

DEVELOPMENTS IN PERSONAL SAFETY FOR INDUSTRIAL CLEANING

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ABSTRACT

In the late 1970s, there has been a major shift in the way cleaning of industrial equipment was performed. Asset owners who have typically been performing the cleaning of their own equipment, based on cost reduction, started to outsource these activities to specialized industrial cleaning companies. Unfortunately, this transformation led to a large number of severe safety incidents due to a lack of training/education, safe equipment, and best practices. To address this gap, safety associations were established in most industrialized countries. These associations developed best practices and guidelines for high-pressure water jetting and evolved to include other mechanical, chemical, and thermal methods, and related disciplines. Countries and regions that lacked these types of guidelines started to reach out to the established Industrial Cleaning Safety Associations.

To address these requests, the Global Industrial Cleaning Coalition (GICC) was established. The founding members, based on their experience, created seven basic principles of safe and effective cleaning to support the further development of best practices and safety associations in these underrepresented regions. In this paper, the history and key drivers in the establishment of these safety associations, their output, and their benefits are summarized.

INTRODUCTION

“Process equipment and piping in the chemical and petrochemical plants and petroleum refineries have to be cleaned periodically as part of normal maintenance operations to remove fouling that interferes with process flow, heat transfer, or other operations”[1], different cleaning methods are being used to accomplish this. Currently, approximately 80% of all industrial cleaning activities are being performed by means of high-pressure water jetting, sometimes referred to as hydro blasting [15]. Due to increased expectations in quality, efficiency, and sustainability, new cleaning techniques have been developed (or existing techniques have been improved).

Performing industrial cleaning is not without risk. Operators performing the activity are exposed to the materials being removed during the cleaning process, and they are also at risk of safety incidents such as water jet cuts and abrasions. These incidents also occur in domestic use. *“An estimated 6,057 people in 2014 alone went to an emergency room with injuries related to pressure washer use, according to the Consumer Product Safety Commission. And 14 percent of those ER visits led to additional hospitalization.”* [2].

To address these incidents and risks, best practices and guidelines must be created that tackle the root causes of such incidents. To achieve that goal safety organizations have been founded around the globe. Dow participated in the founding of SIR, DIRV, EWJI, and GICC, and is an active member of WJTA.

HISTORY OF THE INDUSTRIAL CLEANING INDUSTRY

Looking back at the development of industrial cleaning in the petrochemical industry, it can be said that the first cleaning technologies were developed in the 1920s [1]. Some of them were mechanical but most of them chemical in nature. Due to side-effects (e.g., excessive corrosion, lack of effective cleaning techniques), more effort was put in optimizing current methods of cleaning and the development of other cleaning technologies. This approach led to the creation of service companies that provided contracting offerings, some of which were spin offs of asset owner companies, such as Dowell back in 1939.

In the 1950s, a new mechanical cleaning technology was introduced, water jetting, first as surface preparation method for cleaning surfaces and the removal of blistered paint. By increasing blasting pressures and flows, this method became suitable to remove deposits from tanks and other process equipment, which led to a widespread use for industrial cleaning purposes. In the 1960s, vacuum trucks were built to remove deposits from the bottom of the fire box in fired heaters, and sludge from the bottom of storage tanks, creating, together with water jetting, the foundation for the current industrial cleaning industry.

Since the 1970s, significant changes have occurred in equipment and piping cleaning. Environmental waste disposal and safety concerns have furthered the development of new cleaning methods and less hazardous cleaning chemicals.

“At this point in time, periodic cleaning of process equipment and piping has indeed become one of many necessary maintenance operations for basic chemical plants, gas plants, petroleum refineries, and petrochemical plants. Operating conditions have become more severe than previously. Process units have become more complex and are being operated over longer periods of time between scheduled turnarounds.” [1]

This expansion of the industrial cleaning industry also led to an increase in incidents. The number and severity of these incidents, including fatalities, led to the formation of safety and technology associations in the 1980s. In particular, refining (oil & gas) and petrochemicals where the main sectors that pushed for the formation of safety standards, requirements, and training.

Geographic development

Comparing ethylene production and refinery capacities by country (as is shown in Figure 1) to the regions that have safety associations established or are in the process of establishing such organizations (Figure 2), a clear trend appears. This highlights the importance of these safety associations to these industries.



Fig. 1: Countries with more than 1,000 ktpy Ethylene and more than 1 million BPD refinery capacity [8, 14]

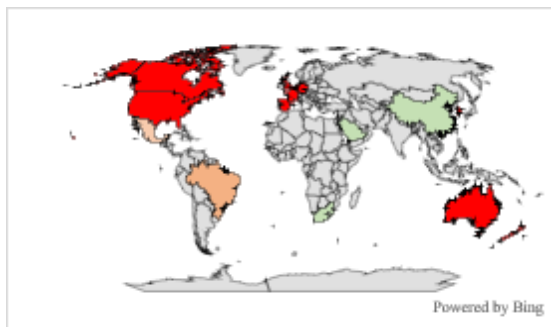


Fig. 2: Countries with established safety associations (red), in process of establishing safety

associations (green) and reached out for support (orange) [4, 5]

Safety associations

“In a speech to the introductory session of the Congress, Dr. Jukka Takala, Chief of the ILO's Health and Safety program, pointed out that the workplace hecatomb of 1.1 million deaths exceeds the average annual deaths from road accidents (999,000), war (502,000), violence (563,000) and HIV/AIDS (312,000). In addition, he said that by conservative estimates workers suffer approximately 250 million occupational accidents and 160 million occupational diseases each year.” [3].

The common ground of most of the safety organizations is that they have been founded as a direct result of serious incidents (fatalities, and severe incident trends). As an example, in the 80s, Stichting Industriële Reiniging (SIR) was founded after a streak of serious incidents that occurred in the Rotterdam, Netherlands area, resulting in multiple fatalities within one year. Incident review learned that lack of safe work procedures, guidelines, training, and equipment requirements were the main contributors. Reflecting on the last 15 years, SIR has seen a total of “only” four fatalities in this region. The Australasian High Pressure Water Jetting Association (AUSJET) was initially formed in the 90s, due to concerns within industry about the high rates of injuries sustained in the water jetting industry.

Globally more safety associations were formed with the same intent. A list with a short description of the leading safety and technology associations follows. The list is arranged chronologically, based on year of founding.

Water Jetting Association (WJA)

The Water Jetting Association (WJA) is the United Kingdom based trade association for businesses, agencies and individuals involved in the water jetting industry, with approximately 300 members.

The WJA is the UK's largest provider of water jetting training. It has developed an internationally recognized Codes of Practice for water jetting which is continuously brought up-to-date and improved.

The WJA was established in 1980 to represent members in the UK and is the oldest association in the world. It also welcomes international members and seeks to work with likeminded organizations across the world to further these goals. [11]

Water Jetting Technology Association (WJTA)

The WJTA is based in the United States and represents contractors, OEMs, asset owners, and training companies across North America. Its purpose is to promote and regulate safe working practices in industrial cleaning. WJTA collates and represents those interests in the US.

Mission & Vision:

The WJTA's mission is to advance safety and technology in industry, which is accomplished through establishing and promoting best practices; providing standardized operator training and certification; delivering education, news, and updates to association members; and organizing an annual trade show.

WJTA best practices for water jetting and industrial vacuuming are frequently reviewed by association committees to reflect advances in industry technology and safe work practices and to address identified safety hazards. Recent revisions to both manuals were published in 2021. In 2017 together with SIR and S3C founded the GICC.

Stichting Industriële Reiniging (SIR)

To promote and regulate safe working practices in industrial cleaning. SIR collates and represents those interests in the Netherlands and (since 2003) in Belgium. SIR is a textbook example of just how effective self-regulation of safety can be within a sector.

Mission & Vision:

Making industrial cleaning work as safe as possible: to achieve that objective, SIR is active in various areas. Setting guidelines is a key activity involving all parties from the sector. The unique makeup in terms of parties involved makes sure that the results obtained are balanced and backed by all those concerned. The guidelines that are defined apply throughout the sector in the Benelux countries. Every party that signs the SIR policy statement thereby undertakes to observe all the guidelines. The strength of the cooperation that is embedded in SIR is that current risks in industrial cleaning are acknowledged and appropriate guidelines for them accepted by all parties. Because the SIR guidelines are unambiguous, applying them reduces unsafe working situations to a minimum.

Industrial cleaning is an ever-changing discipline within which SIR always keeps its finger on the pulse. SIR has a motivating role in the development of safe equipment, and it is actively involved in developing safe working methods. It regularly adapts its guidelines to the latest state of the art. The network of steering committees and working groups containing representatives of various fields within the sector ensures that developments in the working domains are embodied in regulations, training, and examinations. The composition of these groups is always split proportionally between the business categories of SIR's participants so that the interests of all parties – which can sometimes be contradictory – can be properly considered for inclusion in the finalized guidelines. SIR is one of

the founding members of GICC. Since it's founding SIR developed basic principles for safe working, GICC's seven basic principles are deviated from these principles.

AusJet

AUSJET is an Australian based safety association that promotes safe water jetting practices in Australasia.

Mission & Vision:

To develop a safe work environment through standards, training, and advocacy in the interest of our members throughout Australasia.

AUSJET and ADCVA endeavor to be the world leading association for the Water Jetting, Drain Cleaning, Vacuum Loading and Hydro Excavation Industries and lead in standards, safety, training, and industry advocacy. And it's core values are i) Cleaning-up Industry Safely, ii) 'Leadership – Zero Harm'

In 1999 two-joint Australian, New Zealand High Pressure Water Jetting standards were developed (AS/NZS 4233 1&2) and made available to industry. Due to the ever-changing nature of the industry, in 2022 AusJet has launched a project to facilitate a committee made up of member representatives to review the standard and implement changes to AS4233 Water Jetting Systems Operations (New Zealand no longer recognise this standard).

In 2013, high pressure water jetting's close association with drain cleaning, vacuum loading and hydro excavation services was recognised which also required the development of standards and training. This led to the decision to form the Australasian Drain Cleaning and Vacuum Association (ADCVA) and incorporate it with AUSJET.

Although the current training standards are recognized as a Nationally Accredited course and are mandatory to work on a high-pressure water jetting job, once the standard review is completed in 2022, AusJet will then review and update the training for water jetting, vacuum loading, drain cleaning and non-destructive digging to be formalized with a higher learning institute and aligning itself with other construction, manufacturing, and mining industry skills associations. [13]

Systeme de Certification, Competence et Conformite (S3C)

To promote and regulate safe working practices in industrial cleaning. S3C collates and represents those interests in France.

Mission & Vision:

Making industrial cleaning work as safe as possible: to achieve that objective, S3C focusses on

the three C's: Certification, Competence and Conformity.

SIR, DIRV, and S3C have signed a mutual recognition agreement and are working closely together in the European Water Jet Institute to improve safety in the larger European area. [12]

Deutscher Industrie-Reinigungs Verband (DIRV)

DIRV is a German based safety association that promotes safe water jetting practices in Germany. [10]

Mission:

Work together with associated companies for adopting basic principles for safe industrial cleaning.

- To ensure a safe working place the latest developments of technology, working equipment and PPE need to be available to protect employees from risks. These developments need to be implemented by companies working together.
- To ensure qualified employees professional trainings and certification need to be conducted, which empowers the people to raise their working skills to a high level of quality and what is necessary to decide on how to deliver the best results for the task as required.

Vision:

The vision of the DIRV is to implement the safest possible industrial cleaning standards in Germany and to ensure that people doing their work in safe environment. This will be achieved by

- Professional trained and certified labor
- Setting standards for occupational safety and PPE
- Setting standards for highly developed equipment
- Working together with all different cleaning companies for achieving the best available cleaning results
- Setting standards for implementing international guidelines and requirements according to German legal requirements
- Working in communities for the exchange of lessons learned

European Water Jetting Institute (EWJI)

Both the Global Industrial Cleaning Coalition (GICC) and the European Water Jetting Institute (EWJI) are not country-based but work as a forum for the other organizations to interact, streamline, and harmonize their requirements and best practices.

EWJI, as a non-profit organization, has the following objectives:

To be involved and have an impact on health and safety standards, best practices, training, and legislation related with water jetting. To promote European regulations and reference documents on water jetting techniques, to improve processes and ensure quality. To create a network for open communication and exchange among water jetting professionals, companies, associations, and related stakeholders. To exchange information on techniques, applications and working methods among the industry and with other related industries. To foster innovation, through research and cooperation between the industry and universities, and to facilitate the access to funding available for these purposes. To support the existing associations and foster the creation of new organizations in Europe, sharing the knowledge and best practices related with water jetting. To contact and cooperate with similar organizations in other parts of the world.

Global Industrial Cleaning Coalition (GICC)

In 2017 SIR, WJTA and S3C collaborated in the formation of the GICC. This forum aims to assist countries and regions where safety associations lack to provide guidance in forming such organizations. At the foundation of this forum, the coalition published the seven basic principles of industrial cleaning which embraces the principles of all three organizations. Besides providing support for the developing areas this forum provides a platform where the different safety associations can exchange experience and information, to improve safety in the global industrial cleaning industry, without impacting the sovereignty of the specific organizations.

Safety Association		Scope				
Name	Founded	High Pressure Water	Vacuum Loading	Chemical Cleaning	Other Cleaning Tech.	Respiratory Air
WJA	1980	x	x			
WJTA	1983	x	x	x		
SIR	1987	x	x	x		x
AUSJET	1991	x	x			
S3C	2008	x	x			
EWJI	2015	x	x			
GICC	2017	x	x	x		
DIRV	2019	x	x	x	x	

Table 1: Scope of safety and technology associations [4, 5, 7, 10, 11, 12, 13]

Looking at the scope of the safety organizations it shows that high pressure water

jetting activities and vacuum loading are best served.

Safety Association	Focus				
	Petro-Chemical	Municipalities	Construction/Demolition	Mining/Minerals	Other Industry
WJA	x	x	x		x
WJTA	x	x	x	x	x
SIR	x	x			x
AUSJET	x	x	x	x	x
S3C	x	x			x
EWJI	x	x	x		x
DIRV	x				x

Table 2: Focus of safety and technology associations [4, 5, 7, 10, 11, 12, 13]

It should be noted that all the safety associations mentioned above are non-profit.

Additionally, active associations are: ALTAP (Spain), Korean Water Jetting Association (South Korea) are also active. The Industrial Cleaning Association China (China) is currently being established.

PERSONAL SAFETY INCIDENTS

Personal safety is paramount in industrial cleaning. Unfortunately, industrial cleaning activities have a high injury potential: people can be struck by jets or abrasives leading to damaged skin, tissue, broken bones, contamination with fouling products and other more generic risks. Currently, most of the focus in industry with respect to cleaning safety is related to high pressure water jetting. However, other cleaning disciplines have a similar or maybe even greater potential towards number of incidents and their severity.

Incident data review

Data resources for Industrial Cleaning incidents are scarce, for this paper the following sources were used:

- SIR Incident database 2010-2021
- AusJet Waterjet incidents 1998-2012

The benefit of the SIR data is that it creates a better and broader understanding of the incidents that have occurred in the larger industrial cleaning space, while the data from AusJet solely focus on high pressure water jetting.

If we look at the number of incidents per discipline it shows that vacuum loading has a greater impact than high pressure cleaning

followed by respiratory air protection and chemical cleaning.¹

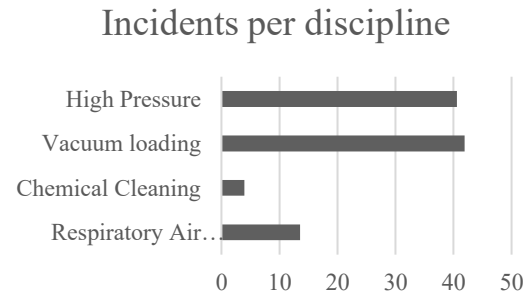


Fig 3: Incidents per discipline [9]

A deeper dive in the same incident data show the following: fatalities cover about 1.5% of all incidents, day away of work cases 29%, first aid cases 22% and non-injury (near misses and damaged cleaning equipment) for 47%.

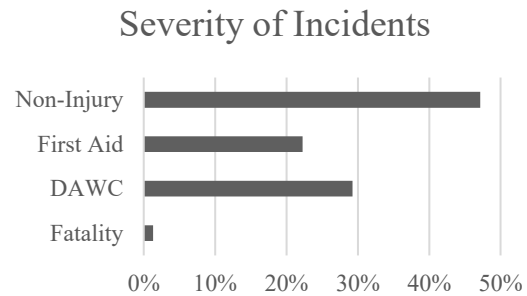


Fig 4. Severity of incidents [9]

The fact that the Day Away of Work Cases (DAWC's) are more common than the first aid cases is interesting to notice, since the safety pyramid would normally say otherwise. This shows the severity potential of getting injured during high pressure cleaning activities.



Fig 5. Illustration of Heinrich's theory "the Safety pyramid" [16]

Continuing the deep dive into the data, the primary reasons of incidents have been identified:i) human behavior, accounting for ca. 70% of the

¹ The magnitude of the vacuum loading and high pressure activities is considerably larger than the chemical cleaning activities.

incidents, ii) equipment failure, accounting for ca 30% and iii) the lack of best practices, regulation or guidelines which accounts for about 1%.² The following sections provide more insights for each of these factors.

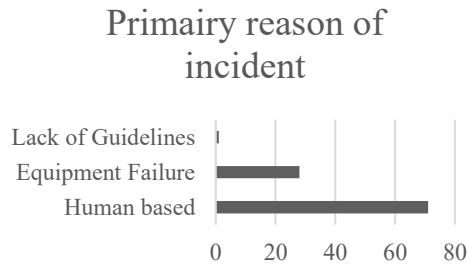


Fig 6. Primary reasons of incidents [9]

The human based factor

The human based factor consists out of two components i) experience/awareness and ii) training. The AusJet data provides an insight in the experience part of this factor.



Fig 7. Prior experience of operators involved in incidents. [13]

The number of incidents where the experience of the operator is less than a year drastically drops and drops even further for operators with more than 5 year experience which clearly shows the importance for training and experience. Incidents were operators with more than 5 years of experience are involved seem of a higher severity rate and seem to be related to complacency.

The equipment based factor

Equipment failures consist mainly of connections and hose failing. In the vacuum loading space mainly design issues. Most of these design issues have been addressed in updated guidelines and requirements.

Lack of best practices

Data for regions where guidelines and best practices are lacking, shows a larger incident rate. This is mainly the reason of reach-out from regions like China, South Africa, Saudi Arabia, Mexico,

and Brazil. Most of these initiatives are driven from asset owners.

To address these issues, the GICC, made up of the standing safety/technology associations, worked together to create basic principles as a blueprint to adhere to. These seven basic principles are further discussed in this paper.

The effect of best practices can be shown with the following example. Through an intensive collaboration between asset owners, industrial cleaning companies and manufacturers/suppliers. Since 2020 Non-manual high pressure cleaning is the new standard which is being achieved by automated and mechanical jetting by SIR in the Netherlands and Belgium, which led to a further decrease in high pressure water jetting incidents.

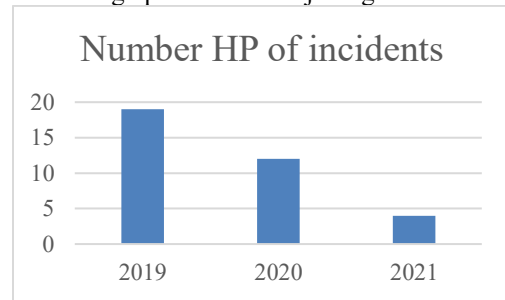


Fig. 8 High pressure water jetting incidents Netherlands and Belgium [9]

The incident rate in comparison to the number of activities and performing hours was already very low, compared with the global incident rates for high-pressure cleaning.

Expansion to other disciplines

Almost all associations originally started with high pressure cleaning and then expanded based on a demand from industry. In the last few years, more focus has been given to subjects such as sustainability, efficiency, and waste, leading to the development and re-invention of other cleaning technologies.

These other technologies require their own set of guidelines and best practices.

SEVEN BASIC PRINCIPLES

Frameworks are important tools that help to improve safety and avoid incidents described above, the Global Industrial Cleaning Coalition introduced the seven basic principles for industrial cleaning safety associations.

These principles provide a blueprint for new to create safety standards.

The seven basic principles are:

1. Joint Responsibility
2. Three Areas of Focus

² Take into account that SIR created and published its guidelines and requirement well ahead 2010.

3. Education & Training
4. Knowledge & Learning
5. Assurance of Guidelines
6. Working with Safe Equipment
7. Working According to Safe Methods

These 7 principles are applicable on all different methods of cleaning, at this moment the following 3 areas have been expanded:

- HP Water jetting
- Industrial Vacuuming
- Chemical Cleaning

Principle 1 to 5 are equal for all different cleaning methods and principle 6 and 7 are tailored to the specific technology. [4]

The guidelines and best practices of all forum members have been reviewed by a technical committee and where required an implementation plan has put in place to improve the guidelines and best practices.

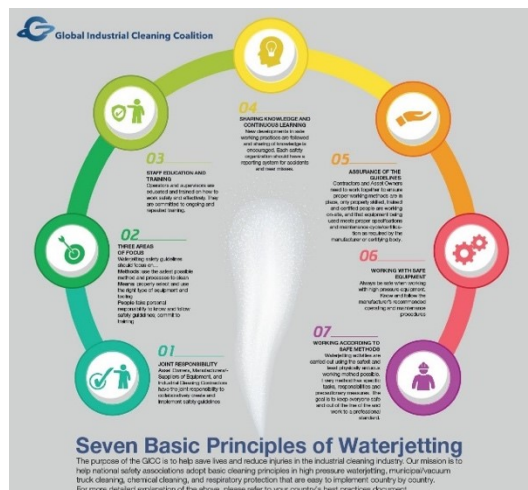


Fig. 9. Schematic overview of the Seven Basic Principles of Water Jetting [4].

Joint Responsibility

Asset Owners, Manufacturers/-Suppliers of Equipment, and Industrial Cleaning Contractors have a joint responsibility to collaboratively create and implement safety guidelines

It is obvious that the occurrence of incidents and accidents is a serious matter, and that effective control of the risks requires cooperation from all parties. That makes it important that the specific responsibilities are known.

The Asset Owner’s policy must focus on making sure that cleaning activities can be carried out under conditions in which the employee is not directly exposed to the associated risks. This means that the client creates conditions where reasonably possible in which the cleaning can be carried out in a fully automatic, mechanized way or in a mechanized way that is controlled from outside the

cleaning area or inside if necessary. The client must consult the cleaning company about this.

Industrial cleaning companies are responsible for carrying out cleaning activities correctly. The employer is also responsible for the well-being and safety of employees who carry out cleaning activities. The legal regulations about working conditions must be observed.

The task of the manufacturer/supplier is to inform and advise the cleaning company and other parties involved in the best possible way about the proper selection, use and maintenance of a cleaning system and/or components. The manufacturer/supplier provides clear user instructions. At the customer’s request, the manufacturer or supplier trains or instructs the users and provides a personalized document as evidence showing that the person in question has been trained or instructed in using the cleaning system and/or cleaning components. Any defects in the cleaning equipment are immediately reported to the customers of the equipment.

Three Areas of Focus

Industrial Cleaning safety guidelines should focus on...

Methods: use the safest possible method and processes to clean.

Means: properly select and use the right type of equipment and tooling.

People take personal responsibility to know and follow safety guidelines; commit to training.

Methods: safe working methods that apply to the client industries, the cleaning companies doing the work, the inspection bodies and other companies that have included the safety guidelines in their safety policy and business operations.

Means: equipment that must comply with the requirements when first used and that must continue to comply during its lifespan. This can be determined by means of regular inspection and testing.

People: staff who remain professional thanks to education, training examination based on the guidelines from the safety association.

Education & Training

Operators and supervisors are educated and trained on how to work safely and effectively. They are committed to ongoing and repeated training.

As showed in the incident data review, most of the incidents are human related. By providing repeated safety and awareness training and instruction, this risk can be addressed.

Knowledge & Learning

New developments in safe working practices are followed and sharing of knowledge is encouraged. Each safety organization should have a reporting system for accidents and near misses.

It's important that the complete industry learns from incidents and issues. Tracking incidents, providing lessons learned and adjusting best practices and guidelines based on that experience will improve the complete industry.

Assurance of Guidelines

Contractors and Asset Owners need to work together to ensure proper working methods are in place, only properly skilled, trained, and certified people are working on-site, and that equipment being used meets proper specifications and maintenance cycle/certifications as required by the manufacturer or certifying body.

People: Training certification based on the guidelines from the safety association.

Means: Test certificates are issued on approval that are valid for a certain period.

Working with Safe Equipment

Always be safe when working with cleaning equipment. Know and follow the manufacturer's recommended operating and maintenance procedures.

Based on experiences and incidents in the past guidelines have been created for equipment, for example EN-1829 documents. These documents deal with all significant hazards, hazardous situations and events arising during assembly, erection, operation and servicing relevant to high pressure water jet machines (EN-1829-1) and hoses (EN 1829-2). Now a harmonization and streamlining project is ongoing with IEC SC61J to create a global/international standard.

Working According to Safe Methods

Cleaning activities are carried out using the safest and least physically arduous working method possible. Every method has specific tasks, responsibilities, and precautionary measures. The goal is to keep everyone safe and out of the line of fire and work to a professional standard.

Following the hierarchy of control will help with the reduction and severity of incidents. Eliminating the hazard and risk is the highest level of control, followed by reducing the risk through engineered solutions. If these don't provide sufficient mitigation of the risks, administrative controls follow. Reducing the risk using protective personal equipment (PPE) is the lowest level of control.

CONCLUSION

Most of the traditional safety/technology associations have been formed between 20 and 40 years ago, as a response to the large number of severe incidents experienced in the refining and petrochemical industries. The regions where such organizations are operating and have been embraced by governments and local industry see a steep decline in these severe incidents.

When following GICC's seven basic principles a clear improvement of safety is being experienced.

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