual risk assessment and control. Australia, Canada and the United States of America have introduced this into their own standards [281].

I.8.1.2. Vibration

Hand–arm vibration can be caused by operating handheld power tools, such as road breakers and hand guided equipment, such as powered lawnmowers or by holding materials being processed by hand fed machines, such as pedestal grinders. Occasional exposure is unlikely to cause ill health and can be usually addressed via tool selection or alternate work methods (see Section I.12.8 for specific issues surrounding vibration related to hand tools).

Whole body vibration can affect drivers of off road vehicles, such as heavy construction machinery. It is mainly associated with low back pain. Addressing the condition typically involves selection of different vehicles,

[34] See www.ccohs.ca/oshanswers/ergonomics/mmh/hlth_haz.html

keeping roadways level, keeping the machine in good repair, and operator training to operate the machines smoothly.

I.8.2. Office related musculoskeletal disorders

Most nuclear facilities employ significant numbers of staff who work in office environments. Repetitive tasks that put strain on muscles and joints cause many office injuries. Tendons are common sites of repetitive strain injury pain and discomfort, but workers can also experience pain in other areas of the body depending on the tasks performed. Well designed offices allow employees to work comfortably without needing to over-reach, sit or stand too long, or use awkward postures. In some cases, the office equipment might be satisfactory but tasks should be redesigned. For example, studies have shown that those working at computers have less discomfort with short breaks every hour.[35]

Many operating organizations provide access to trained ergonomists who can consult on proper office workstation equipment procurement and set-up, as well as train individuals in techniques to minimize the potential for repetitive strain injuries.

The ILO offers a ergonomics checkpoints guide [282] and associated smartphone applications. The International Ergonomics Association offers other related resources. The ISO publishes numerous standards on office ergonomics, notably the ISO 9241 series on ergonomics of human systems interactions, which includes information on visual display terminals and physical input devices (see Refs [283–286] for other standards).

I.8.3. Musculoskeletal disorder controls

Table 35 provides potential methods to help to prevent musculoskeletal disorder (MSD) related injuries caused by high forces, awkward postures and repetitive or prolonged exertions that might be experienced in an industrial environment.

I.9. COMPRESSED OR PRESSURIZED FLUIDS OR GASES

Many types of pressurized equipment can be potentially hazardous. These can include steam boilers and associated pipework, pressurized hot water boilers, air compressors, air receivers and associated pipework, gas storage tanks, gas cylinders and systems containing hydraulic fluids. If such equipment fails and bursts violently apart, parts can be propelled over great distances, causing injury and damage to people and equipment even hundreds of metres away. For breathing air systems, contamination or blocking of the breathing air supply can result in injury or death due to either the lack of sufficient air, or the impact of contaminants other than air being breathed in by the user.

Most nuclear facilities and jurisdictions have mandated programmes in place to ensure the safety of pressurized equipment. These include design controls, pressure testing, regular inspections to meet code requirements, and inspections by national authorized inspection agencies. Tooling and portable equipment are normally less controlled. Basic methods to address tooling hazards include the following:

(a) Using non-pressurized or lower pressure equipment (e.g. using vacuum equipment for cleaning rather than compressed air; do not use compressed air to clean or remove dust or dirt from any part of a person or clothing);
(b) Using pressure equipment that complies with relevant national product regulations;
(c) Perform regular recommended inspection and maintenance of the equipment prior to use;
(d) Follow manufacturer’s instructions to operate the equipment within its safe operating limits;
(e) Train workers who are going to operate the pressure equipment and also include what to do in an emergency;
(f) Only modify equipment according to approved processes.

[35] See www.cdc.gov/niosh/topics/officeenvironment

TABLE 35. POSSIBLE MUSCULOSKELETAL DISORDER PREVENTION CONTROLS FOR PARTICULAR HAZARDS

Hazard	Examples	Prevention controls
High forces	Heavy objects are moved manually 2 or more people lifting an object Object has poor grips Multiple objects carried in the hands Equipment used is not the regular or prescribed equipment for the task	Use carts or dollies Use smaller or lighter containers Use larger or heavier containers so load must be handled mechanically Install lifting anchor points to enable use of lifting devices Maintain floor surfaces to reduce friction Use gravity dumps, chutes or slides
	Forceful pushing, pulling or sliding of items or equipment is required Equipment normally used is unavailable or broken Cart wheels are in poor condition Cart is wheeled over rough/uneven surfaces	Obtain functioning dollies or other rolling devices Modify load so it can be handled with a forklift or other lifting device Maintain floor surfaces to reduce friction
	High forces are exerted with, or on, the hands Hand tools are old Hand tools have steel casing instead of plastic Manual tools used instead of power tools Cart is overloaded	Use power tools where possible Appropriate size and type of gloves for task Tool handle wraps for cushioning or vibration dampening Consider newer tools Use quick connect fasteners versus nuts and bolts
Awkward postures	Work is positioned below waist level Kneeling or squatting required Overhead obstructions below heights of employees No knee pads/stools for low level work Bending required to reach heavy items	Set scaffold to correct level Scissor lift cart to adjust height of materials Store heavy or frequently used items at mid levels Use knee pads or stools
	Work is positioned above shoulder level Heavy items stored overhead Valves above shoulder level	Set scaffold to correct level Store heavy or frequently used items at mid levels Elevate worker so work is between waist and chest level
	Extended reaching is required Elevated work platforms not as close as possible to the work	Set-up scaffolds or platforms as close to work as possible Use hooks or other devices to bring objects closer Support arm or body while reaching
	Bending, leaning or twisting Obstructions between the employee and work	Set-up scaffolds or platforms as close to work as possible Clear obstructions on pathways Keep storage areas clean Store items away from obstructions (e.g. scaffolds and equipment)
	Viewing work area is difficult Lights burnt out in work area Obstacles between employee and work	Ensure lighting is adequate before starting work Portable task lighting Mirrors or camera monitors
Repetitive/prolonged exertions	Workers cannot rotate tasks or take rest breaks when needed Only one person in the group is qualified to perform the job	Plan work to allow workers to rotate tasks and/or share work
	Standing is required for long periods of time No anti-fatigue mats available around work benches or machine equipment	Plan work and breaks to allow regular posture changes Anti-fatigue mats Adjustable stools Footrest to elevate one foot

TABLE 35. POSSIBLE MUSCULOSKELETAL DISORDER PREVENTION CONTROLS FOR PARTICULAR HAZARDS (cont.)

Hazard	Examples	Prevention controls
	Sitting is required for long periods of time Seat height is non-adjustable Not enough clearance for knees or legs	Plan work and breaks to allow regular posture changes Set-up sitting area with adequate leg room
	Material is carried long distances without a cart or lifting device Narrow walkways and/or obstructions on the path to the job	Stage equipment closer to work location Carts or dollies Use conveyor or crane Clear path to work to allow carts or dollies
	Similar motion performed or same muscles used frequently, or frequent wrist or forearm rotation	Automate or use power assists where possible Take frequent rest/stretch breaks Rotate tasks or workers Use quick connect fasteners vs. nuts and bolts where possible

For breathing air, it is necessary to ensure that cylinders or systems used meet applicable standards (e.g. correct grade of air, correct fittings to prevent cross-contamination, maximum moisture content and moisture filters to prevent respirator valve freezing, and carbon monoxide alarms where required). Intakes for such systems also need to be located away from pollution sources (e.g. areas where trucks may be idling).

Barometric pressure increases or decreases can also impact on the human body. Divers can be impacted by decompression associated with gas uptake and release when working underwater (see Section I.12.3). Above water, planned increases in containment pressure during testing can also impact on nuclear compressed air workers, and operating organizations typically invoke special precautions and health (ear) screening prior to such activities.

I.10. BIOLOGICAL HAZARDS

I.10.1. Exposure to bacteria, viruses or disease

Biological hazards in workplaces can include bacteria, viruses, fungi (mould), other micro-organisms and their associated toxins. They can adversely affect human health, ranging from relatively mild, allergic reactions to serious medical conditions, even death. These organisms are widespread in the natural environment; they are found in air, water, soil, plants and animals. Because many microbes reproduce rapidly and require minimal resources for survival, they are a potential danger in a wide variety of occupational settings. At nuclear facilities, health hazards are most likely when there is the presence of rodents, insects and birds and their associated animal waste, during demolition or remodelling activities (mould presence), during work on sewage systems, or during landscaping operations. Respiratory protection for exposure to fungi (mould) will depend on the size of the particle and its level of toxicity. It is importance to limit mould exposure wherever mould is detected.

I.10.2. Biological hazards from other employees or general society

Co-workers or the public can transmit diseases and pathogens in the work environment. Typical OSH industrial regulations do not specifically apply to disease control; however, standard ‘duty of care’ requirements do apply. These require employers to provide a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm to the employees, and means that employers should ensure that any workers likely to be exposed to such hazards take necessary precautions.

Nuclear facilities typically have pandemic plans prepared that ensure adequate response to diseases in the general populace. The plans help to ensure that employees minimize the potential for contracting the applicable disease and that the nuclear facility has sufficient healthy staff available to maintain safe operation.

I.10.3. Exposure to wildlife and poisonous plants

Many nuclear facilities are in remote areas or in areas frequented by wild animals. Venomous snakes, spiders, scorpions and stinging insects can be found in many regions, vector borne diseases may be spread to workers by insects such as mosquitoes or ticks, and larger animals (e.g. wolves, foxes and coyotes) can transmit other diseases such as rabies through their bites. Bite or stings can be especially dangerous to workers who have allergies to the applicable animal.

Many plants are poisonous to humans when ingested or if there is skin contact with plant chemicals. A more common problem with poisonous plants arises from contact with sap oil that can cause an allergic skin reaction (e.g. from plants such as poison ivy, poison oak and poison sumac). Employers should train outdoor workers about their workplace hazards, including hazard identification and recommendations for preventing and controlling their exposures.

I.11. RADIANT HAZARDS

I.11.1. Ionizing radiation

Ionizing radiation programmes at nuclear facilities are typically handled somewhat separately from industrial safety programmes. They are, however, closely linked in that PPE chosen to address ionizing radiation hazards has also to address, or be compatible with, conventional industrial safety concerns (and vice versa). In addition. the JSA and work planning processes used at a facility will need to explicitly address both issues.

I.11.2. Non-ionizing radiation

Non-ionizing radiation is any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules (i.e. completely remove an electron from an atom or molecule). It includes visible light, infrared (thermal) radiation, microwaves and radiowaves. In an industrial setting, the most typical hazards are those from bright lights such as lasers and welding torches, or ultraviolet light from outdoor sunlight, all of which can cause eye damage. Protection of equipment operators with appropriate eye protection, and inadvertant onlookers by using curtains or shields around worksites, are common hazard control mechanisms. Infrared (thermal) radiation can heat objects or personnel at a distance. It is generated when the energy from the movement of charged particles within molecules is converted to the radiant energy of electromagnetic waves. Protective measures are similar to those for direct contact with hot objects.

I.12. SPECIAL WORKSITE OR PERSONNEL CONDITIONS

Special worksite or personnel conditions are described in this section. Such conditions can increase the likelihood of exposure to one or more of the above hazards. Special care should be taken and planning done for work in these conditions.

I.12.1. Confined spaces

A confined space is any space of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions (e.g. lack of oxygen, flooding, high or low temperatures). They include storage tanks, silos, vessels, enclosed drains, ductwork, and unventilated or poorly ventilated rooms [287]. The hazardous conditions can either normally be present, result from the specific work being carried out (e.g. use of gases or volatile solvents) or be due to ineffective isolation of connected systems. Some specific scenarios include [287]:

“• A lack of oxygen.
  This can occur:

— where there is a reaction between some soils and the oxygen in the atmosphere;
— following the action of groundwater on chalk and limestone which can produce carbon dioxide and displace normal air;
— in ships' holds, freight containers, lorries etc as a result of the cargo reacting with oxygen inside the space;
— inside steel tanks and vessels when rust forms.

- Poisonous gas, fume or vapour.
  These can:
  — build up in sewers and manholes and in pits connected to the system;
  — enter tanks or vessels from connecting pipes;
  — leak into trenches and pits in contaminated land, such as old refuse tips and old gas works.
- Liquids and solids which can suddenly fill a space, or release gases into it, when disturbed.
- Free-flowing solids such as grains can also partially solidify or 'bridge' in silos, causing blockages which can collapse unexpectedly.
- Fire and explosions (eg from flammable vapours, excess oxygen etc).
- Residues left in tanks, vessels etc, or remaining on internal surfaces, which can give off gas, fume or vapour.
- Dust present in high concentrations, eg in flour silos.
- Hot conditions leading to a dangerous increase in body temperature.

"The enclosure and working space may increase other dangers arising from the work being carried out, for example:

- machinery being used may require special precautions, such as provision of dust extraction for a portable grinder, or special precautions against electric shock;
- gas, fume or vapour can arise from welding, or by use of volatile and often flammable solvents, adhesives etc;
- if access to the space is through a restricted entrance, such as a manhole, escape or rescue in an emergency will be more difficult...."

Typical regulations enacted in most jurisdictions regarding work in confined spaces require carrying out a suitable and sufficient assessment of the risks for all work activities and putting into place protective measures. These activities include consideration of tasks to be performed, work environment, materials and tools, suitability of personnel and emergency rescue arrangements. Some potential protective measures can include [287]:

— Mechanical and electrical isolation of equipment;
— Cleaning before entry to minimize potential for fume buildup;
— Checking entrance size allows for ready access and rescue;
— Provision of special tools (e.g. non-sparking tools and GFCIs) and lighting (e.g. low voltage);
— Provision of breathing apparatus;
— Preparation of emergency arrangements;
— Provision of rescue harnesses;
— Establishing adequate communications systems into the confined space and to rescue personnel;
— Providing confined space monitors who are able to quickly summon emergency help;
— Formal work permit processes;
— Emergency procedures;
— Staging of rescue and resuscitation equipment.

Some example regulations and standards dealing with confined spaces are given in Ontario Regulation 632/05 Confined Spaces, Occupational Health and Safety Act, and Refs [74, 288–290].

I.12.2. Trenching, digging and excavation

Digging into the earth poses hazards from cave ins, falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment (e.g. contact with electrical, gas or other services, and tip-overs). Cave ins pose the greatest risk and are much more likely than other excavation related accidents to result in worker fatalities. Trenches will often require protective systems, often designed by a professional engineer, to be installed to minimize risks. Advanced sensors, for example, can monitor embankments to predict landslides. Protective systems include benching, shoring, sloping or shielding. Reference [291] reports on buried piping and what a good programme relating to the excavation of buried structures includes:

"— Clear identification of areas to be excavated (e.g. 'white lining' processes whereby lines can be made with paint on hard surfaces, or lime or paint on ground surfaces);
— Underground service location and documentation;
— Work protection and system isolation;
— Confined space entry procedures (including rescue plans);
— Radiological surveys;
— Hold points and back out conditions:
  • Contact with or damage to any pipe, cable, coating, or unknown structure;
  • Where water is accumulating;
  • Following a rainstorm (prior to assessment or additional precautions having been taken);
  • Quality assurance hold points prior to backfilling.
— Trenching and shoring design;
— Groundwater and environmental protection;
— Addressing of design basis loading, extreme weather events (e.g. tornadoes, missiles) and pipe supports while excavation is in place;
— Excavation procedures (hand digging, vacuum truck, backhoes, etc.);
— Contaminated soil disposal;
— Burial and backfill requirements;
— Training and qualification."

Construction activities could involve the use of explosives as part of excavation work. This should be considered high hazard work and special precautions taken.

I.12.3. Working on, near or under water

Work at a nuclear facility often requires work in an area on, near or under water, with an inherent hazard of drowning. Work may involve open water (such as near intake or outfall structures, screenhouses, or spent fuel bays), where staff could fall in from the land or from a platform, boat or barge, or involve working inside of enclosed systems or tanks where water or other liquids could inadvertently be introduced.

Diving operations pose special hazards. Diving can mean work performed underwater by divers or work performed on the surface in support of divers, and includes underwater inspection, investigation, excavation, construction, alteration, repair or maintenance of equipment, machinery, structures or ships and the salvage of sunken property (see Ontario Regulation 629/94 Diving Operations, Occupational Health and Safety Act). Safety standards and regulations exist in many jurisdictions to cover commercial diving operations (see Refs [292–296]). Diving into areas such as the spent fuel pool with its inherent high radiation hazard requires special planning and attention.

I.12.4. Hot work

With regard to fire safety, paras 6.9–6.17 of NS-G-2.1 [21] recommend controls on ignition sources during operation of an nuclear power plant, including restrictions on open flames, administrative procedures surrounding modification and maintenance activities that necessitate use of potential ignitions sources, establishment of fire watches, posting of warning signs and other precautions.

I.12.5. Poor lighting and visibility

Poor visibility can be a contributor to many accidents. People moving into the travelling or working area of mobile machines can be seriously injured if the machine operator does not see them. Adverse weather (see Section I.12.7) can make visibility extremely difficult. Depending on the lighting source, object colours can appear different under artificial light than in normal daylight. Working or driving when visibility is poor can lead to increased chances of accidents. In highly motorized countries, inadequate visibility plays an important role in three types of crash:

— At night, vehicles that run into the rear or sides of slowly moving or stationary vehicles;
— During the day, angled or head-on collisions;
— At all times, rear-end collisions that occur in poor weather conditions.

Day time running lights and high mounted brake lights for motorized vehicles, and colourful clothing, accessories and vehicle parts (e.g. lights and front, rear, and wheel reflectors for bicycles and other non-motorized vehicles) can reduce accident rates [297].

In low income and middle income countries, the poor visibility of pedestrians and vehicles is a serious problem. The mix of motorized and non-motorized traffic, together with poor street lighting, increases the risk of unprotected road users not being seen. Non-use of low cost interventions such as bicycle lamps or reflective equipment exacerbates already unsafe conditions.

The Illuminating Engineering Society publishes numerous standards and training material surrounding best practices for interior and exterior lighting systems (see Ref. [298]). Older workers and workers needing to perform more detailed tasks require higher lighting levels. An important aspect of lighting systems often overlooked in industrial facilities is the need for lighting system maintenance. Regular cleaning of fixtures and group relamping can help to ensure actual field lighting levels are maintained in accordance with design assumptions. Where field conditions are such that lighting is poor, consideration should be given to adding temporary or portable lighting to allow the work to proceed safely and accurately.

I.12.6. Contact with buried or hidden services

Buried services at nuclear power plant sites can include underground cables, station grounding, air lines, water supply lines, gas lines, piping, drains and instrumentation. Other underground concerns such as environmental, archaeological or old gravesites can also come into play during excavations at some locations. Work that penetrates walls, foundations, floors or roofs can encounter hidden hazards.

Each situation and type of service encountered provides its own set of hazards. The main issue with these services is the potential for unintended contact with energized or non-isolated equipment. Many of such services, especially on older sites, do not have their precise locations well documented. In addition, construction waste or temporary services such as old cables or pipe are sometimes buried at construction sites, making distinctions between active (and potentially live) and inactive material difficult.

Many jurisdictions have developed specific safe work procedures for excavation, drilling, cutting of surfaces or driving of rods that may allow a worker to contact buried or embedded surfaces. Such procedures typically require an attempt to locate such services prior to these activities (using drawings, walkdowns and scanning techniques such as ground penetrating radar), isolation of located services, and using safe excavation or drilling practices (e.g. hand digging, hydro excavation, air jet excavation, use of GFCIs for all tools, using depth gauges for drilling, wearing dielectric gloves and boots while drilling, monitoring ampere reading while drilling — increased current can indicate an obstruction or contact). Once located any information regarding specific locations should be recorded and field marked for future reference.

Designs for any new buried service can include means to identify and readily locate such services. Methods for locating services can include using geophysical methods for toneable services and those with tracer wire, or the use of permanent locator ball systems. A combination of above and underground markers can be used to identify and locate underground services. The above ground markers are to identify services, and not to circumvent the need to confirm specific locations before excavation. Above ground markers need to be developed in the design phase of projects, and typically include identification of company name, type of service and emergency contacts.

I.12.7. Adverse weather

Planning for adverse weather conditions such as severe storms can reduce risks for employees working outdoors or travelling to or from work, when weather can make such work or travelling dangerous. Consideration should be given foremost to the safety of the employees; in particular when adverse weather results in severe storms, lightning, fog, road closures or emergent conditions, which result in significant risk to the employees' health and safety. A predefined policy can assist employees and managers in making conservative decisions regarding such activities. Such a policy can include:

(a) A clear statement that employee safety should come foremost during such conditions;
(b) Guidelines for decisions surrounding which employees should be sent home, those who should remain on-site until suitable relief is found, and those who may be directed to remain at home during known or emergent adverse weather;
(c) Guidelines for suspension of outdoor work when storms, high winds, or lightning are anticipated (special considerations may be necessary regarding suspension of craning and hoisting operations, and some jurisdictions limit operations above specific wind speeds);
(d) Treatment of those who arrive late to work due to adverse weather.

Other precautions for winter can include:

— Adding winter storm watches to emergency preparedness procedures;
— Ensuring slip and trip hazards assessments and preparations are ready for winter weather (snow removal plans, access to salt, sand and shovels, and signage);
— Equipping company vehicles with snow tires;
— Installing emergency equipment;
— Increasing communications about winter hazards.

I.12.8. Work with power and hand tools

Power and hand tools if used improperly can cause injury. PPE and proper work practices are needed to operate such tools safely. Routinely employed PPE includes eye protection, gloves (cut resistant for sharp tools, simple abrasion resistant gloves for material handling, or impact resistant gloves with gel or rubber palms to reduce vibration), and safety footwear (to protect from injury caused by a dropped tool).

On account of their high speed of operation, certain power tools require the use of a face shield in addition to safety glasses or goggles. Other personnel in the area where power tools are used should also wear protective eyewear. High noise generating power tools will necessitate the need for hearing protection, and tools that generate dust (e.g. sanding and cutting operations) can require a dust respirator to be worn. Workers should be protected from electric shock by ensuring power tools are properly grounded and use a GFCI for corded tools. A process should be implemented that requires searches for hidden or embedded wires prior to drilling or cutting into walls, floors or similar structures. Owners' manuals should be reviewed to understand proper tool application, limitations, operation and hazards. Each situation should be analysed to determine the type of PPE and practices that are required for the safe use of each type of power tool.

Along with PPE, proper attire is also important while using power tools. Long hair should be tied back or covered, Loose fitting clothes should be worn and all jewellery should be removed to avoid being caught in moving blades. Some nuclear operating organizations enforce a 'no jewellery' policy inside the protected area to minimize the chance and severity of injury from tools and from possible electrical contacts.

Workers should use non-sparking hand tools when in the presence of flammable vapours or dusts. Electric power tools in such environments (or in wet environments) should be avoided. A common application of non-sparking tools in nuclear facilities is for work on battery banks, where hydrogen gas can be produced during charging.

A common saying regarding tools is to 'use the right tool for the right job'. Wrenches, for example, should properly fit the item being turned, extensions should not be used to improve leverage, and tools should not be altered or subjected to excess heat. Tools should be checked periodically for damage such as cracking, severe wear or distortion, damage or wear to any power cables, presence of guards, correct alignment and no binding of components. A tool should only be used for the purpose it was intended for, and proper techniques should be used (e.g. pulling a wrench rather than pushing is typically a safer operation, use both hands for screwdrivers (one to guide and one to drive), strike hammers only squarely to a surface, change blades or drill bits only when unplugged). When practical to do so, clamps, vices or other devices to hold and support the piece being worked on should be used (see Refs [299–304] for standards and regulations on the use of hand and power tools). The European Union [300] specifies vibration daily exposure action values of 2.5 m/s^2 and daily exposure limit values of 5.0 m/s^2, and WHO has produced training material on health effects, risk assessment and prevention [304].

I.12.9. Work in dusty environments

Dust is made up of tiny particles, the smallest of which are too small to be filtered out by the nose and the body's other natural defence systems. Dust with these fine particles can be inhaled deep into the lungs where they cause problems such as lung irritation, emphysema, asthma, bronchitis, cancer, heart disease, allergic reactions and other serious conditions that can lead to death. Some occupational diseases connected to dust inhalation include pneumoconiosis, silicosis and asbestosis.

Construction sites typically have some sort of outdoor dust control programme in place to reduce health effects and to ensure that dust does not pose a problem with poor visibility. Planting areas that are not required to be uncovered, and installing natural or artificial wind screens or geotextile fabrics can assist. In some cases, water spraying or chemical dust suppressant application, changing surface gravel size or improving drainage can also be practical.

Silica dust, often in the form of quartz, is a component of sand, stone, rock, concrete, brick, block and mortar. It is hazardous when inhaled. These respirable dust particles can penetrate deep into the lungs and cause disabling and sometimes fatal lung diseases, including silicosis and lung cancer, as well as kidney disease. Occupational exposure to respirable crystalline silica occurs when cutting, sawing, drilling and crushing concrete, brick, ceramic tiles, rock and stone products. Occupational exposure also occurs in operations that process or use large quantities of sand, such as foundries and the concrete products industries. Many jurisdictions have specific requirements surrounding engineering controls, administrative controls, proper PPE and medical surveillance of this hazard.

Asbestos is a hazard at numerous older nuclear facilities, as it was originally used in many applications including pipe insulation and ceiling tiles. Strong control measures are recommended, including assuming all untested material may contain asbestos, and removing asbestos containing material whenever practical.

Some organic and metal dusts can pose an explosion hazard. Radioactive metals such as hafnium, plutonium, thorium, uranium and zirconium are all highly combustible and loose metal shavings from substances such as magnesium ignite readily.

The National Fire Protection Association provides comprehensive guidance on the control of dusts to prevent explosions, and recommends the following [305]:

(a) Design fire and explosion safety provisions based in a process hazard analysis of a facility, the process, and associated fire and explosion hazards;
(b) Minimize the escape of dust from process equipment or ventilation systems;
(c) Use dust collection systems and filters;
(d) Utilize surfaces that minimize dust accumulation and facilitate cleaning;
(e) Provide access to all hidden areas to permit inspection;
(f) Inspect for dust residues in open and hidden areas at regular intervals;
(g) Clean dust residues at regular intervals;
(h) Use cleaning methods that do not generate dust clouds if ignition sources are present;
(i) Only use vacuum cleaners approved for dust collection;
(j) Locate relief valves away from dust hazard areas;
(k) Develop and implement a hazardous dust inspection, testing, housekeeping, and control programme (preferably in writing with established frequency and methods).

I.12.10. Commissioning, operation and maintenance of pressure vessels

A pressure vessel is a storage tank or vessel designed to operate at pressures above atmospheric (103.4 kPa). Cracked and damaged vessels can leak or rupture and result in poisonings, suffocations, chemical burns, fires, thermal burns or explosions. Rupture failures, such as those associated with boiling liquid expanding vapour explosions (BLEVEs) of tanks, can be particularly catastrophic and can cause considerable damage to life and property. The safe design, installation, operation, and maintenance of pressure vessels in accordance with the appropriate codes and standards are thus essential to worker safety and health.

Most nuclear facilities have programmes to manage their pressure vessels in accordance with national standards. These typically include a process of regular inspections and certifications by an authorized inspection agency, and calibrations of pressure reliving devices. A particular hazard results from the process of pressure testing vessels and associated piping as part of commissioning or maintenance activities. Systems are typically tested at pressures significantly above their normal operating pressures, and personnel are typically nearby to perform the testing activities. Only trained and qualified personnel should be allowed to perform such testing or work on pressurized systems, and written procedures is considered best practice.

I.12.11. Work schedule

There is strong evidence that shift work is correlated to a number of serious health conditions, such as cardiovascular disease, diabetes, and obesity and is also linked to stomach problems and ulcers, depression, and an increased risk of accidents or injury.[36] Workers at a nuclear plant regularly work shift work and are exposed to these risks. Moreover, workers can regularly work extended hours, especially during periods of outages. This can put additional stress on the health of individuals, and increase the potential for fatigue related accidents. Many jurisdictions have hours of work regulations in place for safety sensitive nuclear facility staff as part of their fitness for duty requirements. These help to minimize the potential for adverse incidents due to excess work and fatigue.

Even with limits set on maximum working hours, it is not completely possible to regulate what employees do in their spare time. For example, an employee could be exhausted from having their sleep disturbed by a newborn baby. Tired workers are more likely to make mistakes, and first line supervisors should be attentive to workers displaying signs of fatigue. Operating organizations typically develop processes to address the following [306]:

“1. expectations for self-reporting when workers believe they are too fatigued to competently and safely perform their assigned duties
2. actions for workers to take if they are experiencing a temporary or ongoing circumstance(s) or condition(s) that increase their risk of experiencing fatigue at work
3. actions for supervisors to take if they believe, through self-reporting or observation, that a worker may be unable to competently and safely perform his or her assigned duties because of fatigue
4. expectations related to rest periods that include an opportunity to sleep, if permitted
5. schedules that allow for a planned period of restorative sleep in appropriate accommodations, if permitted” (especially between the hours of 2 a.m. and 6 a.m.).

I.12.12. Psychosocial conditions

In addition to the external public perceptions of a nuclear facility, job security, health and other factors can also add stress, there are also [307]:

> “Psychosocial factors — such as the way work is organised, the working time arrangements, the social relationships, the content of the job and the workload — place certain mental and social demands on each worker. Consequently, psychological and social aspects of work are important factors in every workplace, and the recognition that these factors have an impact on the health and well-being of workers has grown in recent years.”

[36] See www.webmd.com/sleep-disorders/excessive-sleepiness-10/shift-work

A US study by the Centers for Disease Control and Prevention [308] published in 2016 (with 2012 data) indicates that construction and extraction (i.e. mining) workers has the second highest suicide rate (53.3 per 100 000 workers per year) by occupation, following farming, fishing and forestry workers (84.5). The most affected age range was those between 45–54 years old (24.8% of cases). Installation, maintenance, and repair workers were the third most prevalent occupation (47.9 suicides per 100 000 workers per year). Both of these occupation groups are vital to nuclear power plant construction and operation. Possible reasons cited for higher suicide rates in certain occupational groups included [308]:

> "job-related isolation and demands, stressful work environments, and work–home imbalance, as well as socioeconomic inequities, including lower income, lower education level, and lack of access to health services…. Construction workers might be at higher risk because of financial and interpersonal concerns related to lack of steady employment, and fragmented community or isolation".

Many OSH regulations include roles and responsibilities relating to these psychosocial issues. These often include regulations with respect to workplace violence and workplace harassment, including the need to develop and implement policies and programmes and providing information and instruction on the requirements.

Some aspects of the work environment favour better health and well being, such as an organization of working time that favours work–life balance. Involvement of top management combined with worker participation is seen as essential for dealing with these risks effectively, and some jurisdictions are developing policy frameworks for tackling psychosocial risks at work [307]. A number of tools and guidance are available to help address these hazards, such as the ILO guide on stress prevention at work [309].[37]

Critical incidents such as violence, security incidents, threats to life, vehicle accidents, and family or co-worker deaths can produce acute (but normal) responses in individuals. Such events require immediate attention from colleagues and the organization, as the earlier they are addressed the less likelihood that long term problems such as post-traumatic stress disorder or substance abuse will develop. Organizations are recommended to have resources available as needed to assist individuals in dealing with such events.

1.12.13. International travel

Nuclear workers often need to travel internationally, which can pose various risks to health, depending on both the traveller and the trip. Travellers can encounter sudden and significant changes in altitude, humidity, microbes and temperature, all which can result in ill health. The act of travel itself exacerbates the risks: the combination of unfamiliar environments, jet lag and fatigue, different driving conditions, different norms regarding seatbelt use, different cultures and different legal systems all contribute to a degree of vulnerability. In addition, serious health risks may arise in areas where accommodation is of poor quality, hygiene and sanitation are inadequate, medical services are not well developed and clean water is unavailable. Personal security can also be a concern in some jurisdictions. WHO has produced publications on international travel and health [314], and on safe food for travellers [315]. The publications explain how travellers can stay healthy, ensure food safety and provides WHO guidance on vaccinations, malaria chemoprophylaxis and treatment, personal protection against insects and other disease vectors, and safety in different environmental settings.

Organizations are encouraged to treat international travel as like any other job assignment. That is the risks and hazards should be assessed, and measures taken to either eliminate or control the applicable hazards. Specific training for travelling can be beneficial. Such training can provide situational awareness that may steer individuals away from situations that could lead to illness, injury, robbery, assault and accidents.

1.12.14. Working alone

Working 'alone' is when the worker cannot be seen or heard by another person while performing the work. It includes all employees who have periods where they do not have direct contact with a co-worker: for example, the receptionist in a large office building, an engineer working late at night, a warehouse truck driver on an isolated public road, and a construction worker that cannot be seen. Some jurisdictions have specific laws concerning

[37] See also Refs [71, 72, 310–313] and www.copsoq.istas21.net/web/portada.asp

working alone, and other considerations such as personnel security can come into play. Working alone should generally be avoided whenever possible, especially in jobs with a recognized risk. Higher risk tasks should be scheduled during normal business hours, or when another worker capable of helping in an emergency is present. Where this is not possible, a check-in procedure should be established (often via telephone), and regular contact should be kept with all employees. Such check-in systems can, however, suffer from issues related to response time and locating difficulties in emergencies, complacency, loss of productivity and false responses.

To address such concerns commercially available electronic safety monitoring devices, often referred to as 'lone worker devices', are increasingly becoming available (see Ref. [316] for a code of practice on such devices). Such devices can automatically detect falls, motionless employees, failed responses to a check-in request, or can be triggered manually by an employee in distress. Once actuated such systems typically communicate to a central alarm receiving and dispatch centre (via cellular or satellite networks), which can attempt to make voice contact and to summon assistance as needed. Workers are located via GPS or supplemental locating capabilities (where GPS signals are obstructed or inaccurate due to reflections or poor satellite geometry). Figure 59 shows an example of such a device that is worn on a person, and some applicable software.

The Health and Safety Authority[38] finds that:

> "Training is particularly important where there is limited supervision to control, guide and help in situations of uncertainty. Training may be critical to avoid panic reactions in unusual situations. Lone workers need to be sufficiently experienced and to understand the risks and precautions fully. Employers should set the limits to what can and cannot be done while working alone. They should ensure employees are competent to deal with circumstances that are new, unusual or beyond the scope of training, e.g. when to stop work and seek advice from a supervisor and how to handle aggression."

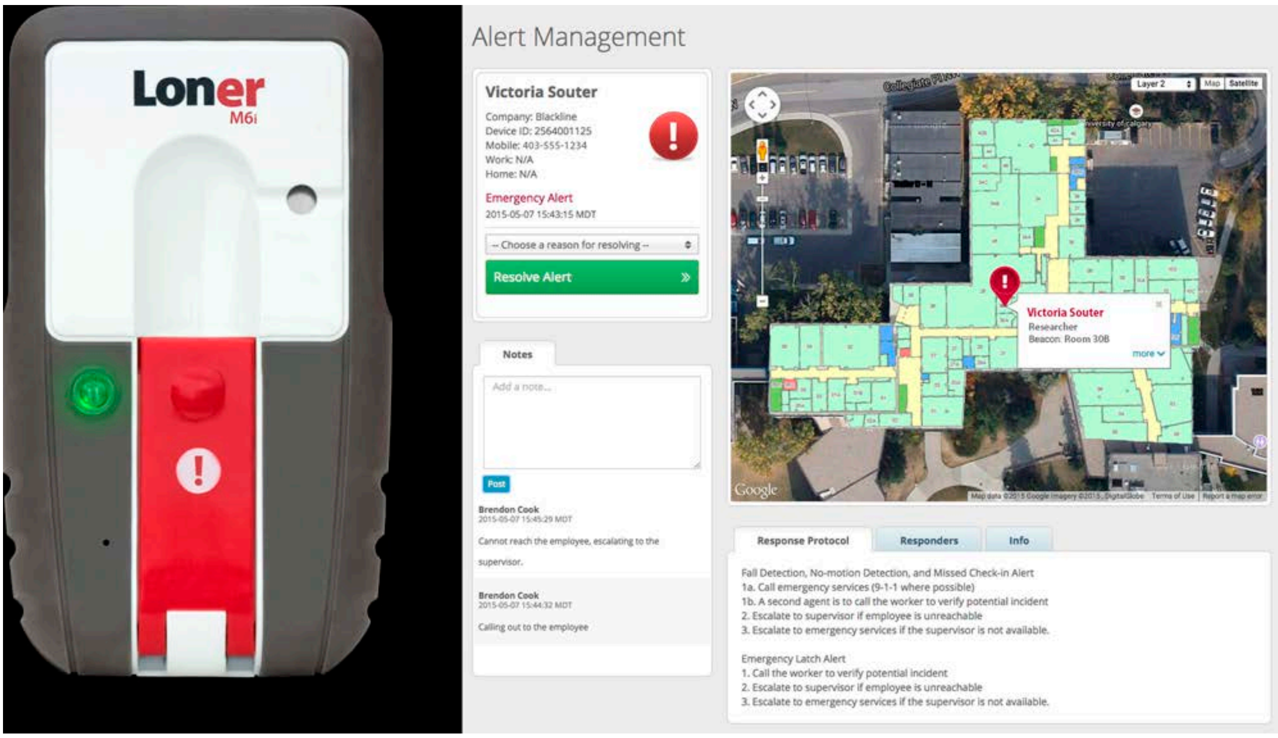

FIG. 59. A personnel safety lone worker monitoring device and central station alert software (courtesy of Blackline Safety Corp).

[38] www.hsa.ie/eng/Topics/Hazards/Lone_Workers

1.12.15. Remote workers

Similar to workers assigned to work alone, certain organizations have a substantial number of workers regularly assigned to duties outside of their normal company premises. These can include, for example, technicians making service calls and IAEA inspectors. Recognizing this similarity, the Health and Safety Authority[39] notes that:

> "Although lone workers cannot be subject to constant supervision, it is still an employer's duty to ensure their safety and health at work. Supervision can help to ensure that employees understand the risks associated with their work and that the necessary safety precautions are carried out. Supervisors can also provide guidance in situations of uncertainty."

Similar to lone workers, remote workers need sufficient training to identify hazards and what actions to take when faced with unusual circumstances or with potential unsafe working conditions. How to address differing practices with respect to industrial and travel safety (e.g. expectations with respect to accessing equipment located at heights, seat belt usage, etc.) is an important subject of training and for employee pre-job (or before travel) briefings.

Pre-job contact with the customer organization regarding company safety practices and requirements is encouraged. It should be clear how the customer organization will protect the remote workers while they are at the remote location. Remote workers, especially those visiting a site for a short duration, often do not receive the full set of compulsory safety training as do full time workers, and are often constantly escorted. This puts them at increased risk of not recognizing all hazards present at a particular location, and they are thus quite dependent on the local staff escorts. The local staff escorts on the other hand may not have full knowledge of the activities planned by the remote worker. For example, a customer organization may plan to have a radiation protection specialist escort a remote working electrician. Good pre-job planning and communication prior to the work being executed is key to avoiding safety issues.

Some potential specific actions that employers and supervisors can consider for their remote workers include[40]:

(a) Providing employee training on recognizing and avoiding hazards.
(b) Determining and documenting the probable range of hazards (routine and non-routine) that employees may encounter at various types of jobs and locations.
(c) Establishing a rule, procedure or form that requires supervision to pause when assigning employees to non-routine jobs, or assigning employees to jobs with which they are less familiar. In these situations, additional training or some type of safety analysis may be necessary.
(d) Requiring employees to (as a minimum) complete a basic and short site safety analysis for small remote jobs. Many electrical and other specialized contractors require employees to complete a few questions on the work order paperwork requiring the employee to pause and consider hazards.
(e) Considering tablets or phone apps for hazard analysis and as a means of tracking compliance and providing advice.
(f) Establishing procedures for employees to call into the home office supervisor whenever they have any questions or concerns.
(g) Performing supervisory spot checks for field workers (i.e. to ensure that workers are performing tasks in a safe manner and are performing hazards analyses).
(h) Considering safety concerns unique to each site, such as lockout for electricians, skylights for those working on roofs, or overhead power lines.
(i) Ensuring that JSAs are thorough, accurate and consider the challenges posed by the remote sites.
(j) Ensuring that employees know that supervisors will back them if they refuse unsafe demands from customers.
(k) Holding regular teleconferences to discuss safety issues and expectations where safety and other concerns can be regularly addressed if remote employees seldom report to a home office site.

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[39] Ibid.

[40] Adapted from www.fisherphillips.com/Workplace-Safety-and-Health-Law-Blog/Safety-Duties-To-Those-Remote-Or-Isolated-Employees

1.12.16. Disruptive events

Disruptive events or crises include natural events (e.g. fires and floods), violent attacks (e.g. bomb threats and active shooters), cyberattacks or civil unrest. Business continuity planning for such events often involves establishing methods for personnel accounting, which helps to determine whether individuals are safe during and following such events and that appropriate responses are in place (see the ISO standard for business continuity planning [317]). Electronic methods of performing accounting, often using individual mobile phones, are increasingly available.

1.12.17. Facility specific hazards

Due to their specific location, design or proximity to other facilities, a nuclear facility may have unique hazards that it may need to account for in its overall safety and emergency preparedness programmes. Nearby rail lines or other transport arteries may bring hazardous material next to the facility boundary, nearby factories may emit toxic substances during abnormal events.

Appendix II

SAMPLE OCCUPATIONAL SAFETY AND HEALTH POLICIES FROM NUCLEAR OPERATING ORGANIZATIONS

This appendix contains examples of OSH policies that exist at nuclear facilities that have been provided by various organizations in France (see Fig. 60), Canada (see Figs 61 and 62), China (see Box 4) and Sweden (see Box 5).

1 Company Policy: Health & Safety

Policy Statement

Building on the Health & Safety policy commitments of our parent company, **I believe all harm is preventable, so my aim is zero harm.**

I believe that a structured risk management approach, where all activities are assessed rigorously for health and safety risks will help us to achieve this aim. I believe in effective consultation and engagement with employees and in signing the Safety Representatives Charter recognise the important role that our safety representatives have in contributing to zero harm. I am responsible for enacting this policy, making nuclear safety, industrial safety and occupational health our priority.

I expect everyone to act professionally and apply the key principles agreed by the Executive Team that should guide all our work activities:

- **Every job will be done safely, no matter how important or urgent it is.**
- **Each of us has a personal responsibility for our own health and safety and for those around us.**
- **Putting people to work carries a specific responsibility and accountability for safety and health which will be visibly demonstrated.**
- **Each near miss we learn from reduces the chance of harm next time.**
- **Each of us will spot, report and deal with hazards to help create a harm free workplace.**

The Company will provide appropriate health and safety training for employees to enable them to meet the required standards of performance. I recognise that accidents, ill health and environmental incidents may result from failings in management control and are not necessarily the fault of an individual employee. All employees and contractors, however, are expected to accept their responsibility to work safely, adhering to safety rules and work procedures, using the equipment provided, and generally to contribute to the maintenance of safe and healthy conditions.

Continuous improvement will be achieved by implementing appropriate management systems and related standards, which will as a minimum, meet all applicable legal and other requirements. We will share best practice across the company and externally. Audit and assessments of compliance will be conducted to measure health and safety performance. These will be reviewed at a senior level.

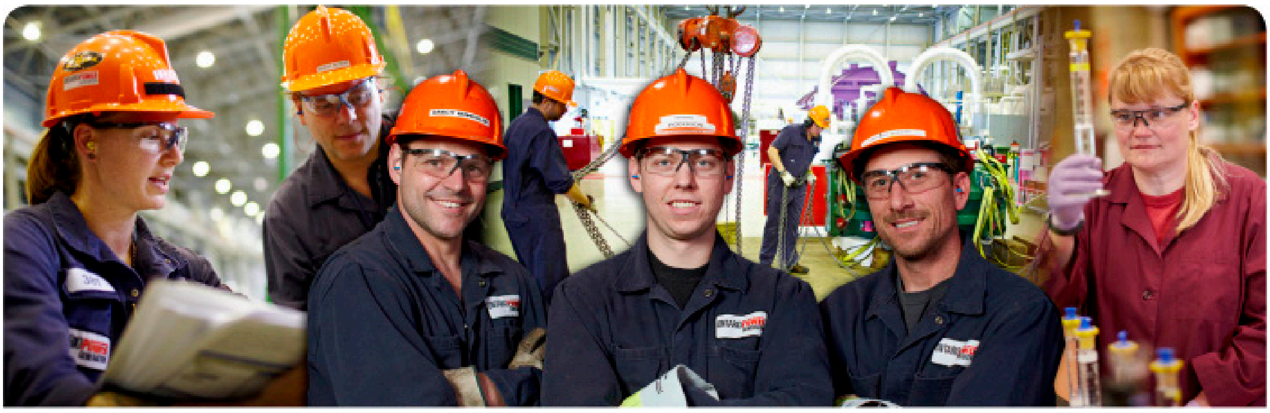
I have charged my Executive Team with establishing effective management arrangements that meet the expectations of EDF Energy's Assurance & Integrity Management Framework (A&IMS) within their respective Business Units and the Corporate Steering Functions. They will be advised by competent occupational health and safety professionals. Implementation of this policy will be through line management who are responsible for reducing the risks arising from our operations to as low as reasonably practicable, making proper provision for the health, safety and welfare of employees, visitors, contractors and those in the community who may be affected by our activities.

I am committed to effective communication on H&S matters with all relevant parties and will report internally and publicly on our H&S performance on a regular basis as part of our sustainability agenda.

Whilst we each have responsibilities for H&S, we do much better when we work as a team.

Vincent de Rivaz CBE, Chief Executive Officer
For and on behalf of the EDF Energy Executive Team

FIG. 60. First section of the EDF Energy health and safety policy document (reproduced from Ref. [318] with permission courtesy of EDF Energy).



Employee Health and Safety Policy

Policy Statement

Ontario Power Generation (OPG) is committed to the prevention of workplace injuries and ill health, and to continuous improvement of its employee health and safety performance.

Document Number: OPG-POL-0001

Sponsoring Unit: Senior Vice-President, People and Culture and Chief Ethics Officer

Approval: Board of Directors

Approval Date: December 13, 2012

Effective Date: January 1, 2013

Requirements

OPG shall meet or exceed all applicable health and safety legislative requirements as well as other associated health and safety standards to which OPG subscribes. OPG shall require that its contractors maintain a level of safety equivalent to that of OPG employees while at OPG workplaces.

OPG shall ensure that employees are involved in decisions that have an impact on their health and safety, either individually, as a group, or through their employee representative groups.

OPG shall ensure that work is planned and performed to protect workers. It shall provide its employees with the information, training, tools, procedures and support required to do their jobs safely.

OPG shall set health and safety targets as part of its annual business planning process. Health and safety performance against these targets shall be regularly measured and evaluated to ensure the effectiveness of OPG's health and safety systems.

Accountabilities

All employees are accountable for their own health and safety and for the health and safety of their co-workers. Resolution of workplace Health and Safety matters shall be through local management.

The Senior Vice-President, People and Culture and Chief Ethics Officer is accountable for the development and maintenance of a health and safety program that achieves the requirements of this policy, including reporting to the Board on OPG's overall health and safety performance.

Operating Unit and Function leaders are accountable for the effective implementation of the health and safety program within their respective organizations and for reporting to the Board on their health and safety performance.

ONTARIO POWER GENERATION

FIG. 61. Ontario Power Generation employee health and safety policy (reproduced from Ref. [319] with permission courtesy of Ontario Power Generation).

BRUCE POWER'S

Occupational Health and Safety Policy

Bruce Power's number one value is Safety First. This is fundamental to our success and is essential to achieving our long-term business goals. A strong safety culture and healthy workplace environment are at the heart of everything we do.

Bruce Power is committed to safety in its pursuit of performance objectives. We minimize risk to the public, visitors, contractors and our employees by integrating robust and effective hazard management into our business planning and work activities.

Our goal of zero occupational injuries and illnesses reflects our steadfast commitment to the prevention of all occupational injuries and illnesses.

Our Occupational Health and Safety (OH&S) managed system provides a framework which regularly realigns our OH&S objectives and programs to ensure continual improvement.

In striving for excellence, legal requirements are considered the minimum standard. We adopt proven and effective best-in-class practices to provide enhanced safeguards vital to sustainable top quartile performance. We comply with these, as well as other OH&S requirements to which we subscribe.

All employees' participation in identifying and effectively resolving OH&S issues is crucial to successfully upholding health and safety in the workplace. At Bruce Power, safety is everyone's responsibility.

May 6, 2016
Date

Kevin Kelly
Acting President and Chief Financial Officer

Bruce Power
Innovation at work

CS160199 MAY 2016

FIG. 62. Bruce Power's Occupational Health and Safety Policy (courtesy of Bruce Power).

BOX 4. CHINA NUCLEAR POWER ENGINEERING COMPANY LTD POLICY ON THE MANAGEMENT OF QUALITY, ENVIRONMENT AND OCCUPATIONAL SAFETY AND HEALTH (*unofficial translation*)

INNOVATION IN NUCLEAR ENERGY, SCIENTIFIC MANAGEMENT, SAFETY AND ENVIRONMENTAL PROTECTION, THE PURSUIT OF EXCELLENCE

Innovation in nuclear energy

Taking as the basis the four pillars — nuclear power, nuclear chemical engineering, nuclear fuel and civil engineering, applying the quality related policy in nuclear engineering of 'safety and quality before all else', through the provision of dependable quality and the highest level of service, ensuring high quality engineering products in compliance with the laws and regulations and meeting the requirements of consumers;

By taking intellectual innovation as guidance, management innovation as the foundation and technological innovation as the guarantee of success, continually improving core competitiveness.

Scientific management

By adhering to the spirit of the nuclear industry 'the enterprise is of paramount importance; responsibility outweighs all else; the need to be rigorous and meticulous is all-pervasive; enterprise is a guarantee of success' by respecting knowledge, by advocating science, by applying modern management techniques, by using the most advanced management approaches — this will ensure that management is increasingly scientific, systematic, properly regulated and highly effective.

Safety and environmental protection

Adhering faithfully to the fundamental principle of 'nuclear safety is an overriding priority', abiding by laws and regulations, following a people-oriented approach, focusing on safety, attaching importance to environmental protection, ensuring that every work procedure demonstrates a responsibility for safety and duty to ensure environmental protection, constantly enhancing safety and environmental awareness, safeguarding employees' physical and mental health, enhancing the management of safety and environmental protection; avoiding accidents and risks, taking measures to prevent and reduce pollution, and creating an impressive corporate image of environmental protection.

Pursuit of excellence

Perfecting the incentive system, creating a harmonious human environment, regarding the upgrading of the overall competence of staff as a fundamental principle, pursuing the shared development of the company and of individual employees; continually reforming the management system, constantly improving management performance in the areas of quality, environmental protection and OSH; developing a specialized, standardized and modern world class engineering company.

Quality related objectives

(1) Strict enforcement of laws and regulations and related requirements, efficient implementation of management that is scientific, highly effective and properly regulated, showing commitment to providing customers with excellent service;

(2) Enhancement of research and development capabilities, innovative creation of a set of core technologies, the development of its own brand of nuclear power;

(3) A 100% acceptance rate for large and medium sized projects, the attainment by the principal projects of the advanced level of similar projects both at home and abroad.

Environmental and occupational safety and health objectives

(1) Compliance with legal requirements, the implementation of environmental protection measures, energy saving and reducing consumption, and prevention of environmental pollution accidents;

(2) Control of major risks, avoidance of serious injuries and elimination of major accidents;

(3) Implementation of effective environmental and occupational health education and training, and continual raising of the overall safety culture and level of environmental and health awareness.

BOX 5. FORSMARKS KRAFTGRUPP AB WORK ENVIRONMENT POLICY

POLICY REV. 18: CHAPTER 9 WORK ENVIRONMENT

FKA shall have a good work environment; both for FKA's own personnel and contracted personnel. Our goal is that no accidents shall occur and that no work related illness shall arise. A good work environment that is appropriate for purpose is a condition for work satisfaction, good results and a high degree of safety. This applies to the physical as well as the psychological work environment.

Work on work environment is an integrated part of the business and the responsibility lies with the line organization. The work on work environment is carried out systematically and preventative in order to achieve continual improvement. Included in this is to take into account our own and other's experiences and to fulfil work environment related requirements, rules and regulations.

Differences between individuals can include gender, ethnic background, age, handicaps, religion and sexual orientation, but also experience, lifestyle, educations, values and family situation. All of this creates a diversity that supplies new ideas, perspective and different behaviours and ways of working.

FKA shall be a workplace characterized by openness and respect for each other's differences. Everyone, no matter what title or position he/she holds, shall be treated respectfully. FKA shall strive to increase diversity and equality in all areas and in all decisions. Our view of the work with diversity involves taking advantage of the creativity and synergy that are present in the interaction between differences.

Everyone at FKA takes responsibility for his/her safety and actions at the work place. With consideration for our co-workers, we have a responsibility to report errors and deficiencies. Managers have a special responsibility to set a good example. A committed and visible leadership is applied.

Working at FKA shall provide opportunities for development, both as an individual and as an employee, in a safe and stimulating environment.

FKA shall be a work place that through long term health and safety work and directed activities creates conditions in which employees shall feel good and have the conditions to be able to meet the day's requirements and to be able to realize their personal goals.

It is not acceptable to be under the influence of or to use drugs at the work place. The abuse of alcohol and other drugs discouraged and is addressed at an early stage. Goal oriented rehabilitation is offered for those who have ended up in an abuse situation.

Appendix III

SAMPLE SAFE WORK PLAN FORM

Figures 63–70 show a safe work plan form in use at Ontario Power Generation for its nuclear and non-nuclear facilities.

ONTARIOPOWER GENERATION

Records File Information:
Records 08965-T1

Internal Use Only

OPG-FORM-0084-R001*

Safe Work Plan

INSTRUCTIONS FOR USE:

Complete prior to work. Review with all affected workers and work groups. Update and communicate as necessary if conditions or hazards change.

JOB TITLE/TASK:

AUTHORITY INFORMATION	
Work Group:	
Supervisor:	
Team Leader/Person in Charge:	
SWP Prepared by:	
Preparation Date:	
Start Date of the Work:	
Duration of Work:	
Work/Job Site Location:	

EMERGENCY PHONE NUMBERS	
Facility/Site:	
Control Centre:	
Police:	
Fire:	
Ambulance:	
Other:	
Address:	

CREW MEMBERS (PRINT/TYPE NAME)	**SWP REVIEW INITIAL**

OTHER WORK GROUPS/CONTRACTORS INVOLVED	
WORK GROUP/ CONTRACTOR	**PERSON INFORMED OF WORK**

SUPERVISOR FIELD CREW VISITS		
NAME	**INITIAL**	**DATE**

*Associated with OPG-PROC-0129, Safe Work Planning

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Page 1 of 8

FIG. 63. Safe Work Plan form (page 1 of 8, courtesy of Ontario Power Generation).

INFORMATION TO ACQUIRE, REVIEW, COMMUINICATE (☒ AS APPLICABLE)	
☐ Confined Space	See Attached Confined Space Work Package
☐ Craning and Rigging	☐ Supervisor or Lift: ☐ Signal/Safety Person: ☐ Qualified Operator:
☐ Drawings	☐ See attached:
☐ Environmental Impact	☐ See attached on spill response, disposal, etc.
☐ Fall Protection	☐ Addressed in Job Safety Analysis ☐ Fall Protection Checklists (optional)
☐ Falling Object	☐ Addressed in Job Safety Analysis ☐ Falling Object Control Checklist (optional)
☐ Hazardous Chemicals including Designated Substances	☐ Addressed in Job Safety Analysis
☐ Musculoskeletal Disorders	☐ Addressed in Job Safety Analysis ☐ Ergonomic Hazards and Controls Checklist (optional)
☐ Public Safety Impacted	☐ Addressed in Job Safety Analysis
☐ Operational Control Documents/Local Procedures	☐ See Attached:
☐ Equipment Certificates (including rentals)	☐ See Attached – Log books, maintenance records, manuals, etc.
☐ Other	

WORK PROTECTION REQUIRED? ☐ YES ☐ NO	
If yes, check permit type required	
☐ PC2/PC2-N	☐ PC17B
☐ PC10A	☐ Personal Protection Tag (PPT)
☐ Approved Work Protection Procedure (AWPP)	

APPROVED ISOLATION PROCEDURE (AIP) REQUIRED?	☐ YES and ATTACHED	☐ NO

RESCUE PLAN	
☐ Describe Below or Attach Rescue Plan	☐ Not Applicable

FIG. 64. Safe Work Plan form (page 2 of 8, courtesy of Ontario Power Generation).

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OPG-FORM-0084-R001
Safe Work Plan

JOB SAFETY ANALYSIS
DESCRIPTION OF THE WORK:

Job Step or Activity (Break work into manageable steps)	Potential Hazards (Identify hazards for each step – refer to checklist job aid)	Control Measure/Barrier (Select controls/barriers to eliminate or minimize each hazard)
FIRST STEP – TWO MINUTE SAFETY DRILL – ***At start of work, each shift, & before work commences after each break***		
LAST STEP – HOUSEKEEPING – ***Leave the work area clean and orderly after each shift and when work is complete***		

TAILBOARD/PRE-JOB BRIEF RECORD							
DATE	INITIALS	DATE	INITIALS	DATE	INITIALS	DATE	INITIALS

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Page 3 of 8

FIG. 65. Safe Work Plan form (page 3 of 8, courtesy of Ontario Power Generation).

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Safe Work Plan

CHANGE LOG				
(1) Monitor for change – before work begins, during work and after breaks. (2) Maintain "situational awareness" of the work and surroundings. (3) When change is encountered, review SWP, adjust for new hazard/condition, determine controls and discuss with crew before proceeding.				
DATE	WHAT CHANGED	NEW HAZARD/CONDITION	ACTIONS, BARRIERS OR ADJUSTMENT REQUIRED	INITIALS

RECOMMENDATIONS FOR IMPROVEMENT
Reviewed by: ____________________

OPG-TMP-0004-R004 (Microsoft® 2007)
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FIG. 66. Safe Work Plan form (page 4 of 8, courtesy of Ontario Power Generation).

HAZARD AND BARRIER/CONTROL MEASURES

Note: *The information in the Work Hazard or Condition with Suggested Barrier/Control measures section is provided to assist in the identification of hazards and the barriers or controls that may be implemented. This is not an all-inclusive list. Use your collective experience, knowledge of the work and the application of the job planning process to complete this form. The business risk register located on the web site may be used to identify additional hazards.*

WORK HAZARD OR CONDITION	SUGGESTED BARRIER/CONTROL MEASURES
Biohazards ☐ Caddis flies/insects ☐ Mould, mildew ☐ Animal feces ☐ Snakes ☐ Plants	☐ Check area/ clean up ☐ PPE required and type noted ☐ Insect repellent
Confined Space ☐ Potential or recognized confined space ☐ Hazardous atmosphere may affect other work groups ☐ Other work groups/processes may create hazardous atmosphere	☐ Compliance with Confined Space procedure ☐ Permits and tags ☐ Ventilation – general or local exhaust required ☐ Pre-entry testing ☐ Emergency/rescue plans ☐ PPE – respiratory protection required and type noted ☐ Lighting ☐ Communication aids
Craning/Rigging/Hoisting – Falling Loads ☐ Mobile crane, gantry crane, monorail or portable hoist ☐ Engineered lifts ☐ Access by foot or vehicular traffic during work ☐ Outdoor conditions (wind, lightning) ☐ Multiple work groups in vicinity	☐ Assign Supervisor of Lift ☐ Qualified operators ☐ Load secure/stable and within equipment capacity ☐ Use of warning signs and barricades or signal person for traffic control ☐ Review of communication requirements ☐ Emergency/rescue plans ☐ Check tag lines ☐ Stable placement of equipment – terrain conditions ☐ Configuration control – load ☐ Use of high visibility PPE ☐ Swing area/designated work area ☐ Vehicle grounded ☐ Outrigger/outrigger pads ☐ Limits of Approach/cover-up ☐ Inspections completed/logged

Driving:
☐ **On Road Vehicle**
☐ **Off Road Vehicle**
  ☐ Frequency, duration, distance of travel
  ☐ Adverse weather conditions
  ☐ Type of roads/terrain
	☐ Qualified operators
	☐ Vehicle grounded
	☐ Use of warning signs/barriers/signal or safety person
	☐ Orientation: operational controls and characteristics
	☐ Circle check/inspection – vehicle condition and log
	☐ Defensive driver technique training
	☐ Review of weather and planning of route
	☐ Communication of departure and arrival times
	☐ Use of rental or company owned vehicles
	☐ Emergency kits
	☐ Driver attention/alertness, e.g., fatigue, distraction, etc.

FIG. 67. Safe Work Plan form (page 5 of 8, courtesy of Ontario Power Generation).

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OPG-FORM-0084-R001
Safe Work Plan

WORK HAZARD OR CONDITION	SUGGESTED BARRIER/CONTROL MEASURES
Electrical ☐ Location – proximity to overhead obstructions, trenching, grounding hazards, high voltage equipment ☐ Outdoor weather conditions ☐ Work Protection ☐ Isolation and de-energization ☐ Live electrical work	☐ Compliance to Workplace Electrical Safety procedure and CSR 3.0 ☐ Application of Work Protection Code ☐ Limits of Approach ☐ Use of warning signs and barricades ☐ Grounding, bonding, potential testing, ground mats ☐ Use of GFI ☐ PPE such as rubber gloves, arc flash, voltage rated gloves, etc. ☐ Wiring diagrams, drawings ☐ Common and shared neutrals ☐ Step/touch potential
Excavation/Breaking Surface/Drilling ☐ Excavations ☐ Auger, earth or core drilling concrete or other ☐ Trench	☐ Use of drawings ☐ Identification of buried or embedded services ☐ Equipment grounded ☐ Use of physical barriers/guardrails or covers ☐ Use of sloped walls or shoring for trench work ☐ Use of warning signs and barricades or safety/signal person ☐ Permit approved and reviewed with Locator ☐ Water control
Falling Objects ☐ Working at height or above other work areas ☐ Scaffolds ☐ Multiple work groups in vicinity ☐ Changing weather - ice, snow, wind ☐ Falling rocks or unstable terrain	☐ Use of tethers, tool and material lanyards ☐ Physical barriers such as containment sheeting, covered openings, kickboards ☐ Minimize materials/tools used at height ☐ Use warning signs and barricades or safety/signal person ☐ Overhead protection ☐ Housekeeping
Fall Protection (falling people) ☐ Working at heights ☐ Work over open liquid, machinery, open hole, hazardous substances or objects ☐ Scaffolds ☐ Ladder use ☐ Elevator shafts ☐ Elevating work platforms ☐ Multiple work groups in vicinity	☐ PPE – fall protection equipment, e.g., harness, lanyard, etc. ☐ Physical barriers such as guardrails, covered openings ☐ Emergency/rescue plans ☐ Scaffolds inspected, signed ☐ Three-point contact use ☐ Anchor points
Hazardous Materials including Designated Substances ☐ Chemicals – toxic, corrosive, flammable ☐ Designated Substance – silica, lead, arsenic, isocyanates, mercury ☐ Asbestos – gaskets, insulation, etc. ☐ Compressed gas ☐ Systems contain chemicals, e.g., hydrogen, hydrazine, chlorine, gasoline, etc. ☐ Dust, fume such as welding ☐ Transportation of Dangerous Goods requirements	☐ Approved product – MSDS available – labels affixed ☐ Ventilation – general or local exhaust required ☐ Specific or defined work procedure/practice ☐ PPE – hand and eye protection required and type noted ☐ Respiratory protection required and type noted ☐ Emergency eyewash and/or shower available ☐ Safe storage requirements – signed area or specific cabinets ☐ Use of safety containers and grounding/bonding as required ☐ Fire extinguishers available ☐ TDG training ☐ TDG placards/labelling/bill of lading/records

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FIG. 68. Safe Work Plan form (page 6 of 8, courtesy of Ontario Power Generation).

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Safe Work Plan

WORK HAZARD OR CONDITION	SUGGESTED BARRIER/CONTROL MEASURES
Heat/Cold ☐ Extreme temperatures in work area ☐ Weather creating extreme temperature conditions	☐ Re-schedule/stop work ☐ Monitor weather, e.g., wind, lightning, etc. ☐ Use of acclimatized workers ☐ Access to cool water and cooler rest area from heat ☐ Access to heated rest area from cold ☐ Use of appropriate clothing, PPE, sunscreen, etc. ☐ Work area monitoring with WBGT or equivalent instrument required ☐ Use of work/rest regimen
Hot Work ☐ Welding ☐ Cutting	☐ Shields and barriers ☐ Fire control ☐ Safe storage of gas cylinders – upright, secure ☐ PPE required and type noted
Manual Material Handling (Ergonomics) ☐ Handling heavy/awkward material/equipment ☐ Repetitive carrying of heavy loads ☐ Frequency, duration and repetition of handling ☐ Awkward work position/posture	☐ Use of carrying aids/devices/lift assists ☐ Modify work area or task ☐ Use of neutral postures and micro breaks, e.g., stretching ☐ Use of lighter loads or additional workers ☐ Proper lifting techniques
Mechanical ☐ Pumps, motors, valves ☐ Hot systems or close to hot surfaces ☐ Rotating/moving equipment ☐ Safety systems	☐ Use of isolation or blocking ☐ Isolation/de-energization ☐ Equipment or tool guards ☐ PPE required and type noted ☐ Use of physical barriers ☐ Eliminate entanglement hazards, e.g., loose clothing, jewellery, hair ☐ Right tools in good condition
Pressurized Fluids/Compressed Gas ☐ Pressure testing – hydrostatic, pneumatic ☐ Systems containing gas cylinders or pressurized fluid	☐ Isolate/de-energize ☐ Vent/drain ☐ Safe storage of gas cylinders – upright, secured ☐ Leak tests performed ☐ PPE required and type noted ☐ Barriers and warning signs ☐ Gauges/lines checked
Tools ☐ Hand/power tools ☐ Power cords/extension cords ☐ Pneumatic tools ☐ Portable Grinders ☐ Other	☐ Inspect for condition prior to use ☐ Follow manufacturer specifications and instructions ☐ Install GFCI ☐ Consider ergonomics of the work ☐ Check for proper tool use for the work
Water ☐ Risk of drowning ☐ Diving operations ☐ Working from a boat	☐ Physical barrier such as guardrails ☐ Fall protection equipment as applicable ☐ Other PPE such as personal flotation device ☐ Emergency/rescue plans ☐ Compliance to diving procedure and O. Reg. 629/94 Diving Operations ☐ Work Protection ☐ Water level communication
Working Alone ☐ Working alone	☐ Communication plan and frequency of reporting ☐ Review of back-out hazards and conditions
Other	

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FIG. 69. Safe Work Plan form (page 7 of 8, courtesy of Ontario Power Generation).

Minimum Criteria for Written Safe Work Plan

A written SWP is required for:

(a) Use of fall arrest system.

(b) Work on or near[1] live exposed electrical equipment.

(c) Work in a confined space.

(d) Work with designated substances.

(e) Work with radioactive sources other than those covered by Nuclear Radiation Protection governing documents.

(f) Excessive heat and cold.

(g) Work using breathing air systems with exception of Nuclear where a plastic suit is required.

(h) Diving operations.

(i) Work where excavation, drilling, cutting surfaces or driving rods involves buried services.

(j) Work on or near open water where a significant risk of drowning exists.

(k) Work involving helicopters.

(l) Work in potentially explosive atmosphere, e.g., gas, dust, or vapour.

(m) Manual material handling of cumulative loads greater than 1,000 kg/shift/worker.

(n) Craning and rigging involving:

(1) Engineered lifts.
(2) Non-routine lifts.
(3) Lifts where other workers could be struck by the load or vehicle.

(o) Unguarded rotating equipment.

(p) Use of transport and work equipment without roll-over protection used on any uneven surface.

(q) Work on live steam or pressurized systems.

(r) Excavations requiring support systems.

[1] For voltages less than 750 volts, near means the worker could make body contact with any exposed live electrical equipment or any exposed live electrical or conductors either directly or through a hand-held tool or device that the worker may be using. For voltages equal to or greater than 750 volts, near means the worker is situated a distance less than the stated Limits of Approach in Tables 1A, 1B and 1C of the Corporate Safety Rules.

FIG. 70. Safe Work Plan form (page 8 of 8, courtesy of Ontario Power Generation).

Appendix IV

CONSTRUCTABILITY, OPERABILITY, MAINTAINABILITY AND SAFETY REVIEW QUESTIONS

Table 36 contains a list of sample industrial safety related questions that can be utilized in a COMS review meeting. As described in Section 6.3.3.1, COMS meetings are designed to ensure that planned modifications are fit for purpose and that industrial safety hazards are ‘designed out’ at an early stage. Questions relating to constructability, operability and maintainability are not included in Table 36.

TABLE 36. COMS REVIEW: SAMPLE INDUSTRIAL SAFETY RELATED QUESTIONS

Safety related questions to be addressed
Are code requirements clearly stated and understood?
Have training requirements been identified?
Are the sizes of hatches, passageways and apertures acceptable for the largest body sizes, allowing for clothing, equipment and strenuous movement?
Can all the required forces (e.g. gripping, pushing, pulling, lifting) be applied by the weakest person expected to use the device?
Has load awkwardness due to shape, size, temperature, instability, sharp edges, unpredictability etc. been minimized?
Have sufficient space needs been accounted for to allow workers to develop an appropriate posture when exerting force?
Can workers maintain an upright and forwards facing posture during all or most of their work (head or body not leaning excessively to the front or sides)?
Is the weight of the body carried equally on both feet when standing (even if foot pedals are used)?
Has the weight of the load been indicated on containers or equipment?
Have permanent provisions (e.g. hoists, lift tables) or work methods been provided and documented for removal and replacement of equipment heavier than 15 kg?
Is the layout designed to avoid twisting or gripping forces applied by the hands or arms held in static postures?
Is the layout designed to avoid excessive repetition of actions (e.g. upper limbs maintained in an unsupported fixed position for greater than 30 s)?
If force must be applied repeatedly, can the worker use either arm or either leg without workplace adjustments?
Are there obstructions (e.g. steps, narrow aisles) that would impede movement of a cart around the equipment?
Have all effects of wearing PPE or clothing been accounted for in the design of the equipment?
Are workstations designed to allow larger or smaller people to fit, reach controls easily and be in a comfortable position?
Is manual work generally to take place between heart level and mid-thigh?
Is the workstation designed so that arm movements are about the elbow rather than the shoulder, and so that work activities are performed with joints at the mid-point of their range of movement?
Does the position or design of any guards result in excessive postural problems in reaching to the work?
In occasional extreme forwards reaching, is there clearance for the head to bend forwards?
Do all tools allow the workers to maintain straight wrists when using them?
Have general requirements for hand–arm vibration been considered and met?
Does the design allow the standing worker's eye position to be set for the tallest, shortest and average user according to the natural body posture in that job?
Have all visual obstructions between key objects and the users' eyes (for a range of user sizes) been removed?
For information work and using displays of high priority, frequency, long duration, high speed and accuracy etc., is there a most relaxed viewing position where the head is upright, facing forwards and slightly inclined?
Have requirements for visual tasks allowed for the wearing of eye or head protection?
Do all illumination levels meet accepted good practice?
Have auditory requirements been assessed for interference by PPE?
Can all warning signals be seen or heard, recognized and understood by workers especially when workers are at their usual workstations?
Are all machines and other controls easily distinguishable and easy to operate?
Have control panels been designed for ease of operation, with appropriate labelling, instrument grouping etc., which will maintain legibility over the plant life?

TABLE 36. COMS REVIEW: SAMPLE INDUSTRIAL SAFETY RELATED QUESTIONS (cont.)

Safety related questions to be addressed
Can tools and equipment be used with either hand?
Do hinged covers or access points that must be raised to open have a means of securing them in their open position against accidental closures that could result in injury?
Do slide assemblies for drawers in cabinets have limit stops to prevent them from being inadvertently pulled out?
Does the equipment or component represent a tipping hazard?
Are floor or walking surfaces uncluttered, even, non-slippery and otherwise safe? (The coefficient of friction should be between 0.2 to 0.5 for unloaded walking and up to 0.8 for heavy pushing or pulling.)
Will workers be exposed (unprotected) to sound pressure levels greater than 80 dB(A) during construction, operation or maintenance activities?
Are ventilation openings small enough to keep fingers away from dangerous places?
Is the equipment posted with a rated load capacity? If yes: (a) Is a warning provided against loading cables, chains and hoists beyond rated limits? (b) Does the warning on hoists also indicate that loads should not be raised or lowered with quick starts or stops that will put high strains on the cable or chains?
Are all hazardous substances eliminated or controlled? Including (but not limited to): (a) Combustible dust: any finely divided solid material 420 µm or smaller in diameter that presents a fire or explosion hazard when dispersed and ignited with air. (b) Combustible fibres: finely divided combustible vegetable or animal fibres and thin sheets or flakes of such material, which in a loose, unbaled condition present a flash fire hazard, including cotton, wool, hemp, sisal, jute, kapok, paper and cloth. (c) Combustible liquid: any liquid with a flash point at or above 37.8ºC and below 93.3ºC. (d) Compressed gas: any contained mixture or material with either an absolute pressure exceeding 275 kPa at 21ºC, or an absolute pressure exceeding 717 kPa at 54ºC, or both, or any liquid with an absolute vapour pressure exceeding 275 kPa at 38ºC. (e) A potential for H2 or D (deuterium) accumulation due to H2 addition or radiolysis. (f) Designated substance: a biological, chemical or physical agent, or combination thereof, prescribed as a designated substance to which the exposure of a worker is prohibited, regulated, restricted, limited or controlled. (g) Flammable liquid: a liquid with a flash point below 37.8ºC, and a vapour.
Are permanent ventilation systems adequate and designed for operation or early installation to meet the construction ventilation requirements where applicable?
Does the work affect the accessibility of the fire zone by plant fire brigade or municipal firefighters (fire route)?
Has consideration been given to isolation requirements for installation?
Are provisions for noise abatement considered?
Are widths of work zones and travel lanes adequate?
Have underground utilities been checked?
Is the floor loading capacity sufficient to handle the equipment during the move?
Is lead paint/asbestos removal or testing required?
Can mechanical and electrical equipment be isolated?
Are overhead clearances sufficient?
Is there any evidence that the design has addressed human factors and ergonomic considerations?
Does the environment have noise, lighting and temperature that would impede safe operation/maintenance?
Are lockout provisions for work protection addressed in the design?
Are all 120 Vac and higher supplies capable of being locked?

TABLE 36. COMS REVIEW: SAMPLE INDUSTRIAL SAFETY RELATED QUESTIONS (cont.)

Safety related questions to be addressed
For mechanical equipment, are proper measures provided for energy isolation?
Has adequate accessibility been provided to perform the operational functions?
Has the layout of equipment and the type of equipment minimized the likelihood of mispositioning caused by bumping?
Are manual valve operators accessible by the average person standing in front of them? If not, should they be motorized or chain operated?
Are any valves manufactured as lockable (note that chain and padlock does not constitute lockable)?
Can operators see all relevant displays to receive feedback on operations activities?
Will operators easily be able to check required equipment without compromising body mechanics? Is equipment requiring routine checks fully accessible without use of ladders or lifting devices (e.g. via a powered elevated work platform)?
Will there be any critical equipment requiring emergency manual operation during a transient? If yes, will the equipment: (a) Be quickly and readily accessible without requiring ladder or lifting devices (e.g. via a powered elevated work platform)? (b) Be oriented in such a manner to reduce the likelihood of musculoskeletal disorder related injuries?
If devices installed by the modification are portable or movable (e.g. skid mounted equipment), is movement achievable without the risk of damage to station structures and components? If yes: (a) Can equipment be moved easily without compromising staff safety? (b) Will there be any special equipment required to facilitate transportation of equipment through the station?
For electrically operated equipment, will the equipment be hardwired (preferred)?
For electrically operated equipment, will the equipment be plugged into a receptacle?
If plugged into a receptacle, are local receptacles available to plug the device into which meet design requirements (e.g. load ratings, GFCI or AFCI protection)?
If plugged into a receptacle, are electrical code requirements being met?
Have designated substances been identified?
Are materials that could be considered hazardous identified?
Is there space or area around the process to bring in lifting equipment?
If a heavy product or assembly must be lifted frequently, are handles or other handling aids provided?
Are tilt points provided and labelled?
Does the modification involve working at a height of greater than 2.5 m?
Can portable or permanently installed platforms or lifting arrangements be used to reduce the need for ladders?
Does the modification involve working in a confined space?
Does the modification involve working near open waterways?
Does the modification involve excavation or trenching?
Does the work require the location, excavation or installation of underground services? If yes, have provisions been made to easily locate such services in the future?
Is the modification close to existing manual control devices (e.g. hand switches)?
Does the modification involve climbing i.e. will the means of access be appropriate for the frequency of access needed (e.g. stairs, fixed ladders, portable ladders, lift, scaffolding)?
Have the design addressed electrical grounding and bonding requirements?

TABLE 36. COMS REVIEW: SAMPLE INDUSTRIAL SAFETY RELATED QUESTIONS (cont.)

Safety related questions to be addressed
Is there potential for exposure to electrical hazards which could cause shock, burn, arcing, electrical explosion or unexpected energization?
Is there potential for exposure to temperature hazards such as live steam repairs, hot surfaces, hot exhaust gases, steam or condensate blowdown, cold flashing liquids or vapours, refrigerated or cryogenic surfaces, extreme ambient temperatures (outdoors or indoors), or heavy or nonporous protective clothing?
Is there potential for exposure to pressure hazards such as compressed air tools, high pressure gas or steam leaks, discharges from vents or relief devices, blowing particulates, hydraulic hammers, container or equipment ruptures or vacuums?
Does the modification install craning or hoisting? If yes, does the modification install a lifting device or travelling crane to existing support structure not originally designed for it?
Does the modification use existing heating, ventilating and air conditioning equipment or does the modification require new installations for heating, ventilating and air conditioning equipment?
Is there potential for exposure to mechanical hazards such as sharp edges or points, obstacles likely to cause head injury or tripping, slippery surfaces, falling objects, unguarded (e.g. cageless or no railing) or unstable platforms or ladders?
Have ejected parts or fragments, unguarded moving equipment (e.g. pulleys, belts, gears, augers, pistons, rotating equipment, including pinch points) been considered?
Will the work increase the potential exposure to hazardous materials?
Will the work increase the potential for incidents involving the release of hazardous materials?
Will the work involve the disturbance or removal of insulation?
Will the work involve the removal of paint (using a torch or grinding)?
Will the work require additional or affect existing eyewash stations, emergency showers or fire protection equipment?
Will the work have potential to expose workers in excess of occupational exposure limits during the use of equipment that either uses or produces a designated substance or a biological or chemical agent?
Will the work affect nomenclature required to meet REACH/WHMIS requirements?
Can the design utilize computer visualization tools to make critical or hazardous construction activities safer (safer and better planned lifts, minimized potential for installation clashes, including those between fixed and temporary construction material such as scaffolding), or to incorporate safety elements (e.g. fall protection, lift/crane access, temporary/movable structures) into the project design?

Note: AFCI — arc fault circuit interrupter; GFCI — ground fault circuit interrupter; PPE — personal protective equipment; REACH — registration, evaluation, authorization and restriction of chemicals; WHMIS — workplace hazardous material information systems.

Appendix V

INCIDENT AND ACCIDENT INVESTIGATIONS

Incident investigation is a key process in collection and analysing internal safety events. Organizations should conduct appropriate investigations into every accident and near miss incident to determine their cause and to initiate appropriate mitigative or corrective measures. These can include measures to improve existing processes to prevent a recurrence of the same or similar types of incidents. Results of such investigations should be entered into a corporate database for trending and analysis.

In certain cases, a team is formed to assist in performing the investigation. To help the team to gather facts and critical information, a checklist for incident investigations is often used. The following sections describe typical responsibilities for line management (supervisor, location manager, location OSH manager) and for the employees involved in the incident investigation.

V.1. RESPONSIBILITIES

Generic examples of key responsibilities for the location management (supervisor, location manager and location OSH manager) and employee are provided in the following sections.

V.1.1. Supervisor or investigation team responsibilities

Depending on the scope and severity of the incident the responsibilities might be given to the supervisor or an investigation team. The responsible supervisor or team investigates the incident and completes the investigation in accordance with the incident notification process. In the case of personal injury, the supervisor or team ensures that the injured employee(s) receive immediate and appropriate medical care. In conducting the incident or accident investigation and completing an investigation report, the supervisor or team is to ensure the following has been completed:

- Assessment of the scene;
- Interviews of witnesses and other parties;
- Identifying the contributing factors;
- Making recommendations for corrective action;
- Ensuring recommendations are acted upon;
- Ensuring recommendations are communicated to employees.

V.1.2. Location manager responsibilities

The location manager ensures that completed investigation reports are entered into an investigation reports database for the site, and works with the location OSH manager to identify the causes or contributing factors. Additional responsibilities include ensuring that all corrective actions have been taken to prevent recurrence and have been communicated to all employees in the work area, and that the lessons learned are incorporated into the development of project plans, readiness reviews, work packages, pre-job briefs and training as required.

V.1.3. Location OSH manager responsibilities

The location OSH manager is typically responsible for the timely review of incident reports and communication of lessons learned to location personnel and corporate wide. Incident advisory bulletins are an effective means to notify project personnel quickly. Responsibilities typically include the following:

- Reviewing incident investigation reports and following up as appropriate or required;
- Ensuring that recommendations are appropriate and that preventive and corrective actions have been taken;

— Assisting or providing direction as needed for the implementation of corrective actions;
— Developing communication bulletins for the site (see Section 4.9.2);
— Ensuring reports are distributed to the corporate OSH director for a review for applicability to other locations.

V.1.4. Corporate OSH director

The corporate OSH director determines whether further OSH process revision or communication bulletins are required at a corporate level.

V.1.5. Employee responsibilities

The employee is responsible for immediately reporting any work related injury or illness to the supervisor. This includes accidents such as cuts, puncture wounds, needle stick injuries, sprains and burns as well as those that are of a gradual onset (chronic) pain (i.e. back pain or repetitive strain injuries). The employee is also responsible for immediately reporting any near miss events or unsafe work situations to the supervisor and providing necessary details. In the case of an emergency, the employee or person providing assistance is required to contact the supervisor as soon as possible following the treatment of the injury.

V.2. INVESTIGATION

When an accident or incident occurs, the primary focus is on obtaining appropriate treatment for injured people and securing the scene to prevent additional hazards or injuries. Once the injured personnel have been cared for and the scene has been secured, it is necessary to initiate a formal investigation to determine the extent of the damage, causal factors and corrective actions to be implemented. Certain tools may be needed to investigate such incidents. The following items should be kept on hand, easily accessible, to avoid delay in investigation:

— Barricade tape and identification tags;
— Camera, with spare batteries;
— Chalk and chalk line;
— Flashlight with batteries;
— Notebook or clipboard with pens or pencils;
— Measuring tape or ruler;
— Surgical gloves and work gloves;
— Blank incident report.

Initial identification of evidence immediately following the incident includes a list of people, equipment and materials involved and a recording of environmental factors such as weather, illumination, temperature, noise, ventilation and physical factors such as fatigue and age of the workers. The five Ws (what, who, when, where and why) are useful to remember in incident investigation and are described in the following sections.

V.2.1. What

Every incident or near miss should be investigated to determine the cause or causes and corrective measures. Some examples of such incidents include:

— Near miss or high potential near miss incidents;
— Injuries involving a doctor’s care;
— Recordable injuries and illnesses;
— Restricted work day cases;
— Lost work day cases;
— Utility damage;
— Fires;

— Motor vehicle accidents;
— Equipment damage or loss.

V.2.2. Who

Individuals with knowledge of the incident should be interviewed and a written statement should be developed. Such a statement can be used to refresh a witness's memory later. Individuals to be interviewed can include:

— Eyewitnesses;
— Anyone who heard or saw something;
— Anyone else who may have been on-site;
— Anyone who knows something about conditions or practices that might have contributed to incident;
— Subject matter experts.

V.2.3. When

Investigations should proceed immediately after incident, since:

— Witnesses remember more.
— The scene is most like it was at the time of the incident.
— Important evidence can be preserved.

V.2.4. Where

The best place to perform the investigation is at the site where it occurred. Some steps to be done include:

— Securing the site as soon as possible — after taking any emergency actions and damage control measures;
— Taking lots of photos from every possible angle;
— Making a sketch or drawing of the scene;
— Taking measurements of relevant items.

Evidence such as people, positions of equipment, parts and papers needs to be promptly preserved, secured and collected through notes, photographs, witness statements, flagging and impoundment of documents and equipment. Five working days is a common timeframe for such activities.

V.2.5. Why

The investigation should reach a conclusion of why the event occurred, develop corrective actions to prevent future incidents, and report its findings to communicate information to others. A standard format for reporting should be utilized. Typical reports contain the following:

— A description of the accident/incident (use employee classification and not names);
— The root cause of the accident/incident;
— Contributing cause(s);
— Corrective actions to be implemented;
— Improvement ideas from this accident/incident applicable to other activities and projects.

A variety of methods may be used to analyse events and develop conclusions. Root cause analysis as discussed in Ref. [211] and Section 7.2.3 is a common method used in the nuclear industry. The United States Department of Energy identifies root cause analysis and four other methods as 'core analytical tools' for accident analysis [213]. The other four techniques are event and causal factor charting and analysis, barrier analysis, change analysis and verification analysis. Various other advanced methods specific to occupational accidents can be used in conjunction with these. Overviews of common techniques are available in Refs [88, 213, 320, 321]. Some of the methods overlap or are more common in specific countries, and some are commercial/proprietary in nature. The following sections describe some of the core and advanced techniques.

V.2.5.1. Event and causal factors analysis

Event and causal factors analysis is a method that produces a chart of an accident sequence of events. Different chart symbols are used for events, conditions, the accident itself, contextual conditions, connections and causal factors. The technique is designed to identify the significant events and conditions that led to the event. As the accident investigation proceeds a causal factors chart is developed and refined, and input from other techniques such as barrier analysis and change analysis is incorporated. An example causal factors chart for a hypothetical event is shown in Fig. 71.

V.2.5.2. Barrier analysis

Barrier analysis is used to document the barriers between the worker and the hazard that failed during the accident. The barriers may be physical (e.g. guards, railings and PPE) or management or administrative in nature (e.g. exposure limits, regulations, procedures, work planning and control processes, training and supervision). A result of a barrier analysis is typically a worksheet that identifies the following:

— What were the barriers?
— How did each barrier perform?
— Why did each barrier fail?
— How did each barrier affect the accident?

V.2.5.3. Change analysis

Change analysis is useful in identifying obscure contributing causes of accidents that result from system changes. It examines planned or unplanned changes that caused undesired results. The accident sequence is compared to the accident free sequence of events, and differences are identified [321]. The differences are then analysed with regard to their effect on the accident, and the results are fed back into the event and casual factors analysis chart described in Section V.2.5.1. Investigators compare which events, conditions or equipment were present in the accident that are not present in the baseline event, any differences in time, location, or personnel and on how the work was managed prior to the accident. The analysis is most effective when a prior accident free or typical situation is already documented or can be reconstructed.

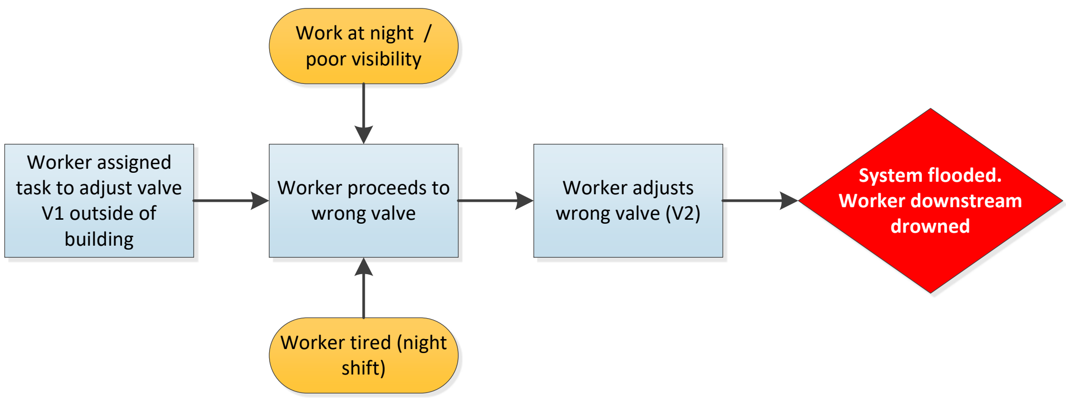

FIG. 71. SAMPLE event and causal factors chart.

V.2.5.4. Verification analysis

Verification analysis is conducted on draft accident or root cause reports after all analytical work is done. It is designed to ensure that all aspects of the report are accurate and consistent, and verifies that the conclusions are consistent with the facts, analyses and judgements of need.

V.2.5.5. Fault tree analysis

A fault tree is a graphical model displaying normal events, equipment failures, human errors and environmental factors that resulted in an accident [321]. The items are connected via a series of logic gates showing how each contributed to the undesirable event, which appears as the top event of the fault tree. The fault tree may include quantitative or qualitative analysis, or both. Fault trees in the context of process analysis were discussed in Section 6.3.1.2. Use of the method typically requires extensive training. An example of an accident investigation is shown in Fig. 72.

V.2.5.6. Event tree analysis

An event tree is primarily a proactive risk analysis tool used to identify possible undesirable event sequences [321]. In an accident scenario, the accident path can be shown as one of the possible sequences (see Fig. 73).

V.2.5.7. Management oversight and risk tree

Management oversight and risk tree (MORT) is a systematic method of accident investigation that requires extensive training. The MORT manual [322] contains a set of questions to help investigators guide their inquiries. A MORT chart [323] is available to help to navigate the questions and to record the answers. In the MORT tradition, incident analysis follows three steps:

(1) Document the sequence of events in which the incident happened (e.g. using events and conditional factors analysis [324]);
(2) Define and characterize the events to be analysed (e.g. using control change cause analysis, 3CA [325], or energy trace and barrier analysis [322]);
(3) Evaluate the hypothesis that the events happened as a result of how risks were being managed in the activity in which the incident occurred (e.g. using 3CA or MORT analysis).

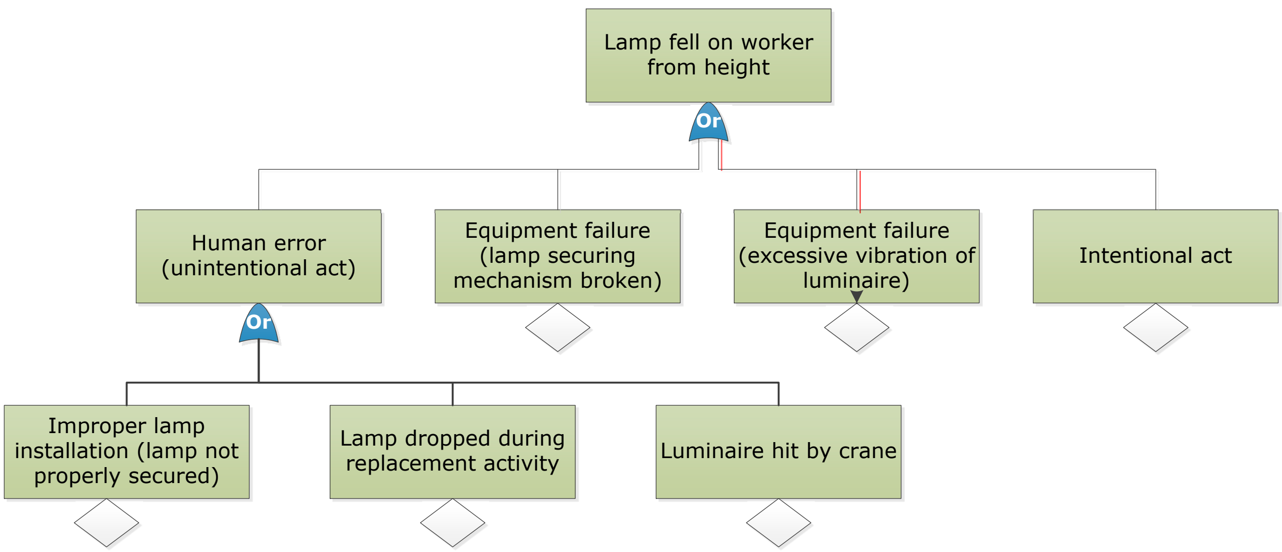

FIG. 72. Sample fault tree analysis.

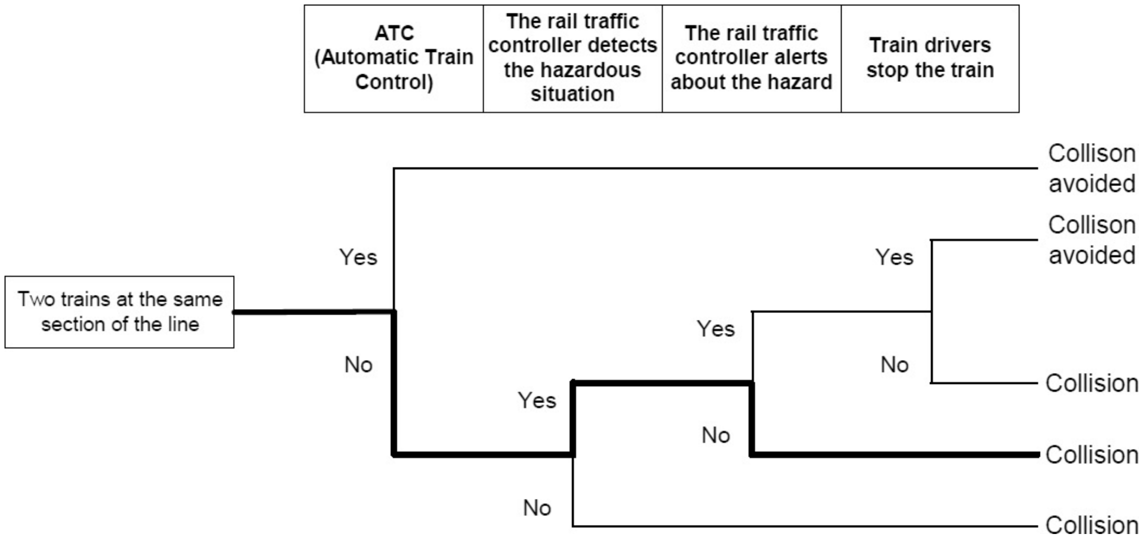

FIG. 73. Sample event tree analysis [320].

V.2.5.8. Systematic cause analysis technique

Systematic cause analysis technique (SCAT) was developed by the International Loss Control Institute, and is now incorporated into the part of the Det Norske Veritas International Safety Rating System [77] framework. It systematically classifies events into various types, identifies immediate and direct causes such as substandard acts or conditions, and then explores deeper into basic or root causes, which are divided into the general categories of personal, job and system factors. Areas for corrective action are then identified. Various aids such as SCAT worksheet charts are available from Det Norske Veritas.

V.2.5.9. Sequential timed events plotting

Sequential timed events plotting (STEP) was developed in the 1980s [326], and is another systematic process for accident investigation. It is based on a process view of accident sequences in which many activities take place at a given time. Accidents are represented as a series of blocks with each block being one actor performing one action at a point of time; when completed, the sequence resembles a series of steps (see Fig. 74).

V.2.5.10. Accident analysis and barrier function

The accident analysis and barrier function (AEB) models the interaction of humans and technical systems by connecting human and technical errors (as opposed to documenting an event sequence), and then analysing where barrier functions were effective, ineffective or non-existent. Barrier functions can be an operator, procedure, physical separation, emergency control system, or other safety related system [320] (see Fig. 75).

V.2.5.11. Acci-Map

The Acci-Map accident analysis technique is based on Rasmussen's risk management framework [327]. Initially, different accident scenarios are selected and the causal chains of events are analysed using a cause–consequence chart. A cause–consequence chart represents a generalization that aggregates a set of accidental courses of events. Acci-Map serves to identify relevant decision makers (e.g. governments, regulators, company, management and workers) and the normal work situation in which they influence and modulate possible accidents. The focus of Acci-Map is not on the traditional search for identifying the 'guilty person', but on the identification of those people in the system that can make decisions resulting in improved risk management, and hence, to the design of an improved system safety.

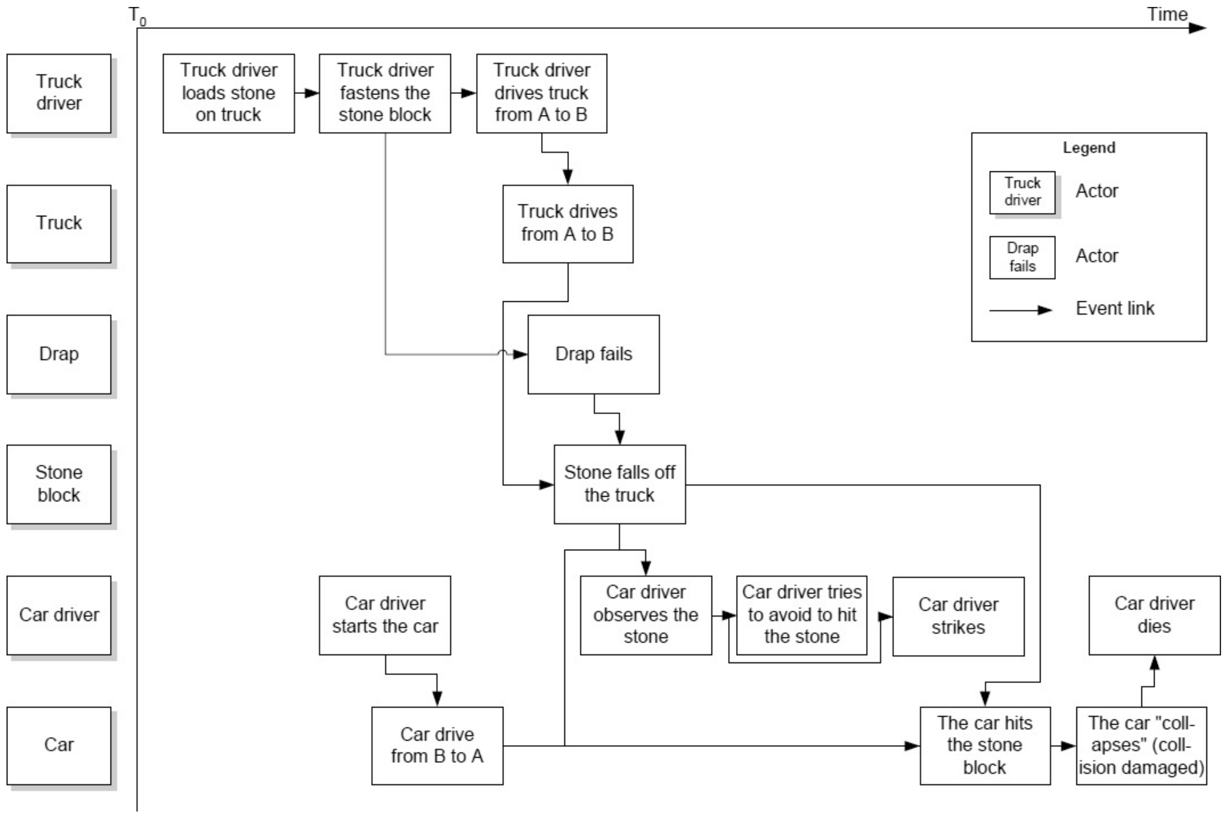

FIG. 74. Example STEP diagram for a car accident [320].

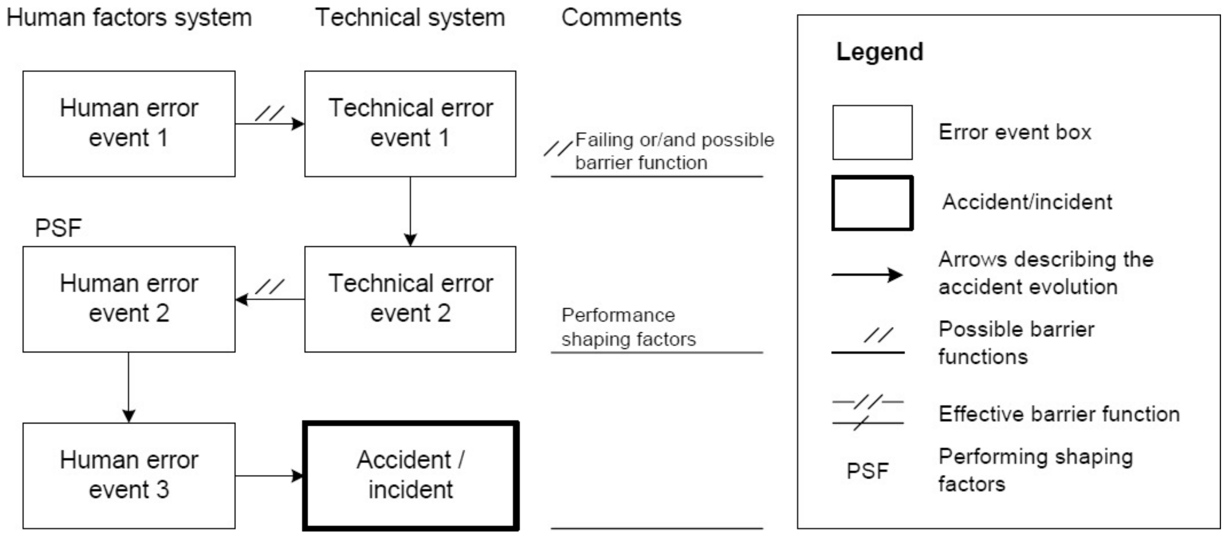

FIG. 75. Example AEB analysis [320].

V.2.5.12. Tripod Delta

Tripod Delta is an incident investigation and analysis methodology[41]:

"The influencing environment within the workplace can be summarised as 11 Basic Risk Factors:

[41] See https://publishing.energyinst.org/tripod/delta

- Design;
- Hardware;
- Maintenance management;
- Housekeeping;
- Error enforcing conditions;
- Procedures;
- Training;
- Communication;
- Incompatible goals;
- Organisation;
- Defences.

"These basic risk factors help determine the psychological precursors which can lead to 'unsafe acts' — unsafe behaviours, either in the planning of work or its implementation."

The TRIPOD Beta tool is a computer based environment that provides the user with a tree-like overview of an accident. It incorporates the above precursors as potential failed defences or failed controls that led to the accident. Guidance on the tool is available in Ref. [328].

V.2.5.13. Systems theoretic accident modelling and processes

STAMP uses system theory to analyse accidents, and focuses on the role of constraints in safety management [329]:

"The process leading up to an accident (loss event) can be described in terms of an adaptive feedback function that fails to maintain safety as performance changes over time to meet a complex set of goals and values.

"Instead of defining safety management in terms of preventing component failure events, it is defined as a continuous control task to impose the constraints necessary to limit system behavior to safe changes and adaptations. Accidents can be understood, using this model, in terms of why the controls that were in place did not prevent or detect maladaptive changes, that is, by identifying the safety constraints that were violated and determining why the controls were inadequate in enforcing them."

This adaptive feedback mechanism allows the model to incorporate adaptation as a fundamental property [329].

V.2.5.14. MTO analysis

Reference [321] reports that:

"The basis for MTO-analysis is that human, organisational, and technical factors should be focused equally in an accident investigation....

"The MTO-analysis is based on three methods:

1. Structured analysis using an event- and cause-diagrams.
2. Change analysis by describing how events have deviated from earlier events or common practice.
3. Barrier analysis by identifying technological and administrative barriers which have failed or are missing.

....

"A checklist for identification of failure causes is also part of the MTO methodology.... The checklist contains the following factors: Work organization, Work practice, Management of work, Change procedures, Ergonomic/deficiencies in the technology, Communication, Instructions/procedures, Education/competence, and Work environment."

The method is commonly used in the Norwegian offshore industry and the Swedish nuclear power industry [88].

V.2.5.15. Functional resonance accident model

Reference [330] reports that:

"The Functional Resonance Accident Model [FRAM] and the associated method provide a way to describe how multiple functions and conditions can combine to produce an adverse outcome.... FRAM is based on the following principles:

- *The principle of equivalence of successes and failures*. FRAM adheres to the resilience engineering view that failures represent the flip side of the adaptations necessary to cope with the real world complexity rather than a failure of normal system functions. Success depends on the ability of organisations, groups and individuals to anticipate risks and critical situations, to recognise them in time, and to take appropriate action; failure is due to the temporary or permanent absence of that ability.
- *The principle of approximate adjustments*. Since the conditions of work never completely match what has been specified or prescribed, individuals and organisations must always adjust their performance so that it can succeed under the existing conditions, specifically the actual resources and requirements. Because resources (time, manpower, information, etc.) always are finite, such adjustments are invariably approximate rather than exact.
- *The principle of emergence*. The variability of normal performance is rarely large enough to be the cause of an accident in itself or even to constitute a malfunction. But the variability from multiple functions may combine in unexpected ways, leading to consequences that are disproportionally large....
- *The principle of functional resonance*. The variability of a number of functions may every now and then resonate, i.e., reinforce each other and thereby cause the variability of one function to exceed normal limits. ...The resonance analogy emphasises that this is a dynamic phenomenon, hence not attributable to a simple combination of causal links.

....

"In the context of an accident investigation using FRAM, the explanation is produced by proceeding through the following steps....

"*Identify essential system functions* [inputs, outputs, time, preconditions, resources and controls], using normal or accident-free performance as a baseline....

....

"*Characterize the observed variability of system functions*, considering both actual and potential variability....

"*Identify and describe the functional resonance* from the observed dependencies/couplings among functions and the observed performance variability....

....

"*Identify barriers for variability* (damping factors) and specify required performance monitoring....

"Besides recommendations for barriers, a FRAM analysis can provide the basis for recommendations on how to monitor performance in order to detect excessive variability. Performance indicators may be developed both for functions and for the couplings between them."

V.3. CLOSURE

The location OSH manager typically performs a final review of all incident investigation reports and assures follow-up as appropriate/required. The corporate OSH director then determines whether further OSH process revisions or communication bulletins are required at a corporate level.

Appendix VI

PERSONAL PROTECTIVE EQUIPMENT STANDARDS

Table 37 provides a list of selected internationally recognized standards for PPE. It is not intended to be a comprehensive list of all standards available, and does not include testing standards for such equipment. Individuals should consult their national regulations for applicability of such standards within their jurisdiction.

TABLE 37. SELECTED STANDARDS FOR PERSONAL PROTECTIVE EQUIPMENT

Standard	Additional information
General	
ISO 13688:2013, Protective Clothing: General Requirements [331]	
ISO/TR 11610:2004, Protective Clothing: Vocabulary [332]	List of terms frequently used in the standardization of protective clothing
ASTM F1494-14, Standard Terminology Relating to Protective Clothing [333]	Defines the specialized terms used in standards developed by ASTM Committee F23 on protective clothing
Abrasive blasting	
ISO 14877:2002, Protective Clothing for Abrasive Blasting Operations Using Granular Abrasives [334]	Requirements and test methods for protective clothing for abrasive blasting operations and for hand protection
Chemicals	
ISO 13982-1:2004, Protective Clothing for Use against Solid Particulates, Part 1: Performance Requirements for Chemical Protective Clothing Providing Protection to the Full Body against Airborne Solid Particulates (Type 5 Clothing) [335]	
ISO 16602:2007, Protective Clothing for Protection against Chemicals: Classification, Labelling and Performance Requirements [336]	
ISO 27065, Protective Clothing: Performance Requirements for Protective Clothing Worn by Operators Applying Pesticides and for Re-entry Workers [337]	
ASTM F1296-08(2015), Standard Guide for Evaluating Chemical Protective Clothing [338]	Aid in application of standards for development, specification and selection of chemical protective clothing
ASTM F1461-17, Standard Practice for Chemical Protective Clothing Program [339]	Selection, use, maintenance and limitations of chemical protective clothing
ASTM F2061-17, Standard Practice for Chemical Protective Clothing: Wearing, Care, and Maintenance Instructions [340]	Minimum information to be conveyed by the sellers to end users for the wearing, care and maintenance of chemical protective clothing
EN 14605:2005+A1:2009, Protective Clothing against Liquid Chemicals: Performance Requirements for Clothing with Liquid-Tight (Type 3) or Spray-Tight (Type 4) Connections, Including Items Providing Protection to Parts of the Body Only (Types PB [3] and PB [4]) [341]	Specifies minimum requirements for limited use and reusable chemical protective clothing Full body protective clothing with liquid-tight connections between different parts of the clothing (Type 3: liquid-tight clothing) and, if applicable, with liquid-tight connections to component parts, such as hoods, gloves, boots, visors or respiratory protective equipment, which may be specified in other European standards
BS 7184:2001, Selection, Use and Maintenance of Chemical Protective Clothing: Guidance [342]	

TABLE 37. SELECTED STANDARDS FOR PERSONAL PROTECTIVE EQUIPMENT (cont.)

Standard	Additional information
CAN/CGSB/CSA-Z16602:14, Protective Clothing for Protection against Chemicals: Classification, Labelling and Performance Requirements (Adopted ISO 16602:2007, first edition, 2007-12-15, Including Amendment 1:2012, with Canadian Deviations) [343]	
JIS T 8124-1:2010-05-25, Protective Clothing for Use against Solid Particulates, Part 1: Performance Requirements for Chemical Protective Clothing Providing Protection to the Full Body against Airborne Solid Particulates (Type 5 Clothing) [344]	
Cut and stab protection	
ISO 13998:2003, Protective Clothing: Aprons, Trousers and Vests Protecting against Cuts and Stabs by Hand Knives [345]	
Electrical and arc flash	
IEC 61482-2:2018, Live Working: Protective Clothing against the Thermal Hazards of an Electric Arc, Part 2: Requirements [346]	Requirements and test methods applicable to materials and garments for protective clothing for electrical workers against the thermal hazards of an electric arc
IEC 60903:2014, Live Working: Electrical Insulating Gloves [347]	Applicable to electrical insulating gloves and mitts that provide protection against electric shock Also covers electrical insulating gloves with additional integrated mechanical protection referred to in this publication as ‘composite gloves’
NFPA 70E Standard for Electrical Safety in the Workplace [267]	Encompass safety related work practices, safety related maintenance requirements and safety requirements for special equipment Includes guidance for making hazard identification and risk assessments, selecting appropriate personal protective equipment, establishing an electrically safe work condition, and employee training
CSA Z462-15, Workplace Electrical Safety [75]	Includes tables for the selection of personal protective equipment for electrical work
ASTM D120-14a, Standard Specification for Rubber Insulating Gloves [348]	Standard specification for the protection of workers from electrical shock
Eyes	
ANSI Z87.1-2015, American National Standard for Occupational and Educational Personal Eye and Face Protection Devices [349]	
CSA Z94.3-15, Eye and Face Protectors [350]	Applies to eye and face protectors used in all occupational and educational operations or processes involving hazards to the eyes or face
BS 7028:1999, Eye Protection for Industrial and Other Uses: Guidance on Selection, Use and Maintenance [351]	

TABLE 37. SELECTED STANDARDS FOR PERSONAL PROTECTIVE EQUIPMENT (cont.)

Standard	Additional information
Feet	
ASTM F2413-11, Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear [352]	Design, performance, testing, and classification requirements and fit, function and performance criteria for protective footwear
CSA Z195-14, Protective Footwear [353]	Design and performance requirements, toe protection, sole puncture protection, metatarsal protection, electric shock resistant soles, slip resistant soles and other requirements relating to the general stability of footwear
CSA Z334-14, Over-the-shoe Toe Protectors [354]	
ISO/TR 18690:2012, Guidance for the Selection, Use and Maintenance of Safety and Occupational Footwear and Other Personal Protective Equipment Offering Foot and Leg Protection [355]	
Hands	
EN 374-1:2003, Protective Gloves against Chemicals and Micro-organisms, Part 1: Terminology and Performance Requirements [356]	
EN 388-1:2003, Protective Gloves against Mechanical Risks [357]	Risks such as abrasion resistance, blade cut resistance, tear resistance, puncture resistance
EN 420.2003+A1:2009, Protective Gloves: General Requirements and Test Methods [358]	General requirements and relevant test procedures for glove design and construction, resistance of glove materials to water penetration, innocuousness, comfort and efficiency, marking and information supplied by the manufacturer applicable to all protective gloves
EN 511:2006, Protective Gloves against Cold [359]	Specifies requirements and test methods for gloves which protect against convective and conductive cold down to −50°C
EN 1082-1:1996, Protective Clothing: Gloves and Arm Guards Protecting against Cuts and Stabs by Hand Knives, Part 1: Chain Mail Gloves and Arm Guards [360], and EN 1082-2:1996, Part 2: Gloves and Arm Guards Made of Material Other than Chain Mail [361]	
EN 12477:2001/A1:2005, Protective Gloves for Welders [362]	Specifies requirements and test methods for protective gloves for use in manual metal welding, cutting and allied processes
EN 14328:2005, Protective Clothing: Gloves and Armguards Protecting against Cuts by Powered Knives — Requirements and Test Methods [363]	Specifies requirements for design, cut resistance, ergonomic characteristics, innocuousness, fixings, construction materials, marking and instructions for use, for chain mail gloves and armguards providing protection against powered knives
Head	
ANSI/ISEA Z89.1-2014, American National Standard for Industrial Head Protection [364]	

TABLE 37. SELECTED STANDARDS FOR PERSONAL PROTECTIVE EQUIPMENT (cont.)

Standard	Additional information
CSA Z94.1-15, Industrial Protective Headwear: Performance, Selection, Care, and Use [365]	Applies to protective headwear for industrial, construction, mining, utility and forestry workers Defines the areas of the head that are to be protected and basic performance requirements
EN 397:2012+A1:2012, Industrial Safety Helmets [366]	Specifies physical and performance requirements, methods of test and marking requirements for industrial safety helmets
EN 812:2012, Industrial Bump Caps [367]	Specifies physical and performance requirements, methods of test and marking requirements for industrial bump caps
EN 14052:2012+A1:2012, High Performance Industrial Helmets [368]	Specifies physical, performance, test and marking requirements for high performance industrial helmets
JIS T 8131:2015, Industrial Safety Helmets [369]	Specifies the requirements for physical properties and performance of the industrial safety helmets
Hearing	
CSA Z94.2-14, Hearing Protection Devices: Performance, Selection, Care, and Use [370]	Performance, acoustical testing, packaging, selection, care and use of hearing protection devices
EN 458:2015, Hearing Protectors: Recommendations for Selection, Use, Care and Maintenance — Guidance Document [371]	
Heat and flame	
ISO/TR 2801:2007, Clothing for Protection against Heat and Flame: General Recommendations for Selection, Care and Use of Protective Clothing [372]	
ISO 11612:2015, Protective Clothing: Clothing to Protect against Heat and Flame — Minimum Performance Requirements [373]	Performance requirements for protective clothing made from flexible materials, which are designed to protect the wearer's body, except the hands, from heat and flame
ISO 14116:2015, Protective Clothing: Protection against Flame — Limited Flame Spread Materials, Material Assemblies and Clothing [374]	
ASTM F1731-96(2013), Standard Practice for Body Measurements and Sizing of Fire and Rescue Services Uniforms and Other Thermal Hazard Protective Clothing [375]	
High visibility personal protective equipment	
ISO 20471:2013, High Visibility Clothing: Test Methods and Requirements [376]	
ANSI/ISEA 107-2010, American National Standard for High-Visibility Safety Apparel and Headwear Devices [377]	
CSA Z96-15, High-visibility Safety Apparel [378]	Selection, use and care of high visibility safety material

TABLE 37. SELECTED STANDARDS FOR PERSONAL PROTECTIVE EQUIPMENT (cont.)

Standard	Additional information
CSA Z96.1-08, Guideline on Selection, Use, and Care of High-visibility Safety Apparel [379]	Best practices, to be used in conjunction with CSA-Z96-15 [378]
NFPA 1992-2012 Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies [380]	
Respirators	
CAN/CSA-Z94.4-11, Selection, Use, and Care of Respirators [381]	Requirements for selection, use and care of respirators and for administration of an effective respiratory protection programme in the workplace
CSA Z180.1-13, Compressed Breathing Air and Systems [382]	Provides the minimum requirements for the purity of compressed breathing air supplied to service outlets and for breathing air systems required to produce, store and distribute such air
29 CFR 1910.134 Respiratory Protection [383]	Requirements for respiratory protection programmes
EN 529:2005, Respiratory Protective Devices: Recommendations for Selection, Use, Care and Maintenance — Guidance Document [384]	
Welding	
ISO 20349-1:2017, Personal Protective Equipment: Footwear Protecting against Risks and in Foundries and Welding, Part 1: Requirements and Test Methods for Protection against Risks in Foundries [385]	Requirements and test methods for footwear protecting users against thermal risks and molten iron or aluminium metal splashes
ASTM F1002-15, Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards [386]	Minimum design and performance requirements for protective clothing and protective clothing materials for both primary and secondary protection from exposure to molten substances and related thermal hazards
ISO 11611:2015, Protective Clothing for Use in Welding and Allied Processes [387]	Specifies minimum basic safety requirements and test methods for protective clothing including hoods, aprons, sleeves, and gaiters that are designed to protect the wearer’s body including head (hoods) and feet (gaiters) and that are to be worn during welding and allied processes

Appendix VII

SAMPLE TARGETED SAFETY PROGRAMMES

This appendix provides two examples of targeted safety programmes that have been implemented at nuclear facilities.

VII.1. MUSCULOSKELETAL DISORDER PREVENTION PROGRAMME

The following is an example of a targeted safety programme on MSD prevention, which resulted from performance trending showing a high prevalence of MSDs. The MSD prevention programme was a major initiative to achieve top quartile safety performance. Businesses completed actions defined in their MSD prevention implementation plans. To increase commitment and buy-in, company unions were invited to participate. Examples of initiatives to improve in this area include:

(a) An ergonomic change database to share ergonomic success stories across the businesses;
(b) MSD computer based training developed to raise awareness of the risk area and to educate employees on steps they can take to reduce the risk;
(c) An office ergonomics video to show employees how to adjust their workstation;
(d) Identifying activities leading to MSD incidents through reporting in the corporate incident management system database and on the corporate incident report form;
(e) MSD prevention safety communications, including a safety communication campaign with slide presentations, and monthly safety pauses;
(f) Issuing MSD governance;
(g) Incorporating MSD hazard awareness into pre-job briefings;
(h) Completing ergonomic assessments across the businesses;
(i) Establishing an MSD practitioner's team with representation from all the businesses, with corporate safety and business unit staff holding regular teleconference meetings.

VII.2. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN

Table 38 is an integrated sample falling object improvement plan status report used at a Ontario Power Generation. This is an example of a targeted safety programme, resulting from safety performance trending showing a high prevalence of incidents involving falling objects.

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT

Specific action	Accountability	Due date	Status
1. GENERAL			
Senior leadership develop lessons learned report. Development of business unit falling object improvement plans. Corporate safety review of falling object investigation reports as required. Falling object communication campaign (safety meeting package, video, safety pause, posters, corporate newsletter articles). Union involvement — joint working committee development of falling object inspection checklist for JHSCs.	1. Corporate safety to prepare briefings 2. Corporate safety 3. Business units 4. Businesses and corporate safety 5. Corporate safety		
Business 1			
Site 1			
1. Evaluate falling object issues at site based on historical data for the last ten years. Identify common issues related to falling objects (i.e. categories). Safety staff to retrieve historical data from the last ten years for falling objects and work protection. Include a summary of incidents and a graphical presentation. 2. Assign station staff to review data and identify gaps in our OSH managed system related to falling objects. Assign appropriate staff to evaluate the station's falling object issues. 3. Develop a workshop to assist station staff in reviewing falling object issues and to identify gaps in our managed system. Prepare and deliver a workshop to assist station staff in the process required to review and address gaps. 4. Assess falling object issues (categories) by assessing the four workplace elements (people, procedures, hardware and environment) for each category and to determine their impact, if any, on the residual risk to workers. Utilize the risk based information that was delivered to station staff to determine any gaps in the H&S managed system related to falling objects that may increase the residual risk to our workers. 5. Develop a corresponding action plan to address issues with residual risk based on the assessment process. Prepare and deliver a corrective action plan with deliverables and dates to the Plant Manager.			
Site 2			
1. JHSC inspection: Update monthly JHSC inspection packages to include Occupational Health and Safety Act requirements regarding lifting devices and rigging, ladders, scaffolds, barricades and signage for overhead work. Review JHSC inspection checklist with JHSC.	1. H&S advisors and JHSC		
Site 3			
1. There will be two falling object improvement opportunities selected and implement in the operations, maintenance and stores sections. These improvements will be highlighted in the safety meeting agenda to reinforce the information in the agenda that covered the falling objects subject area. 2. The participants in the JHSC workplace inspections will also be encouraged to focus on this hazard when they are undertaking their regulatory monthly workplace inspections.	1. Department managers 2. JHSC		
Business 2			
1. Governance: Revise and issue existing governance (non-intent change). 2. Determine need for self-assessment.			

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 3			
1. Governance: Review governance to ensure falling object issues raised in the trend report are addressed in the governance for safe work planning, housekeeping, manual material handling, and any other governance as applicable. 2. Obtain five year safety incident reporting of falling objects incidents and review effectiveness of lessons learned. 3. Rollout inspection checklist for JHSCs on falling objects.			
2. FOCUS AREA: DAMAGE OR FAILURE OF PLANT EQUIPMENT OR STRUCTURES (INCLUDES PREVENTION OF FALLING CONCRETE SPALLING RELATED TO COAL CONVEYOR SYSTEMS)			
Business 1			
1. Include the identification of the following potential issues during facility inspections: concrete spalling issues; potential failure of building cladding systems; and ice buildup areas (including snow and ice sliding risks). 2. Establish corrective actions to address identified deficiencies. 3. Conduct a review of rock fall management programmes for adequacy to eliminate or control falling rock hazards, and revise as necessary.	1. Plant group managers 2. Plant group managers 3. Plant group managers		
Business 2			
Site 1			
1. Implement engineered controls in the form of screening to minimize the hazard of spalling concrete. 2. Review and amend the tech spec and tender documents to include inspection and removal protocols for spalled concrete. 3. Amend wash-down protocols and frequencies to reduce the hazard of spalling concrete. 4. Develop preventative schedule for focused inspections of civil structures.	1. Engineering 2. Projects department 3. Engineering 4. Asset management and integration		
Site 2			
1. Review inspection protocol on building structures and facilities (including close up visual and testing) and revise as needed. 2. Establish work programmes and/or review current preventative maintenance programmes to correct identified deficiencies (metal cladding, concrete spalling, etc.) in a timely manner. 3. As preventative maintenance programmes are reviewed or created for equipment need to ensure areas that could cause a falling object from that equipment are identified and managed. 4. Establish a work practice that pre-inspection of equipment for loose parts that could fall is part of the JSA for operations/maintenance staff prior to its use or repair.			
Site 3			
1. Conduct annual inspections, maintenance notifications and condition assessments of powerhouse, administration, facilities buildings, equipment and the stack. 2. Daily observations and inspection of buildings and equipment. 3. Supervisory field visits. 4. Inspect and repair brickwork on the south powerhouse wall.	1. Engineering 2. Operations 3. All supervisors 4. Engineering		

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 2			
1. Contact facilities managers with regard to preventative maintenance on-site out buildings. 2. Check east complex non-occupied buildings for wind damage. 3. Check engineering service buildings/info centre for potential falling objects (e.g. cladding, roof edges and equipment). 4. Outbuilding preventative maintenance check of cladding/roof material/ equipment. 5. Confirm roof/cladding preventative maintenance frequency.	1. Tom F. 2. Gordon W. 3. Gordon W. 4. Civil maintenance section managers		
Business 3			
1. Focused facility inspections of condition of plant: infrastructure and bricks of sites. Inspections to identify concrete spalling issues, less than adequate metal cladding, potential ice buildup areas, potential rock falling areas, check for wind damage. This will be part of an ongoing routine annual inspection plan at each of the business unit owned buildings. 2. Establish work programme to correct identified deficiencies.			
3. FOCUS AREA: PROPER STORAGE AND HOUSEKEEPING OF TOOLS/EQUIPMENT AT HEIGHT			
Business 1			
1. Review housekeeping for items stored at height against guidelines in Appendix A of Falling Object Prevention and Protection, and take corrective action as appropriate. 2. Review adequacy of kickboards for permanent indoor railing systems against existing requirements and potential falling object hazards specific to each location; establish corrective actions to address deficiencies that are identified.	1. Plant group managers 2. Plant group managers		
Business 2			
Site 1			
1. Pre-outage safety kick-offs to be held with contractors and staff prior to each outage. 2. Creation of a detailed outage guide including falling object prevention. 3. Laydowns to be located on ground floor, where possible to reduce or eliminate the risk of falling objects. 4. Transportation of materials from laydown areas to heights only when necessary. 5. Initiation of an outage walkdown inspection schedule and post-outage walkdown. 6. Regular safety management audits and supervisory field visits to audit work areas for hazards. 7. Continue usage of last minute risk assessment process to determine and eliminate falling object hazards.	1. Outage manager 2. Outage manager 3. Outage manager 4. Management 5. Outage manager 6. Department managers and safety advisors 7. Contractors		

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Site 2			
1. Joint H&S inspections will consider storage and housekeeping of material that can fall from heights as an identified risk (i.e. use of falling objects checklist). 2. Create a falling objects team that will conduct inspections before, during and after outages to ensure falling object barriers are clearly established and maintained, and unauthorized storage areas are corrected. 3. Staging of material and material control are established to ensure material remains where it was placed (i.e. kickboards, guardrails, tethering, etc.). 4. Review housekeeping procedures for business and correct as necessary to ensure storage and housekeeping of tools/equipment at heights are identified.			
Site 3			
1. Job safety planning: hazards and controls of falling objects are always considered when creating JSAs for working at heights. 2. Tethered tools and floor coverings. 3. Identify overhead walkways and areas at risk of falling objects. 4. Screen handrails of high risk areas. 5. Contract completion: inspection of work area for parts, tools, etc.	1. All staff 2. All staff 3. Production/station managers 4. Production/station managers 5. Contract administrators and monitors	1. As required 2. As required 3. Q4 20XX 4. Q4 20XX 5. As required	
Business 3			
1. Attend scaffold crew meetings to review focused operations and conditions. 2. Review awareness of grab and twist (200% handoff) at crew meetings. 3. Ensure new contractors are aware of and following same requirements as scaffold crews.			
Business 4			
1. Perform site walkdown for hidden materials which could fall. 2. Perform housekeeping inspections for materials which could fall. 3. Safe work plans to include materials which could fall.		1. Ongoing 2. Ongoing 3. Ongoing	
4. FOCUS AREA: MANAGEMENT OF NEW OVERHEAD DOORS			
Business 1			
1. Prepare safety and issue communications targeted at staff involved in purchasing overhead doors, to reinforce the new engineering division governing documents on the purchase, installation and maintenance requirements for overhead doors in the business unit.			

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 2			
Site 1			
1. Project management lifecycle governance review and update to ensure that the purchase of overhead doors triggers the development of a quality plan with quality control and reliability protocols and each stage of the project life cycle as well as inspection and test plans. 2. Work practices in place that prohibit pedestrian traffic under operating overhead doors. 3. Confirm that proper signage is posted on all overhead doors to reduce hazard. 4. Review the engineering specifications for overhead doors prepared for applicability.			
Site 2			
1. Review the existing procedures for the installation of new overhead door installations. 2. Ensure this is identified as a high risk activity.	1. Engineering 2. Engineering		
Business 3			
1. Review of actions from overhead door action plan.			
Business 4			
1. Review procurement and installation process for new overhead doors, including owner only doors when transferred to OPG and doors purchased and installed by OPG. 2. Continue to implement the overhead door replacement programme: 3. All high risk doors are complete. Currently addressing medium and low risk overhead doors. 4. Review maintenance programmes for overhead doors.			
5. FOCUS AREA: CRANING AND RIGGING AND BEAM TROLLEYS			
Business 1			
1. Update inspection protocols for hoist beam trolleys, to ensure the inspection protocols include inspection of ‘end of rail stops’.	1. Plant group managers	1. 30 June 20XX	
Business 2			
Site 1			
1. Investigate the possibility of establishing a corporate wide standard for the use of beam trolley end stops. 2. Include consideration of beam trolley stops in the job safety planning process. 3. Ensure proper hoisting and rigging training for appropriate staff.	1. Station human resources manager in conjunction with corporate safety 2. All staff 3. Management		
Site 2			
1. Complete annual callups and notifications of hoisting and rigging equipment and cranes. 2. Review the management and maintenance of beam trolley stops.	1. Production supervisor: maintenance 2. Engineering and maintenance		

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 3			
1. Establish a standard for the use of beam trolley end stops specifying and will review current hoisting and rigging inspection checklists.			
6. FOCUS AREA: MATERIAL HANDLING TRANSPORTING MATERIAL WITH CARTS AND FORKLIFTS			
Business 1			
1. Conduct a local review of manual material handling push/pull carts soliciting input from end users and local engineering to assess the adequacy of each for the intended use of the device (e.g. design, load rating, wheels, condition, etc.). Label carts to indicate load rating and restrictions on use, where applicable. 2. Prepare and issue safety education materials (e.g. posters, bulletins, safety meeting materials, etc.) to reinforce the need to properly load, and secure loads on material handling devices, carts and forklifts.	1. Plant group managers 2. Larry S.		
Business 2			
Site 1			
1. Review the materials on material handling. Consider incorporating key learnings from these materials into our processes. 2. Ensure roll out of the corporate safety meeting package regarding falling object prevention.	1. H&S 2. H&S		
Site 2			
1. Load security is considered in creating the JSA prior to working at heights.	1. All staff	1. As required	
Site 3			
1. Develop a checklist to conduct material handling cart assessments (load ratings, condition assessments, tray lips, etc.) on an annual basis. 2. Ensure roll out of the corporate safety meeting package on falling objects reinforces the need to ensure secure loads on forklifts and material handling devices (content of material, size, weight, centre of gravity, travel route, etc.).			
Business 3			
1. Review use of carts for falling object prevention. Consider sides on carts to reduce risk of materials falling. Consider cart height to reduce musculoskeletal disorder risk for workers loading and unloading heavy/awkward materials. 2. Review material handling cart standards for applicability to business and make recommendations.			
7. COMMUNICATION AND TRAINING (INITIATIVES THAT ARE NOT IDENTIFIED ABOVE)			
1. Falling object communication campaign (safety meeting package, video, safety pause, posters, corporate newspaper articles and insert).	1. Corporate safety		

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 1			
Site 1			
1. Ensure roll out of the corporate safety meeting package regarding falling objects. 2. Ongoing communication to raise awareness of falling object hazards: tailboards, posters and signage.	1. Human resources 2. Human resources		
Site 2			
1. The safety topic for the May monthly safety meeting will include the corporate falling object slide presentation and a review of local procedures. 2. Incorporate new posters. 3. Orientation of new employees/temporary staff. 4. Conduct contractor orientations (include extensive information on this hazard). 5. Review the job safety planning checklist with all supervisors and workers at the May H&S meeting.	1. H&S advisors and Supervisors 2. H&S advisors 3. H&S advisors 4. Contract administrators 5. H&S advisors		
Site 3			
1. Develop a situation awareness training package for supervisors to deliver to staff. The session, with emphasis on falling objects, will address the higher level issue of staff failing to identify hazards and assess the residual risk associated with performing work. 2. Deliver training. 3. Ensure roll out of the corporate safety meeting package on falling objects reinforces the need to ensure secure loads on forklifts and material handling devices (content of material, size, weight, centre of gravity, travel route, etc.). 4. Distribute falling object posters throughout the plant. 5. As part of the corporate safety meeting falling objects roll out in June ensure need to control falling tools with appropriate techniques are emphasized (toe boards, fencing, tethering, barriers, exclusion zones, etc.).	1. All managers 2. All managers 3. All managers 4. All managers 5. All managers		
Site 4			
1. One safety meeting will be dedicated to raise the awareness of staff to the hazard of falling objects. 2. Securing loads in transit is included in the April safety meeting agenda. 3. The craning and rigging topic will be investigated to determine the availability of a four hour refresher training course for trade staff and to subsequently offer this refresher training for all staff at the Lennox site that are involved with hoisting.	1. Department managers 2. Department managers 3. Human Resources Manager		

TABLE 38. INTEGRATED FALLING OBJECT IMPROVEMENT PLAN STATUS REPORT (cont.)

Specific action	Accountability	Due date	Status
Business 2			
1. Communication plan: — Draft communication plan and send out for team member review; — Team to review and provide feedback; — Finalize communication plan. 2. Prepare safety meeting agenda item (safety basics use): check alignment with corporate communication plan HR-PLAN-08965.9. 3. Prepare safety pause (safety basics). 4. Think 3-D falling object poster. 5. Prepare questions and answers (if necessary). 6. Distribute appropriate communications on supervisor's toolkit, maintenance matters, manager's briefing card, etc. 7. Include in communication package the need to review same elevation dropped articles as part of falling objects initiative (same as foreign material exclusion).			
Business 3			
1. Preventing falling objects communication campaign rollout at upcoming safety meetings. 2. Continue to review all flash reports, Ministry of Labour blitz information, and safety pauses at direct report meetings and disseminate relevant information to staff. 3. Staff will continue with ongoing training and refresher training as required.			

Note: H&S — health and safety; JHSC — joint health and safety committee; JSA — job safety analysis; OPG — Ontario Power Generation; OSH — occupational safety and health.

Appendix VIII

SAMPLE OUTAGE RAPID TRENDING PROGRAMMES

As described in Section 6.6.15 an outage rapid trending programme can be used to help put focus on outage safety. Figures 76 and 77 are two pages of a trending card used at the Darlington nuclear power plant, in Ontario, during an outage in 2013.

Rapid Trending Card for D1321

Location:

Activity / Standard	Excel Comm	Met Std	AFI	Details
Body Mechanics (BDYM) (CSR 12.1)				
1. Structures in work location are not imposing an impact hazard or are identified as a hazard (i.e. low hanging, impeding access ways etc)				
2. Mechanical aids (i.e. lift assists) and/or proper techniques (i.e. push vs. pull) are used during manual handling tasks				
3. Appropriate practices used on stairwells (using handrail, taking one step at a time etc)				
4. Worker kneeling on hard surfaces with padding				
Chemical Control (CC) (N-INS-07080-10002, N-INS-01806-10000)				
1. Chemicals stored properly (i.e. flammables and corrosives stored in appropriate cabinets)				
2. All Chemicals (including decanted) are properly WHMIS labeled				
3. Chemistry colour indicated on label (inventory label, WHMIS work place label or chemistry colour sticker)				
Confined Spaces (CS) (N-INS-08965-10020)				
1. Confined space entry monitor is present while confined space is open				
2. Air samples are taken, as required, when confined space is open				
3. Barriers are in place when confined space is closed				
Electrical Hazards (ELE) (N-INS-08965-10021)				
1. Correct electrical PPE is worn for the task				
2. An electrical exclusion boundary has been set-up as required				
3. Personnel performing electrical work are not wearing conductive jewelry				
4. Test before Touch method is utilized where required				
FME (FME) (N-INS-09106-10001, N-PROC-MA-0018)				
1. FME material (pink sheeting, tool lanyards etc) is appropriately used				
2. FME area has appropriate signs & barriers				
Falling Object Hazards (FO) (N-INS-08965-10035)				
1. Materials staged over grating/beside handrails have falling object controls in place (i.e. plywood, blue sheeting etc)				
2. Safe work area is setup below areas where overhead work is being performed				
3. Tools are secured and toe boards/kick plates are installed while working from elevated work platforms/scaffolding				
Fire Protection (FP) (N-PROC-RA-0057)				
1. Emergency equipment/routes are accessible (extinguishers, eyewash stations etc)				
2. Hot work area correctly established				
Hand Safety Hazards (HAND) (N-PROC-HR-0012, N-MAN-08965-10000 Sheet A14.1)				
1. While performing hands-on work, the correct gloves are being worn				
2. Staff avoiding pinch hazards while transporting loads				
Hoisting & Rigging (HOIST & RIG) (Hoisting & Rigging Handbook)				
1. Engineered lifting scaffold tag has inspector's signature & Working Load Limit for scaffolds greater than 500lbs				
2. Equipment is marked with current inspection color &/or tag **(2013= BLUE)**				
3. Rigging equipment is in good condition				

Excel Comm – Excellence Commended
Met Std – Meets Standard
AFI – Area for Improvement

FIG. 76. Ontario Power Generation Darlington outage rapid trending card form: page 1 of 2 (courtesy of Ontario Power Generation).

Rapid Trending Card for D1321

Location:

Activity / Standard	Excel Comm	Met Std	AFI	Details
Human Performance (HP) (N-PROG-AS-0002)				
1. 3-way Communication				
2. Correct Component Verification				
3. Pre-Job Brief, Post-Job Debrief				
4. Procedure Use and Adherence (i.e. type, current revision etc)				
5. Self Check/Peer Check				
6. 2 Minute Drill / Situational Awareness				
7. Use of Safety Basics				
Material Handling				
1. Is cart stenciled with load rating and not overloaded				
2. Is cart the correct cart to transport the material				
3. Is load affixed / secured properly				
4. Was travel path reviewed for hazards				
Operation of In Plant/Off Road Vehicles (VEHICLE) (N-INS-08965-10001)				
1. Vehicles are operated safely (i.e. slow, pedestrian right of way, sound horn etc) and loads are secured				
Radiation Hazards (RAD HAZARD) (N-PROC-RA-0024)				
1. Radioactive materials are appropriately labeled				
2. Rooms with radiation hazards are identified and signed (i.e. rad level, date etc)				
Radioactive Waste Minimization (RAD WASTE) (N-PROC-RA-0017)				
1. Waste properly bagged/identified (Likely Clean, Rad Waste)				
Radiation Worker Practices (RAD WORKER) (N-PROG-RA-0013)				
1. Personnel dress, undress and wear RPPE correctly				
2. Worker knows REP and back out limits/conditions				
Signs & Barriers (SIGNS BARRIERS) (N-INS-08965-10013)				
1. Work area is signed appropriately (i.e. hazard identified, contact names etc)				
2. Work area has barriers surrounding entire perimeter				
Slips & Trips				
1. Material in pathway creating hazard (eg. Breathing Air Hoses)				
Spill Management (SM) (N-STD-OP-0026)				
1. Spill containment is installed and is correct size to contain liquids				
2. Dyke integrity is maintained (i.e. walls are erected, plywood under dyke when staged on grating etc)				
3. Spill materials are readily available (i.e. kits, socks etc), drain covers are in place, and there is no risk of chemicals/oils to be exposed to the environment				
4. Spill socks are used for proper application (yellow – chemicals, blue – oils)				
Working at Heights (WKH) (CSR 2.0 & N-INS-08960-10001)				
1. Fall arrest/travel restraint inspected, worn correctly and affixed to approved anchor points				
2. Ladders are properly secured and personnel maintain 3 point contact				
3. Scaffold has in-date inspection tags, hazards identified and contains guardrails/swing gates				
Work Protection (WP) (N-PROC-MA-0012)				
1. Equipment isolated, de-energized and locked out for the specified work				
2. PPT properly used				
3. Safe work area and isolated equipment has been identified				
4. Documentation (AWPP, AIP) is adequate to perform task				

Excel Comm – Excellence Commended
Met Std – Meets Standard
AFI – Area for Improvement

FIG. 77. Ontario Power Generation Darlington outage rapid trending card form: page 2 of 2 (courtesy of Ontario Power Generation).

Appendix IX

SAMPLE OCCUPATIONAL SAFETY AND HEALTH CULTURE PERCEPTION SURVEY

Table 39 provides sample topic areas and statements for an OSH culture perception survey. Some of the statements are worded in a positive manner (i.e. a good safety practice or condition) and some in a negative manner (i.e. a poor safety practice or condition). Organizations can adapt the questions as necessary for their own purposes. Responses collected would normally be in the form of a selection of level of agreement with the statement given (e.g. strongly disagree, disagree, somewhat agree, agree or strongly agree), with an opportunity for individual comments. A similar survey that uses a four category response (with no 'somewhat agree' category included) is also available in the Nordic Occupational Safety Climate Questionnaire (NOSACQ-50), and its questions are included in Table 39. Results from such a survey are typically analysed in some detail by work group and demographic (e.g. age, gender and years with company). Topic areas are reviewed at a high level to see where major performance gaps may be (areas to focus on going forwards) and individual questions and comments are reviewed for specific issues that may need to be addressed (see Fig. 8, Section 2.5.1, for a sample analysis by topic area).

TABLE 39. SAMPLE TOPIC AREAS AND STATEMENTS FOR AN OCCUPATIONAL SAFETY AND HEALTH CULTURE PERCEPTION SURVEY

Topic area	Sample statements
Management safety priority and ability	Management encourages employees here to work in accordance with safety rules, even when the work schedule is tight. Management ensures that everyone receives the necessary information on safety. Management places safety before production. We have confidence in management's ability to deal with safety. Management ensures that safety problems discovered during safety rounds/evaluations are corrected immediately. Management looks the other way when someone is careless with safety. Management accepts employees here taking risks when the work schedule is tight. When a risk is detected, management ignores it without action. Management lacks the ability to deal with safety properly. I am provided with the safety training I need to do my job. When I visit a new facility or am given a new task, I am aware of the hazards I will face and how to protect myself. We improve safety by openly identifying safety issues, reporting events, investigating and taking timely corrective action. I would be comfortable calling my supervisor in the middle of the night or on weekends for advice if I felt I was unsure of a safety issue at a field location. My direct supervisor is committed to safety. The resources we have show that safety is the top priority. Resolution of conflicts between safety and production shows that safety is the top priority. My direct supervisor communicates effectively about safety. There are adequate safety resources (training, personal protective equipment, tools, etc.) to perform our work safely. We improve safety by investigating past complaints and taking corrective action in a timely manner. My supervisor ensures that I am clear on my safety responsibilities. My direct supervisor demonstrates good safety leadership and behaviours. I am familiar with safety precautions my staff need to take when performing their jobs. My direct supervisor understands the conditions I work under. If I raise a safety concern, I am confident that my supervisor and management will take it seriously. My supervisor regularly asks me questions about the safety practices at locations to which I have travel. My supervisor regularly directly observes my work activities and provides safety coaching as necessary.
Management safety empowerment	Management strives to design safety routines that are meaningful and actually work. Management makes sure that everyone can influence safety in their work environment. Management encourages employees here to participate in decisions which affect their safety. Management never considers employees' suggestions regarding safety. Management strives for everybody at the worksite to have high competence concerning safety and risks. Management never asks employees for their opinions before making decisions with regard to safety. Management involves employees in decisions regarding safety. Before given a new assignment, my supervisor discusses the safety aspects of the work and what to do when I am unsure of how to proceed. It is easy to report safety events. When I started my current job, I was given adequate safety training on hazards and situations I would face. I am encouraged to bring forwards my ideas of new ways to do our work safer.

TABLE 39. SAMPLE TOPIC AREAS AND STATEMENTS FOR AN OCCUPATIONAL SAFETY AND HEALTH CULTURE PERCEPTION SURVEY (cont.)

Topic area	Sample statements
Management safety justice	Management collects accurate information in accident investigations. Fear of sanctions (negative consequences) from management discourages employees here from reporting near miss accidents. Management listens carefully to all who have been involved in an accident. Management looks for causes, not guilty persons, when an accident occurs. Management always blames employees for accidents. Management treats employees involved in an accident fairly. People in my organization are treated with respect. When a safety issue or incident occurs, our organization initiates lessons learned or investigations and makes changes when necessary. I feel free to report mistakes. I feel free to raise questions about safety conditions of which I am uncertain.
Workers' safety commitment	We try hard together to achieve a high level of safety. We take joint responsibility to ensure that the workplace is always kept tidy. We do not care about each other's safety. We avoid tackling risks that are discovered. We help each other to work safely. We take no responsibility for each other's safety. People on my team accept ownership for occupational safety and health. I believe that I model the right safety behaviours and leadership skills to my team. Everybody in my team follows safety procedures. People on my team encourage each other to work safely.
Workers' safety priority and risk non-acceptance	We regard risks as unavoidable. We consider minor accidents to be a normal part of our daily work. We accept dangerous behaviour as long as there are no accidents. We break safety rules in order to complete work on time. We never accept risk taking even if the work schedule is tight. We consider that our work is unsuitable for cowards. We accept risk taking at work. I encourage quick action on safety concerns when they are raised. I never need to cut corners with respect to safety to get my work done. People on my team always follow safety rules.
Peer safety communication learning, and trust in safety ability	We try to find a solution if someone points out a safety problem. We feel safe when working together. We have great trust in each other's ability to ensure safety. We learn from our experiences to prevent accidents. We take each other's opinions and suggestions concerning safety seriously. We seldom talk about safety. We always discuss safety issues when such issues come up. We can talk freely and openly about safety. My team regularly discusses safety at team meetings. I would be surprised if someone on my team is seriously hurt on the job in the next year.

TABLE 39. SAMPLE TOPIC AREAS AND STATEMENTS FOR AN OCCUPATIONAL SAFETY AND HEALTH CULTURE PERCEPTION SURVEY (cont.)

Topic area	Sample statements
Workers' trust in efficacy of safety systems	We consider that a good safety representative plays an important role in preventing accidents. We consider that safety rounds/evaluations have no effect on safety. We consider safety training to be good for preventing accidents. We consider early planning for safety as meaningless. We consider that safety rounds/evaluations help find serious hazards. We consider safety training to be meaningless. We consider it important to have clear-cut goals for safety. We use performance indicators to help us improve safety. The quality of safety rules, procedures and safe work planning is very high. I was frightened for my personal safety on the job at least once over the past year. I understand where our team is having the most near misses or accidents. I know if our safety performance is getting better or worse.

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Annex I

HAZARD RISK ASSESSMENT TOOLS

I–1. ONTARIO POWER GENERATION RISK ASSESSMENT TOOLKIT

Ontario Power Generation has developed a number of tools for risk assessment targeted at specific sites or the corporation as a whole. There are forms for filling out manually as well as an on-line corporate wide web based tool. The tools assess and provide ratings for consequence severity, likelihood, exposure factors, barrier effectiveness, and probability and then calculate a risk score on a scale of 1–10 for each potential hazard. Definitions and calculation methods are described below in Table I–1, and a worked example is provided in Table I–2 and Fig. I–1.

TABLE I–1. DEFINITIONS APPLIED TO THE ONTARIO POWER GENERATION RISK ASSESSMENT TOOL

Consequence severity rating (worst credible)		
0 = minimal (no medical attention)		
1 = minor (minor injury causing medical attention)		
2 = moderate (e.g. cut, crushed finger, lost time injury)		
3 = serious (serious injury)		
4 = extreme (total disability)		
5 = fatality		
Likelihood rating		
0 = very unlikely (once in every 300 person years of this activity)		
1 = unlikely (once in every 30 person years of this activity)		
2 = somewhat likely (once in every 3 person years of this activity)		
3 = very likely (once in every 1/3 person year of this activity)		
Exposure factor (person days per year)		
1–9 = Score of 0		
10–99 = Score of 1		
100–999 = Score of 2		
1000–9999 = Score of 3		
Barrier category value/weighting	Barrier type	Barrier effectiveness rating
A = 3	Very strong barrier (e.g. engineering design to eliminate or control hazard)	3 = very low (barrier category sum 0–2.5)
B = 3	Subset of engineering controls, design to minimize exposure to hazards, hazard continually monitored	2 = low (barrier category sum 3–5.5)
C = 2	Personal protective equipment, specialized tools	1 = medium (barrier category sum 6–8.5)
D = 1	Awareness mechanisms, hazard periodically monitored	0 = high (barrier category sum 9–10)
E = 0.5	Rules, procedures, instructions, drawings, warning devices	
F = 0.5	Effective training, qualifications, experience, supervision, situational awareness	
Weighted sum of all barrier categories (0–10 max.) is applied to determine barrier effectiveness value (i.e. 3 × A + 3 × B + 2 × C + D + 0.5 × E + 0.5 × F), which is converted to a rating on a scale of 1–3 per the right side column above		
Probability = Exposure factor score + Likelihood rating + Barrier effectiveness rating		
Risk = Probability + Consequence severity rating		

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Weather	4	0	3	3	3	2	1	0.5	0.5	10	0	3	7	Re-schedule/stop work Bring the work indoors Access to cool water Bring water to remote site as required Access to cooler rest area Access to heated rest area Skin protection (ultraviolet protective) Thermal clothing Monitor weather
Biological: Facility related	1	0	3	0	0	2	1	0.5	0.5	4	2	5	6	Respiratory protection and protection Insect repellent Skin protection Rules and procedures Guidelines Safe work planning Pre-job briefings Equipment inspection and maintenance Housekeeping Waste management
Biological: Exposure to bacteria/virus/ disease	1	0	3	0	3	2	0	0.5	0.5	6	1	4	5	Bug zappers Insect repellent Respiratory protection Skin protection Hand protection Rules and procedures Guidelines Safe work planning Pre-job briefings Education Situational awareness
Biological: Exposure to wildlife	1	1	3	0	3	0	1	0.5	0.5	5	2	6	7	Animal deterrent programmes: bird squawker, bear bangers, bird dog programme, pigeon programme Warning signs Guidelines Safe work planning Pre-job briefings Education Situational awareness

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Body mechanics: Office related musculoskeletal disorders	1	0	4	0	3	2	0	0.5	0.5	6	1	5	6	Workstation layout Mechanical lifting aids Ergonomic workstation equipment/ accessories Adjustable seating Guidelines Proper technique Workstation assessment tools Housekeeping Equipment inspection
Body mechanics: Industrial related musculoskeletal disorders	1	1	4	0	3	0	1	0.5	0.5	5	2	7	8	Use of carrying aids/devices/lift assists Load weight labels Guidelines Occupational Health and Safety Act and regulations Work instructions Safe work planning Pre-job briefings Use of lighter loads Additional workers
Chemical: Confined space	5	0	2	3	3	2	1	0.5	0.5	10	0	2	7	Isolation/blanking Ventilate/purge/drain Access control Pre-entry and ongoing atmosphere tests Respiratory protection Respirator fit testing Rescue personal protective equipment Warning signs Audible alarms Visible alarms (e.g. strobe lights)
Chemical: Hazardous materials	1	1	4	3	3	2	1	0.5	0.5	10	0	5	6	Substitution for safe materials Engineering conveyance systems Substitute safer product Designated safe storage Segregation of chemicals Safety containers Decrease exposed combustibles Fire detection/suppression Grounding/bonding

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Chemical: Asbestos exposure	4	0	1	3	3	2	1	0.5	0.5	10	0	1	5	Substitution for safer materials Encapsulation Respiratory protection Respirator fit testing Warning tapes e.g. safe work area Warning signs Labelling Inventory Inspections Occupational Health and Safety Act and regulations Rules and procedures
Chemical: Exposure to other designated substances	4	0	2	3	3	2	1	0.5	0.5	10	0	2	6	Substitution for safer materials Encapsulation Respiratory protection Hand protection Skin protection Warning signs Labelling Musculoskeletal disorders Inventory Occupational Health and Safety Act and regulations Rules and procedures Guidelines Safe work planning
Chemical: On or near water	5	0	2	3	3	2	1	0.5	0.5	10	0	2	7	Dewater the area Work protection to prevent water entry Physical barrier i.e. guardrails Life jacket Fall arrest/travel restraint Personal flotation device Warning signs Audible alarms Visible alarms (e.g. strobe lights)
Electrical: On or near electrical > 300 V	5	0	3	3	3	2	1	0.5	0.5	10	0	3	8	Application of work protection code Interlocks Safe work area Configuration management Ground fault circuit interrupter Arc flash resistant equipment Physical barriers Equipment maintenance Ground mats Grounding/bonding Engineer approved apparatus Visible alarms

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Electrical: On or near electrical < 300 V	3	0	3	3	3	2	1	0.5	0.5	10	0	3	6	Application of work protection code Safe work area Interlocks Configuration management Ground fault circuit interrupter Arc flash resistant equipment Physical barriers Equipment maintenance Equipment calibration Rubber blankets and cover-up Ground mats
Gravitational: Falling objects	3	1	3	3	3	2	1	0.5	0.5	10	0	4	7	Bring work to ground level Secure objects at height Minimize materials/tools used at height Tool tethers/material lanyards Containment sheeting, covered openings, kickboards Head protection Warning signs Warning tapes
Gravitational: At heights > 3 m	5	0	3	0	3	2	1	0.5	0.5	7	1	4	9	Approved scaffold Approved elevated work platform Physical barriers such as guardrails, covered openings Occupational Health and Safety Act and regulations Rules and procedures Standards Work instructions Schematics and drawings Safe work planning
Gravitational: At heights ≤ 3 m	1	0	3	0	3	0	1	0.5	0.5	5	2	5	6	Physical barriers such as guardrails, covered openings Warning tapes (e.g. safe work area) Occupational Health and Safety Act and regulations Rules and procedures Work instructions Safe work planning Pre-job briefings Equipment inspection and maintenance

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Gravitational: Same level	1	1	4	0	3	2	1	0.5	0.5	7	1	6	7	Slip resistant surfaces Footwear selection Warning signs Paint indicators for level changes Rules and procedures Occupational Health and Safety Act and regulations Work instructions Safe work planning Pre-job briefings
Mechanical: Contact with sharp objects	1	1	3	3	3	2	1	0.5	0.5	10	0	4	5	Design (e.g. smooth edges) Equipment guards, enclosures Hand protection Skin protection Hand tool selection Warning tapes (e.g. safe work area) Occupational Health and Safety Act and regulations Rules and procedures Work instructions Safe work planning
Mechanical: Contact with buried or hidden services	3	0	2	3	3	2	1	0.5	0.5	10	0	2	5	Isolation and de-energizing of energy sources Scanning/buried service locate Equipment grounded Shoring/walls sloped Barriers (e.g. hoarding) Physical barriers/guardrails or covers Dielectric personal protective equipment (gloves, footwear)
Mechanical: Craning, hoisting and rigging	5	0	2	3	3	2	1	0.5	0.5	10	0	2	7	Lockout tagout Load secure/stable and within equipment capacity Load charts Type of operation, remote or cab Hardware condition/suitability Tagline use Communication systems Electrical apparatus cover-up Vehicle grounded Outriggers Boom angle indicators

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Mechanical: Driving (off road)	4	0	2	0	3	2	1	0.5	0.5	7	1	3	7	Equipment suitability Load secure/stable and within equipment capacity Communication systems Roll-over protection High visibility personal protective equipment Warning signs Occupational Health and Safety Act and regulations Rules and procedures Safe work planning Pre-job briefing
Mechanical: Driving (on road)	4	1	3	3	3	0	1	0.5	0.5	8	1	5	9	Vehicle standards Vehicle maintenance Audible alarms Visible alarms (e.g. strobe lights) Occupational Health and Safety Act and regulations Rules and procedures Work instructions Safe work planning Pre-job briefings Effective communications
Mechanical: Object in eye	1	1	3	0	3	2	1	0.5	0.5	7	1	5	6	Dust control vacuum systems Wetting to reduce dust Warning signs Warning tapes (e.g. safe work area) Occupational Health and Safety Act and regulations Rules and procedures Work instructions Safe work planning Pre-job briefings Effective communications
Mechanical: Rotating or moving parts	4	0	3	3	3	0	1	0.5	0.5	8	1	4	8	Isolation/de-energization Access control to rotating apparatus Power tools/guards Operating machinery/guards Warning signs Warning tapes (e.g. safe work area) Audible alarms Visible alarms (e.g. strobe lights) Occupational Health and Safety Act and regulations

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Mechanical: Struck by flying object	3	0	2	0	3	2	1	0.5	0.5	7	1	3	6	Work configuration Equipment guards and shielding Physical barriers between worker and hazard Face shields/eye protection Warning signs Warning tapes (e.g. safe work area) Occupational Health and Safety Act and regulations Rules and procedures
Mechanical: Struck or crushed by	4	0	2	0	3	2	1	0.5	0.5	7	1	3	7	Equipment selection appropriate for work loads Warning signs Warning tapes (e.g. safe work area) Audible alarms Visible alarms (e.g. strobe lights) Flashing lights Signs/cones Barrier tape Guard rails Occupational Health and Safety Act and regulations
Noise	2	1	3	3	3	2	1	0.5	0.5	10	0	4	6	Design to reduce noise Vibration/shock dampers Insulation/noise dampers Hearing protection Noise warning signs Occupational Health and Safety Act and regulations Rules and procedures Guidelines Standards Work instructions Safe work planning
Pressure: Compressed, pressurized fluid/gas	4	0	3	3	3	2	1	0.5	0.5	10	0	3	7	Isolate/de-energize Substitution Vent/drain Ventilate/drain/purge Segregation of incompatibles Cylinders capped if not in use Compatible valves/fixtures Ventilation Leak tests performed Barriers and warning signs

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Psychosocial hazards: Personal	2	1	3	0	0	0	1	0.5	0.5	2	3	7	9	Peer monitoring and reporting Occupational Health and Safety Act and regulations Rules and procedures Policies Work rest cycles Shift work strategies Harassment and violence in the workplace legislation, policies and procedures Confidentiality
Public safety: Impact of public on OPG employees	0	1	1	0	3	2	1	0.5	0.5	7	1	3	3	Access control (fences/gates/locks etc.) Security cameras Communication systems Emergency phones/alerts devices Warning signs Audible alarms Visible alarms (e.g. strobe lights) Rules and procedures Work instructions
Radiation: Ionizing radiation (not covered by nuclear radiation protection)	1	0	1	0	3	2	1	0.5	0.5	7	1	2	3	Minimize exposure duration Eye/skin protection Shielding Cover-up Dosimeters Warning signs Detectors or sensors Occupational Health and Safety Act and regulations Rules and procedures Standards Guidelines Work instructions Safe work plans

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Radiation: Non-ionizing radiation	1	1	3	0	3	2	1	0.5	0.5	7	1	5	6	Minimize exposure duration Eye/skin protection Shielding Cover-up Warning tapes (e.g. safe work area) Warning signs Occupational Health and Safety Act and regulations Rules and procedures Standards Guidelines Work instructions Safe work plan
Thermal: Contact with hot objects	3	1	2	0	3	2	1	0.5	0.5	7	1	4	7	Access control to hot work zone Welding curtains Barriers/guards Welding helmet and visor, gloves, apron and clothing Warning tapes (e.g. safe work area) Signage for hot/cold objects or surfaces
Thermal: Cryogenic hazards	3	0	1	0	3	2	1	0.5	0.5	7	1	2	5	Container design Skin protection Warning tapes (e.g. safe work area) Signs Musculoskeletal disorders Effective communications (devices, procedures) Pre-job briefings Safe work planning Work instructions Rules and procedures Occupational Health and Safety Act and regulations
Thermal: Extreme heat	1	0	2	3	3	2	1	0.5	0.5	10	0	2	3	Stop or re-schedule work Air conditioning Increase ventilation Access to cooler rest area Use of appropriate clothing, personal protective equipment, sunscreen, etc. Weather information/warnings Monitor weather (e.g. wind, lightning, etc.) Occupational Health and Safety Act and regulations

TABLE I–2. EXAMPLE RISK ASSESSMENT TOOL WORKSHEET (cont.)

Hazard topic	Consequence severity rating (0–5)	Likelihood rating (0–3)	Exposure factor	Barrier A effectiveness	Barrier B effectiveness	Barrier C effectiveness	Barrier D effectiveness	Barrier E effectiveness	Barrier F effectiveness	Barrier effectiveness value (0–10)	Barrier effectiveness rating (0–3)	Probability	Risk	Effectiveness notes (existing barriers)
Thermal: Extreme cold	1	1	3	3	3	2	1	0.5	0.5	10	0	4	5	Timing of work to avoid extreme weather Shelters Access to warm rest area Thermal suits Thermometers Wind chill information Weather information and warnings Occupational Health and Safety Act and regulations Rules and procedures Guidelines Safe work planning
Electromagnetic: Electromagnetic fields	0	0	0	0	0	0	1	0.5	0.5	2	3	3	3	Warning signs Occupational Health and Safety Act and regulations Guidelines Awareness education Situational awareness Work experience On the job mentoring

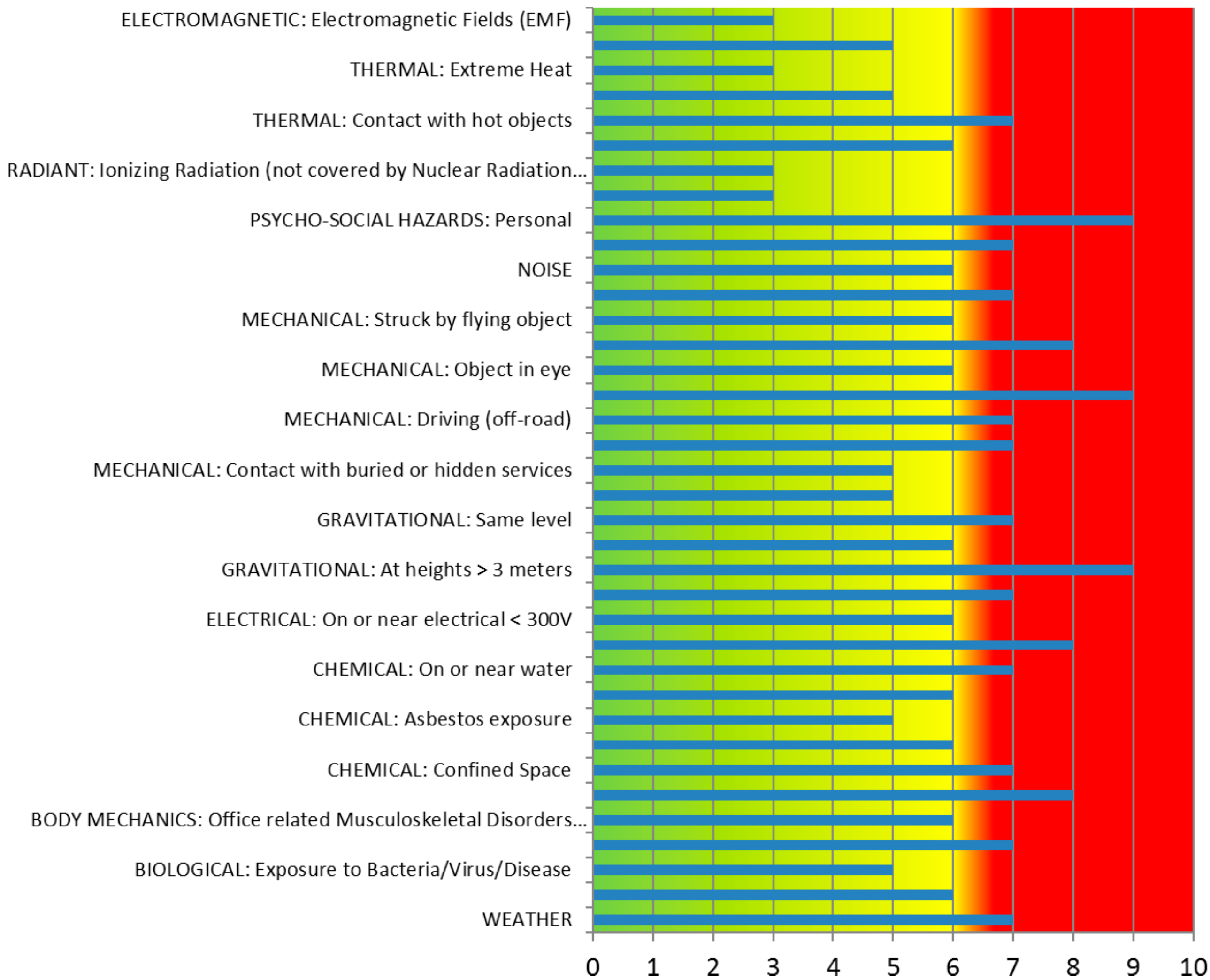

FIG. I–1. Summary of risk ranking (e.g. Table I–2).

Annex II

IAEA 2015 INDUSTRIAL SAFETY SURVEY

Annex II documents the results of a survey sent by the IAEA to a general audience of worldwide nuclear professionals prior to a November 2015 Technical Meeting on industrial safety management at nuclear facilities. The survey was designed to seek information on current occupational safety and health (OSH) practices and trends within the nuclear industry. It was distributed to all subscribers to the IAEA Nuclear Engineering electronic newsletter, and informally to other known industry contacts via the IAEA industrial safety team that worked on this publication, and via other IAEA staff members. Of the 80 responses received, 48 provided specific location information (see Fig. II–1). Analysis of IP addresses of the remaining respondents shows a potential, slight increase in the weighting for European respondents, (impact would be to raise Europe to 52% of the sample size from 48%), a slight lowering for North America (29%), and slight increases for most other remaining regions (increases for Asia to 10%, Africa to 5%, Middle East to 3%, and South America lowered to 1%).

Twenty-two respondents (56%) were in an OSH related role at an operating nuclear power plant, 7 (18%) were at other nuclear facilities, with the next largest answer (10%) being in an engineering role at a nuclear power plant. Responses were also received from non-plant engineering staff, regulators and suppliers.

II–1. MANAGEMENT SYSTEMS AND ORGANIZATION

II–1.1. Management system standards applied

The question was on what management system standards are applied relating to industrial safety at the respondent's facility. Responses are shown in Fig. II–2 and Table II–1. The most common response was the OHSAS 18000 series standard (30 of 77 responses, 39%). Answers given in the 'other' category included a number of country or organization specific laws or regulations.

II–1.2. Industrial safety regulator

The question was on the regulation of OSH at the respondent's facility. Of the 76 respondents over 71% indicated that there was a separate non-nuclear regulator (e.g. labour ministry and OSH authority) in place that had jurisdiction over the facility in this area. Eighteen respondents (24%) indicated that the nuclear regulator had jurisdiction over both areas, while four respondents indicated that there was no specific industrial safety regulator in place for the facility.

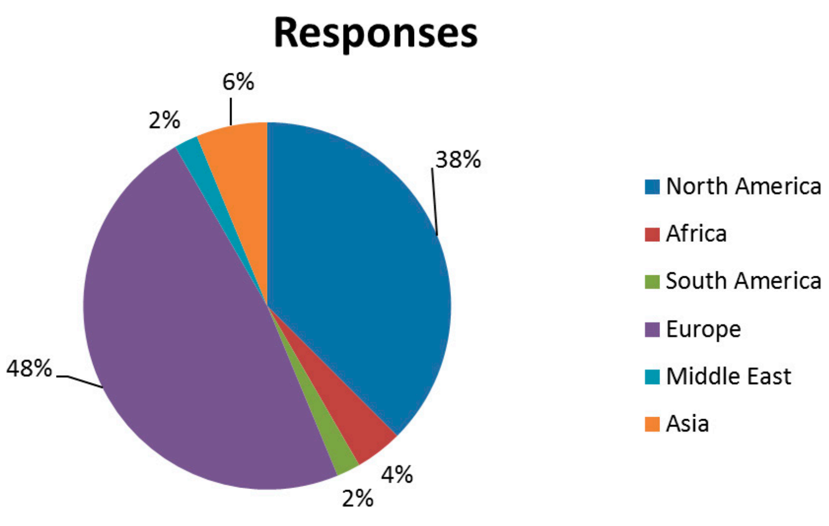

FIG. II–1. Responses by country for industrial safety survey.

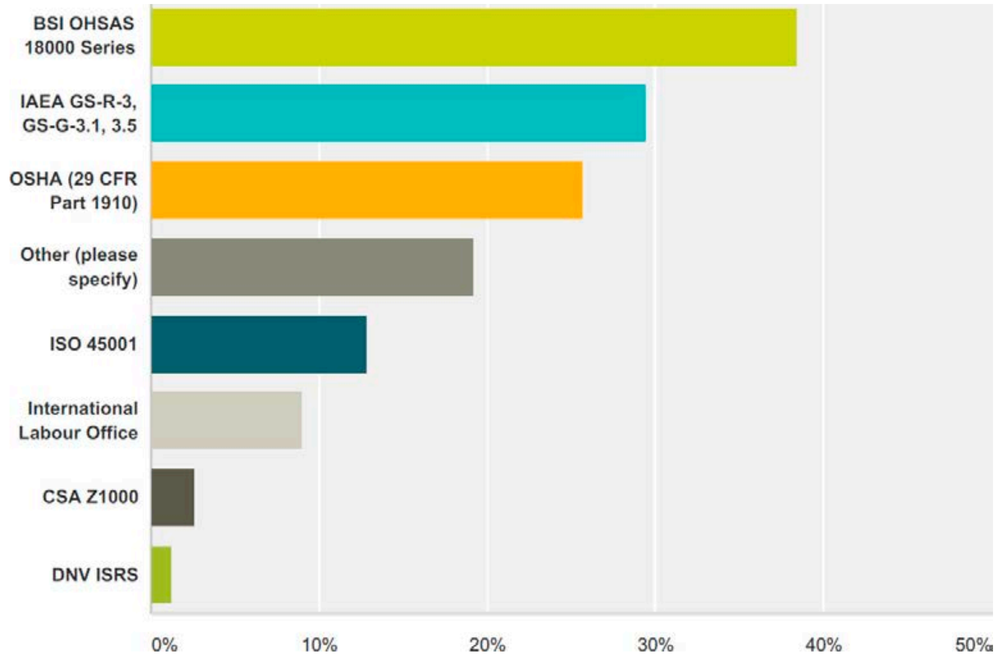

FIG. II–2. Industrial safety management system standards in use.

TABLE II–1. RESPONSE DETAILS FOR MANAGEMENT SYSTEM STANDARDS IN USE

Standard	Per cent	No. of responses
BSI OHSAS 18000 Series	38.96	30
GS-R-3* GS-G-3.1 [II–2] GS-G-3.5 [II–3]	29.87	23
OSHA (29 CFR Part 1910) [II–4]	25.97	20
Other	19.48	15
ISO 45001	11.69	9
International Labour Office	9.09	7
CSA Z1000 [II–5]	2.60	2
DNV ISRS [II–6]	1.30	1

* GS-R-3, The Management System for facilities and activities has since been superseded by GSR Part 2 [II–1].

II–1.3. Separate organizations to deal with industrial and radiological safety issues

The question was on the organization of industrial safety support organizations at a facility level. Of the 75 respondents, 63 (84%) indicated that their facility had separate organizations to deal with industrial safety and radiological safety issues. Twelve (16%) indicated that a common organization was used.

II–1.4. Specialized occupational safety related software

The question was on the use of software to help manage the respondent's OSH programme at their facility. Of the 66 respondents, 11 (17%) indicated that their facility used commercial OSH software, 21 (32%) indicated that they used custom software specific to industrial safety, 22 (33%) indicated that they used primarily their site's common corrective action programme software, while 12 (18%) indicated that their site used no software at all (see Fig. II–3). There thus appears to be significant scope for increased use of OSH software tools to assist nuclear industry programmes.

II–1.5. Q15: Full time safety director

The question was about whether there was a full time safety director or similar position at the respondent's facility. Of the 56 respondents, 42 (75%) indicated one was in place, while 14 (25%) indicated there was not.

II–1.6. Safety policy

The question was about whether there was a documented safety policy at the respondent's facility. Almost all respondents (94%) indicated that there was such a policy. When asked when the safety policy was last revised, of 53 respondents, 26 (49%) indicated that it had been revised within the last year, and 19 (36%) indicated that it had been revised within the last three years. Training on such policies was generally in line with the revision cycle. Of the 54 respondents, 29 (54%) indicated that they had been trained on the policy within the last year, and 14 (26%) indicated that they had been trained on the policy within the last three years.

II–2. OPERATING EXPERIENCE AND BENCHMARKING

II–2.1. Sharing and gathering of industrial safety audit findings

The question was about whether the respondent's company shared industrial safety audits or audit findings with other outside companies or organizations. Approximately half of the 59 respondents (31, 53%) said they did so. A greater number (37, 63%) indicated that they gather information from industrial safety audits or audit findings from other outside companies or organizations.

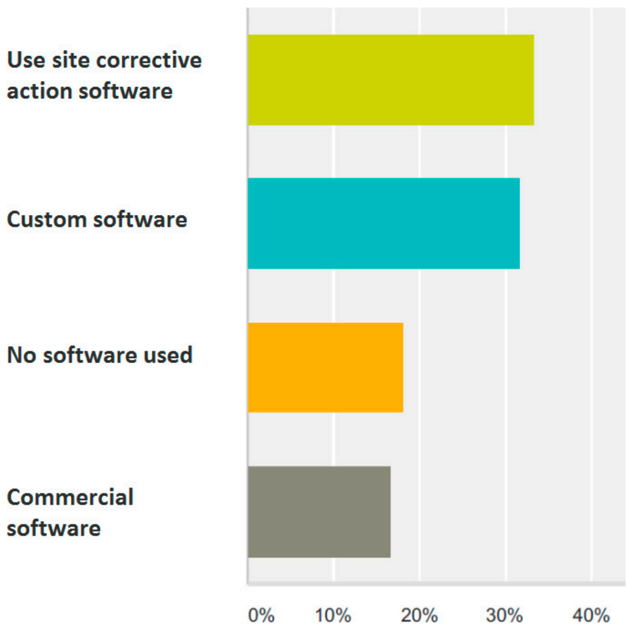

FIG. II–3. Occupational safety and health software use.

II–2.2. Benchmarking activities

The question was about whether the respondent's company benchmarked their safety performance against outside industry. Benchmarking was relatively common within one's own fleet (34 of 58 respondents, 59%) or the broader nuclear industry (35, 60%), but less so with external non-nuclear generators and external construction companies (all less than 25%). There is thus an opportunity for nuclear companies to gather valuable lessons by implementing a wider scope of benchmarking activities (see Fig. II–4).

II–2.3. Use of external industry databases

The question was about whether the respondent's company obtained safety data from external industry databases. Only 17 of 47 respondents (36%) indicated that they did so. It is unclear if this is a result of a lack of available information or lack of knowledge as to how to access such information.

II–2.4. Incident tracking

Respondents were asked to indicate what types of industrial safety related incidents, events and statistics they keep track of (see Table II–2).

II–2.5. Formal investigations of incidents

Respondents reported that they formally investigate incidents as shown in Fig. II–5. A majority (40 of 59 respondents, 68%) indicated that they investigate all reported incidents, with slightly lower numbers for just recordable accidents (38, 64%) and lost time accidents (37, 63%). Near misses were formally investigated by 27 respondents' companies (46%).

II–2.6. Formal process for evaluating internal organization safety performance

Respondents reported that a strong majority of their companies (37 of 51 respondents, 73%) have a formal process for evaluating the safety performance of their internal organizations. The remaining responses (14) were split evenly between 'no' and 'don't know' responses.

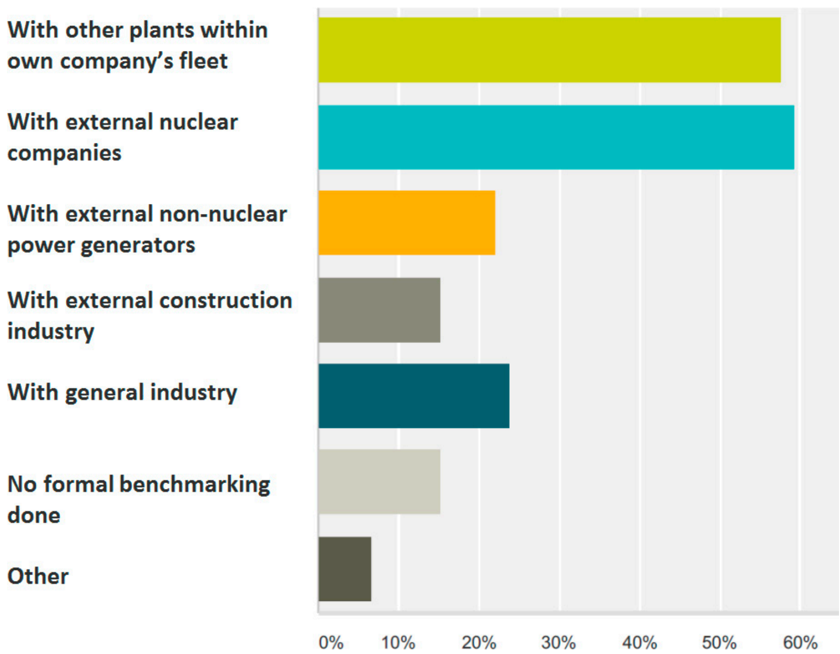

FIG. II–4. Benchmarking activities.

TABLE II–2. INCIDENT TRACKING SURVEY RESULTS

Type of event/incident	Per cent	No. of responses
Fatalities	93.33	56
Medically treated first aid incidents	93.33	56
Lost time accidents	90.00	54
Near misses	88.33	53
Unsafe behaviours	85.00	51
Incidents where individuals were placed on restricted duties (but returned to work immediately)	83.33	50
Statistics for employees and contractors (separately)	73.33	44
Other leading safety indicators	70.00	42
Quality of pre-job briefings	58.33	35
Statistics related to specific contactor (company) performance	53.33	32
Other	11.67	7
Total	100	60

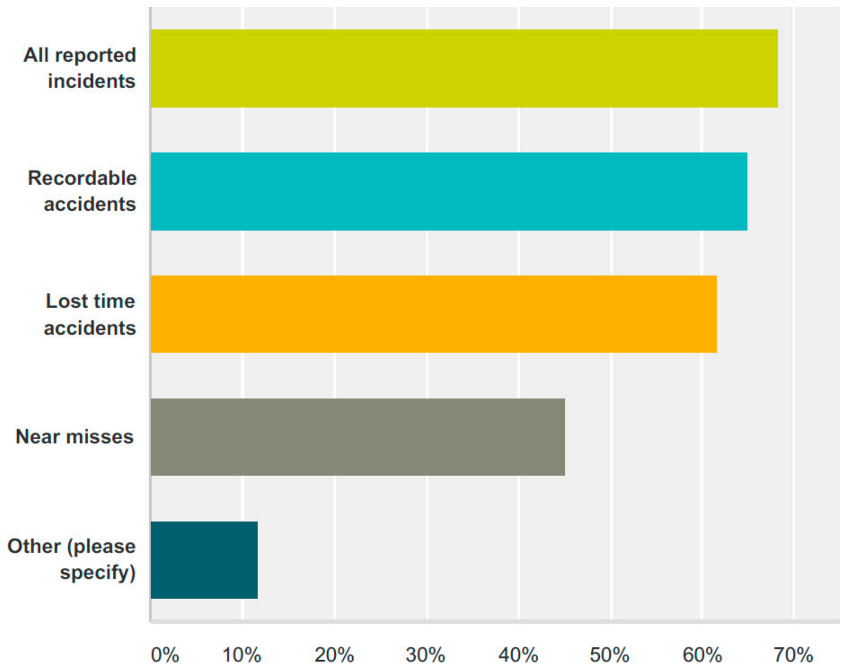

FIG. II–5. Formal incident investigations.

II–3. CONTRACTOR SAFETY MANAGEMENT

II–3.1. Amount of work contracted out

Respondents reported that their nuclear facilities contract work out in the amounts shown in Table II–3. The most common work contracted was construction or installation work (on average 63% contracted out), followed by maintenance (36%) and then design engineering (34%).

II–3.2. Expected changes in levels of contracting

Respondents indicated that they expect the level of contracting out to either increase (17 of 51 respondents, 33%) or stay the same (29, 57%) over the next operating cycle. Only 5 (9.8%) thought that the amount of contracting out would decrease over the next operating cycle.

II–3.3. Working with contractor management in a structured way

Respondents indicated that they generally work on safety issues with contractor management in a structured manner. Approximately, three quarters of respondents (37 of 49, 76%) indicated that this occurs.

II–3.4. Formal informed customer/intelligent customer/knowledgeable customer/smart buyer function

Respondents reported that they generally have developed informed customer/intelligent customer/knowledgeable customer/smart buyer functions for certain key activities (see Fig. II–6). Commonly set-up functions provide an oversight of construction or maintenance services (37 of 67 respondents, 55%), major equipment purchases (35, 52%), and design/engineering services (32, 48%). Fourteen respondents (21%) indicated that they do not have such functions set up but are actively planning them.

II–3.5. Contractor prequalification based on safety record

Most respondents (39 of 58, 83%) indicated that their companies prequalify contractor firms based on their safety record.

TABLE II–3. LEVELS OF WORK CONTRACTED

Response	Av. (%)	No. of responses
Construction or installation	63	39
Maintenance	36	39
Design engineering	34	39
Testing or inspection services (i.e. quality surveillance)	30	38
Training	29	39
Other engineering services	28	38
Expediting services	26	34
Warehousing services	25	39
Administrative services (e.g. records, human resources, clerical)	11	38
Operations	8	37

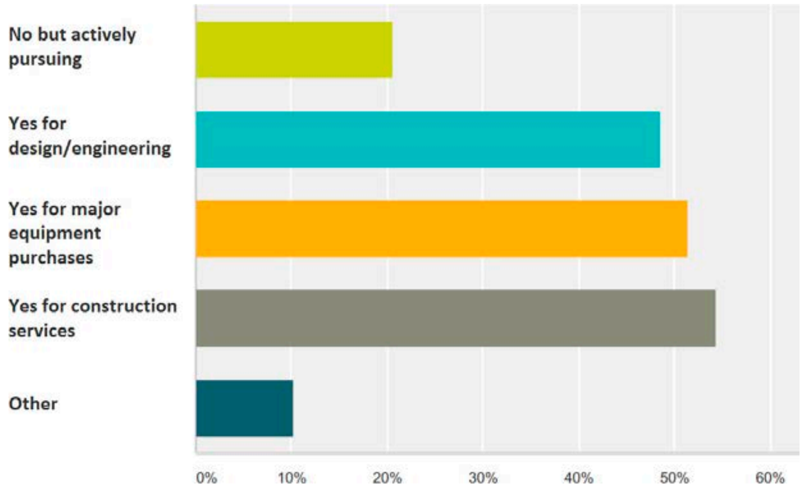

FIG. II–6. Informed customer functions.

II–3.6. Contractors hold own safety meetings

A large majority of respondents (43 of 52, 67%) indicated that their subcontractors hold their own safety meetings separate from regular staff.

II–3.7. Formal process for supplier safety performance tracking

When asked about whether their companies have a formal process for supplier safety performance tracking or assessment, 23 of 51 respondents (45%) indicated that they have such a process. Sixteen (31%) indicated that they did not, while 12 (24%) indicated that they did not know if such a process exists.

II–4. PERSONAL PROTECTIVE EQUIPMENT

II–4.1. Mandatory personal protective equipment requirements for general access

Respondents were asked what the mandatory personal protective equipment was for general access to the facility's construction site or operating island (see Table II–4). Within the 'other' category were several indications of high visibility vests, which are increasingly becoming common on construction sites.

II–5. SAFETY CULTURE

II–5.1. Worker safety perception surveys

Respondents were asked as to whether their companies regularly perform worker safety perception surveys to gauge worker attitudes about the organization's safety attitudes and practices. Most organizations performed such surveys, with 26 of 58 respondents (45%) doing so annually and 21 (36%) doing so less frequently. Eleven respondents (19%) indicated that their companies do not perform such surveys.

II–5.2. Safety discussions

Respondents were asked to detail when safety is typically discussed at their work sites. Many (33 of 56 respondents, 59%) indicated that safety was discussed at the start of every meeting. Other times included before starting field work (38, 68%), before starting any work (24, 43%), or when needed (29, 52%). Only a small percentage (7, 13%) indicated that safety was only discussed at formal safety meetings.

TABLE II–4. MANDATORY PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS

	To be worn at all times (%)	To be worn at all times in designated areas (%)	To be readily available (on person and used as needed) (%)	Only if job requires it (%)	No. of responses
Hard hat	27.27 [15]	69.09 [38]	1.82 [1]	1.82 [1]	55
Safety glasses	23.21 [13]	60.71 [34]	3.57 [2]	12.50 [7]	56
Gloves	1.82 [1]	38.18 [21]	30.91 [17]	29.09 [16]	55
Safety shoes	33.93 [19]	53.57 [30]	1.79 [1]	10.71 [6]	56
Hearing protection	3.70 [2]	68.52 [37]	11.11 [6]	16.67 [9]	54
Other	25.00 [3]	41.67 [5]	8.33 [1]	25.00 [3]	12

Note: Number of response are given in brackets.

II–5.3. Safety record a factor in raises or promotions

Respondents were asked as to whether safety records are a factor in giving supervisors raises or further promotions. A majority of respondents (30 of 54, 56%) indicated that it was a factor. An additional question on whether supervisors were evaluated based on their safety performance showed that 38 respondents (70%) believed that this was part of the supervisor evaluation process.

II–5.4. Senior executives regularly communicating about industrial safety as a priority

Respondents were asked as to whether senior executives at their company regularly talk or write about industrial safety as a priority. A large majority of respondents (48 of 57, 84%) indicated that this does occur and that they believe such communications to be sincere. Small numbers (5, 9%) indicated that they thought such communication insincere, or that no communication regulatory occurred (4, 7%).

II–5.5. Raising industrial safety concerns

Respondents were asked if they believed that if they ever raised an industrial safety concern, that they would be confident that it would be considered in an urgent manner. A large majority (51 of 57 respondents, 89%) indicated that they believe that this would occur.

II–5.6. ‘Stop work’ authority

Respondents were asked if they believed that workers have clear ‘stop work’ authority at their facility where industrial safety is concerned. A large majority (50 of 58 respondents, 86%) indicated that they believe that this is in place.

II–5.7. First aid training

Respondents indicated that first aid training is most commonly provided to some internal staff and contractors (25 of 54 respondents, 46%). Some organizations only provide training for some of their own staff but not contractors (15, 28%), some provide for all of their own staff but not contractors (5, 9%), while some provide first aid training for both organizations (8, 15%).

II–5.8. Employee family communications

Only a small number of organizations (14 of 54 respondents, 26%) communicate with their employee's families with respect to safety messages. This is a potential growth area for the industry.

II–5.9. Safety meeting frequency

Respondents were asked regarding the frequency of safety meetings at their work location. A safety meeting was defined as a general meeting to discuss safety issues not specific to a particular job. The most common response was weekly (20 of 54 respondents, 37%), followed by monthly (18, 33%) and quarterly (8, 15%). No attempt was made to distinguish between differing frequencies for different work groups. Some respondents (7, 13%) indicated that they do not hold such safety meetings.

II–6. INCENTIVE PROGRAMMES

II–6.1. Incentive programmes

Respondents reported that their organizations most commonly (21 of 54, 39%) had no formal safety incentive rewards programme (see Fig. II–7). Where award programmes existed, they were most frequently targeted at individuals (19, 35%), followed by supervisors (14, 26%), and then crews (13, 24%). The 'other' category included some bonus schemes targeted at managers and certain site wide/company rewards.

When asked about how often such awards were given out, the most common response was annually (14 of 52, 27%), followed by quarterly (4, 7%) and monthly (4, 7%). Twenty-one responses (40%) indicated that no awards are given out. Awards given were indicated generally (41 or 54 responses, 76%) as not being progressive in nature (i.e. they do not grow bigger with longer good performance).

II–7. DRUG AND ALCOHOL TESTING

Survey participants were asked if their company has any drug or alcohol testing programmes in place. About one fifth of respondents (12 of 55, 22%) said that they had no programme in place. The most common feature was pre-employment screening (34, 62%), followed by random testing (33, 60%), and testing for reasonable cause (27, 49%). The least common was blanket testing (3, 5%) (see Fig. II–8).

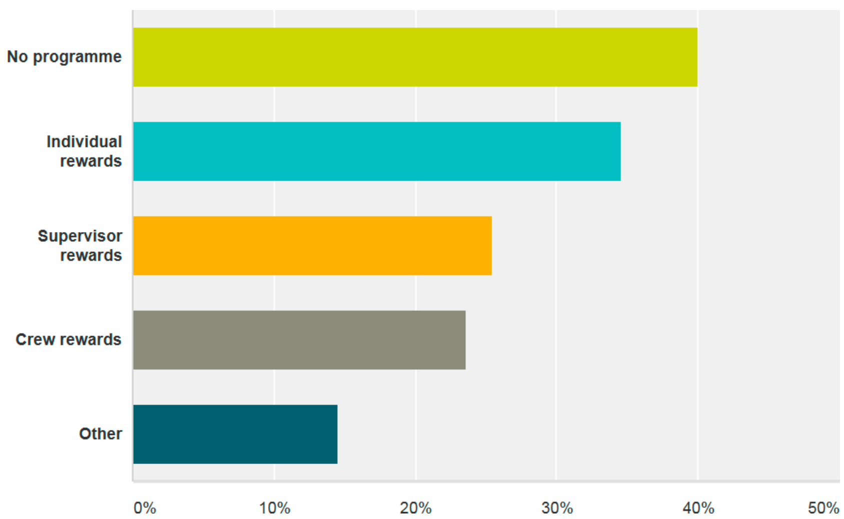

FIG. II–7. Safety incentive scheme responses.

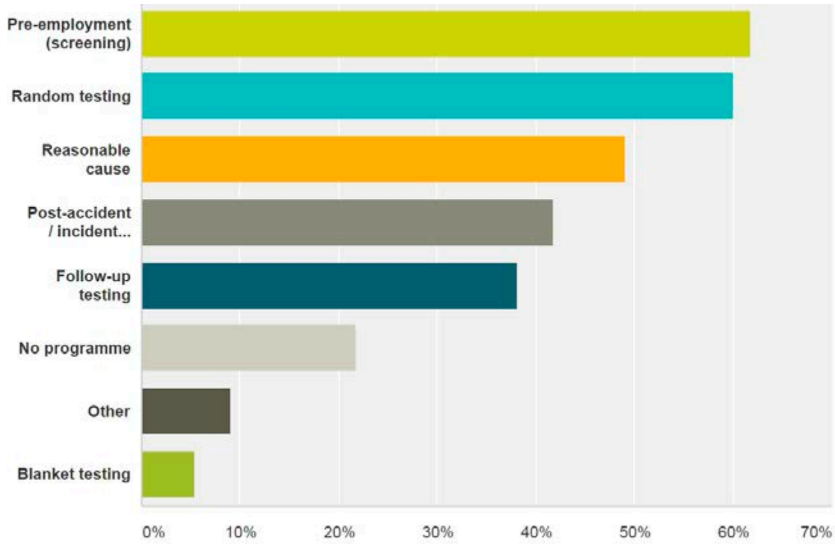

FIG. II–8. Drug and alcohol testing programmes.

A separate question asked whether these programmes were as mandated by regulators or beyond regulatory requirements. The most common response was that these programmes were as mandated by regulators (25 of 55 respondents, 45%). However, significant numbers (19, 35%) went beyond regulatory requirements. The remaining answers (11, 20%) indicated that no programme was in place.

II–8. HEALTH TRACKING

A question on employee health tracking was asked. The most common types of health tracking were for hearing loss and asbestos exposure. Fourteen of 46 responses (30%) tracked employees for both concerns, 5 (11%) indicated companies that tracked employees for hearing loss only, 3 (7%) indicated companies that tracked employees for asbestos exposure only, and 6 (13%) indicated companies that tracked employees for exposure to some other substance. Other responses indicated that general health surveillance and/or surveillance for musculoskeletal disorders was done at some locations.

II–9. TRAINING AND QUALIFICATION

II–9.1. Formal industrial safety training and qualification programmes

Survey participants were asked what formal industrial safety training and qualification programmes were in place at their locations (see Table II–5).

II–9.2. Top training needs

Survey participants were asked what the top industrial safety training needs were at their locations (see Fig. II–9).

II–10. FATALITIES

Survey participants were asked if they could recall any fatalities during their career at their organizations. Approximately half of the respondents (28 of 50, 46%) could not recall any. However, 16 (32%) could recall one fatality at their job site due to industrial safety, and 6 (12%) could recall more than one fatality.

TABLE II–5. FORMAL TRAINING AND QUALIFICATION PROGRAMMES

Training and qualification area	No. of responses	Per cent
Fall protection	45	90
Site orientation	40	80
First aid	40	80
Confined spaces	40	80
Fire response	39	78
Hazard recognition	38	76
Personal protective equipment selection	34	68
Observation and coaching	34	68
Performing quality pre-job briefings	34	68
Managing contractors/temporary workers	26	52
Membership in occupational safety and health committees	22	44
Defensive driving	17	34
Constructability reviews	10	20

II–11. LESSONS FOR NEWCOMERS

Survey participants were asked is they could provide any lessons learned that they would want newcomer countries to be aware of related industrial safety for nuclear power plants or other nuclear facilities. The documented responses are listed below. Many of them reflect the themes expressed elsewhere in this publication.

- Industrial safety is as important as nuclear and radiological safety at a nuclear facility.
- Industrial safety accidents have the same importance as radiation related accidents.
- Industrial safety typically presents a higher risk than radiation safety.
- Industrial safety has to be planned into operations and all activities.
- Low level reporting of events and the investigation and management of those events is important.
- Make safety an inherent value that you build a culture around.
- Employee involvement is essential for a successful programme.
- Allow space and protection for whistleblowers to voice their concerns.
- Oversight of supplemental contractors is crucial.
- Always strive to get better and listen to the trades/craft workers.
- Make sure you provide supervisors with the tools and time needed to implement safety in the field.
- Safety is not about regulatory compliance. While important, safety is about a culture of excellence: leadership behaviours, quality safety systems, staff engagement, critical examination and continual learning and improvement.
- Follow international best practices, not just the regulations of the State.
- Industrial safety will improve at your sites when you analyse and apply the operative experience, perform a complete previous risk assessment and develop an effective on field supervision programme.
- The safety leadership of managers and directors is important for a successful programme.
- Focus on pre-job briefings, wearing personal protective equipment, and your relationship with contractors.
- Do not separate OSH, chemicals, radiation protection, environment and safety culture. These all should be integrated.

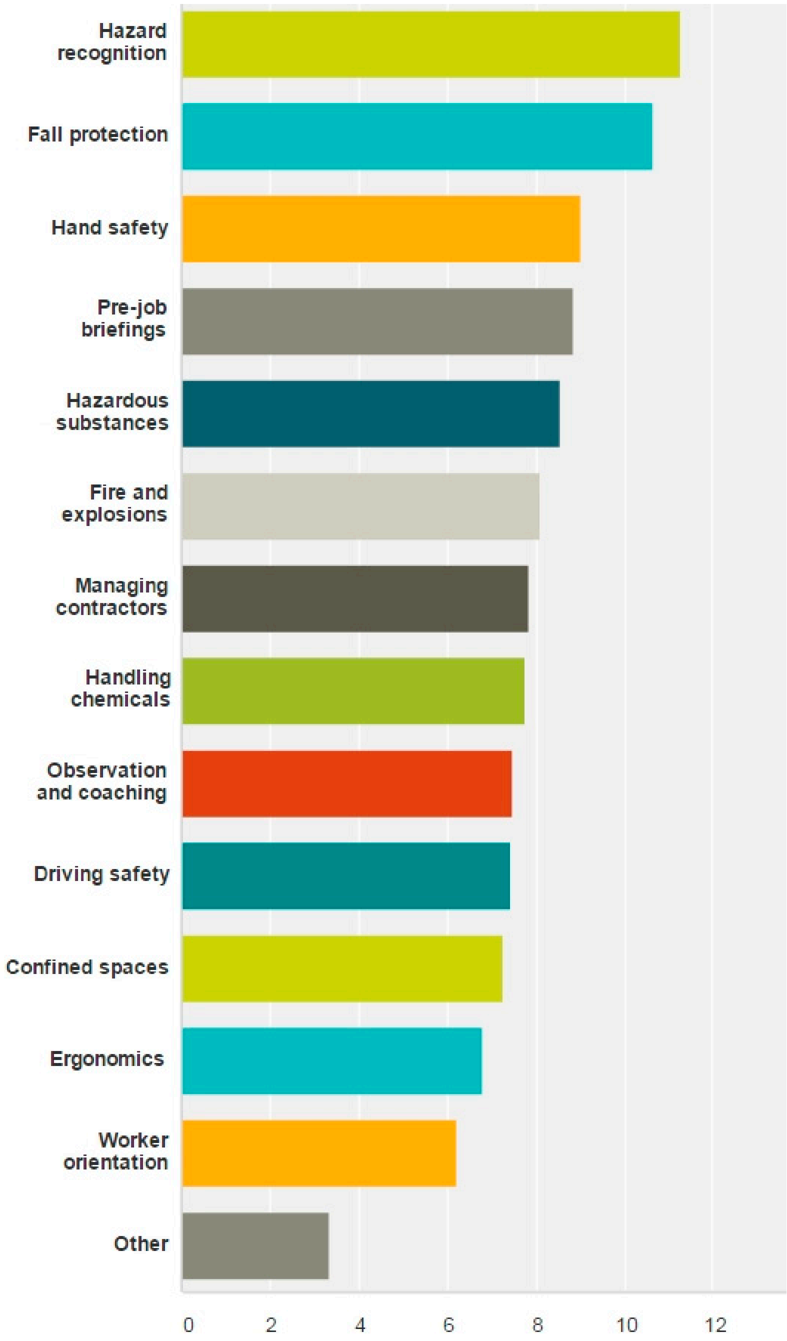

FIG. II–9. Top training needs.

- Normally, most accidents happen during construction phases, therefore newcomers should use the experience and feedback from industry, acquire knowledge of national and international industrial safety standards, and apply them.
- Use key performance indicators to monitor contractors safety performance and to implement corrective actions and training.
- Implement a programme based on behaviour monitoring.
- Briefings on hazards before and after the job are very significant in reducing injury.
- Focus on training, supervisors and pre-job briefings.
- Worker personal behaviours and the effectiveness of supervisors are the most significant ways in which safety performance is affected.

— Industrial safety should be included in each step of the process from project development, to assignment of contractors, to planning of the work, to supervision of the work, and documenting lessons learned.
— Industrial safety is not just about slips, trips and falls, but is also about process safety (see Ref. [II–7]).
— When you see something broken or not working that is not being addressed, your first question should be, ‘Is it my responsibility as a worker, manager or safety professional to address this matter?’
— Nuclear safety is a culture that is led by management, supervision and individuals.

II–12. MESSAGES TO THE IAEA

Survey participants were asked is they could provide any messages on industrial safety to the IAEA, and the responses included:

— The need for a more global collection of performance, event operating experience, lesson learnings, peer support/networking, and peer benchmarking.
— The impact of industrial safety should not be downplayed because more often it poses a significant potential for initiating nuclear events.
— The IAEA efforts for realizing the importance of industrial safety and the development of a specific standard are appreciated.
— Concentrate more on leadership, supervision and personal accountability for safety than on procedures when formulating safety standards.

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ABBREVIATIONS

CHAZOP	computer hazard and operability study
CII	Construction Industry Institute
COMS	constructability, operability, maintainability and safety
FMEA	failure modes and effects analysis
GFCI	ground fault circuit interrupter
HAZOP	hazard and operability study
ILO	International Labour Organization
INPO	Institute of Nuclear Power Operations
IRS	internal responsibility system
ISAR	industrial safety accident rate
ISO	International Organization for Standardization
JSA	job safety analysis
MSD	musculoskeletal disorder
OSART	Operational Safety Review Team
OSH	occupational safety and health
OSHA	Occupational Safety and Health Administration
OSHC	occupational safety and health committee
OSHMS	occupational safety and health management system
PPE	personal protective equipment
WANO	World Association of Nuclear Operators
WHO	World Health Organization

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Lindmark, C.	Forsmark Kraftgrupp AB, Sweden
McNulty, P.	Institute of Nuclear Power Operators, United States of America
Moore, J.H.	International Atomic Energy Agency
Niu, S.	International Labour Organization
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Vanuxem, P.	Électricité de France, France
Yu, H.	China Nuclear Power Engineering, China
Zhao, X.	China Nuclear Power Engineering, China

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Fuquin, China: 16–18 November 2015

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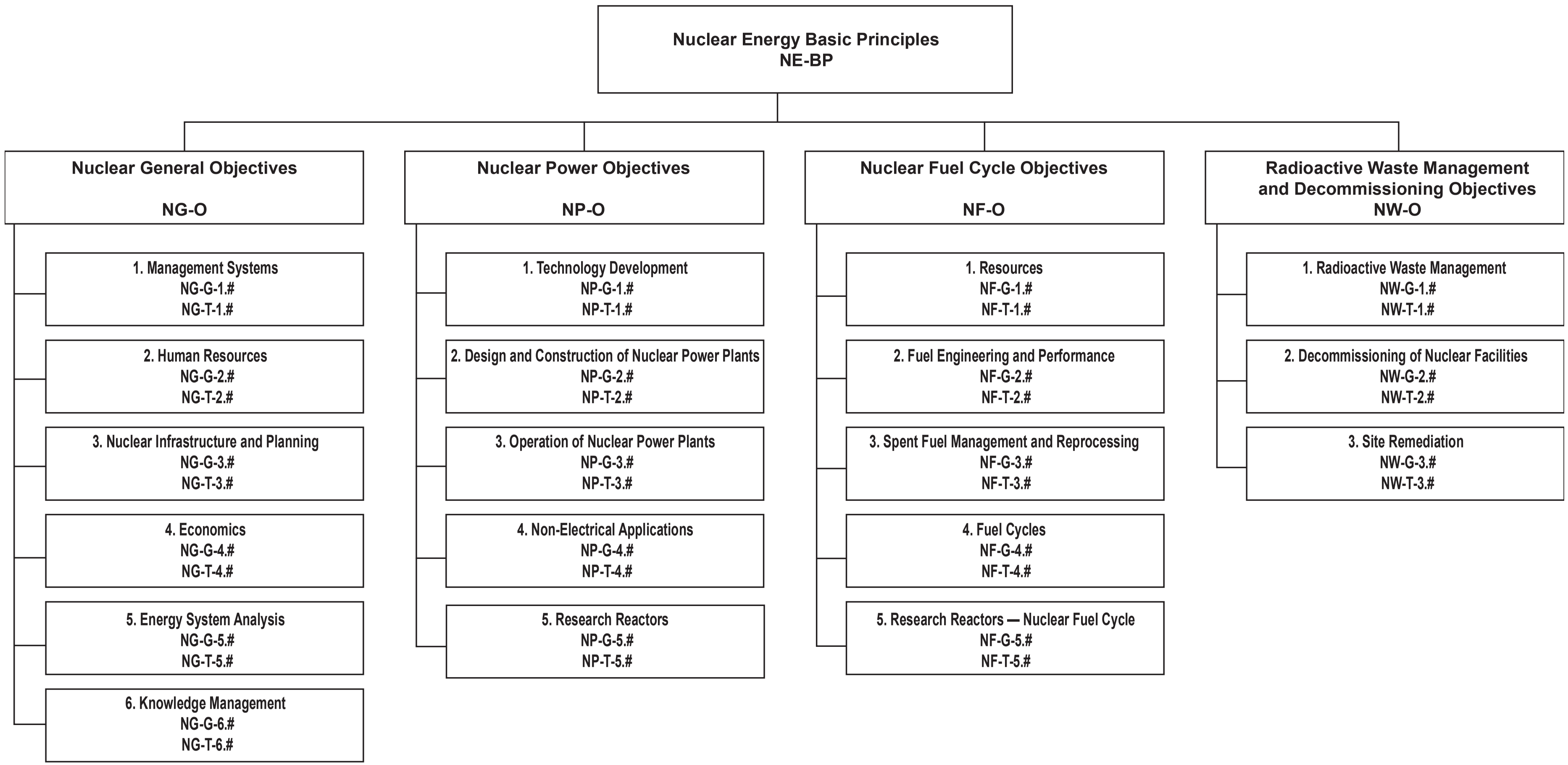

Key

BP: Basic Principles
O: Objectives
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Nos 1-6: Topic designations
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Examples

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