FOREWORD

Workplace safety and health (WSH) plays a key role in a chemical plant in achieving better productivity and good reputation. Hence, every chemical plant should be designed to be safe and easy to manage and operate. However, accidents can still occur due to other factors such as technical and engineering failures, human errors or management/procedural faults.

As part of our continuous effort to support the chemical industry, the WSH Council (Chemical Industries) Committee has formed a workgroup to put together a compilation of local case studies. The case studies will be a useful reference to Managers, Supervisors and WSH Professionals in the chemical industry, particularly those with manufacturing or operations portfolio and working in Small- and Medium-sized Enterprises (SMEs).

This booklet offers insights to past accidents/incidents that have taken place in Singapore. The case studies not only provide lessons learnt for the industry, but more importantly, they remind us to actively review our current practices and continually find ways to make our workplaces safer. Readers are encouraged to carefully think through each case, review its relevancy and context to specific workplace situations, and incorporate the lessons learnt where appropriate.

This booklet is divided into various sections according to type of incident for easy reference. The 5M (Mission, Man, Machine and Management, Medium) Model (see Appendix B) is used to analyse the contributing factors of each case. At the end of the booklet is a section on occupational health hazards. Unlike safety hazards, consequences posed by occupational health hazards may not be as obvious and immediate. Adverse health effects may be chronic in nature and can take a long time for the occupational disease to manifest. This section will show innovative approaches used in addressing exposure to occupational health hazards involving noise, ergonomics and chemicals.

I hope that the case studies will be useful to you in creating a safer and healthier workplace for your organisation.

Mr Karthikeyan s/o R. Krishnamurthy  
Chairman  
Workplace Safety and Health Council  
(Chemical Industries) Committee
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CONTACT WITH HAZARDOUS SUBSTANCES
Exposure to hazardous substances without suitable protection measures in place may result in serious injuries or even death. For example, a corrosive chemical splash could cause skin burns and acute inhalation of toxic gases could result in severe irritation or damage to the respiratory system or even death.

Always carry out Risk Assessment (RA) before handling chemicals at the workplace. Apply the hierarchy of controls (elimination, substitution, engineering controls, administrative measures, and personal protective equipment) to minimise exposure to chemicals. Refer to the container label/Safety Data Sheet (SDS) of the chemicals that are being handled and understand its basic chemistry including its incompatibility with other substances and environmental conditions. When working with hazardous substances, it is important to develop safe work practices and train workers to handle them safely. If personal protective equipment (PPE) is required, make sure that they are appropriate to protect against the specific hazard(s), well-maintained and in good condition, worn correctly, and easily available to workers.

The following cases show the outcome when important safeguards are missing or lacking.
CASE 1
CHEMICAL SPLASH AT PROCESS PLANT

Description of Incident
A worker was sent to collect samples from a process plant at midnight as there was a recent process upset. For a representative sample, flushing of the sampling line was carried out before taking the actual sample. The worker drained the flushing liquid into an open bucket which would then be disposed into a waste pit. When the worker failed to locate the hatch on the pit cover for proper disposal of the liquid, he decided to open the pit cover. While moving the pit cover, the worker knocked over the bucket. Contents from the bucket splashed onto his arms, neck and lower half of his face. The worker suffered from chemical burns as result of the incident.

Sample collection point.

Disposal pit with pit cover removed.

1. Location of hatch on the pit cover.
Possible Causes and Contributing Factors

Medium
• The work area was insufficiently lit for the task and made it difficult for the worker to locate the hatch on the pit cover to carry out the disposal.

Management
• Risk assessment was not performed; hence the job hazards were not identified.

• There was no safe work procedures for proper disposal of flushing liquid.

• The worker was not provided with suitable PPE for protection against chemical splash during the sampling and disposal process.

Man
• The worker decided to open the pit cover to dispose the flushing liquid when he failed to locate the disposal hatch.

• While moving the heavy pit cover, the worker lost his balance and knocked over the bucket containing flushing liquid from the sampling line.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One worker injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Contact with hazardous substance (chemical)</td>
</tr>
</tbody>
</table>
| Immediate cause(s) | • Inadequate lighting in work area  
                        • Deviation from standard operating procedures  
                        • Use of open container for transfer of chemical  
                        • Inadequate PPE |
| Basic cause(s)     | • No safe work procedures developed for the task  
                        • No job hazard analysis |
| Failure of OSHMS   | • Hazard identification, risk assessment and risk control  
                        • Operating procedures and safe work practices  
                        • Management of change  
                        • Control of hazardous substances |
Recommendations and Learning Points

- Carry out risk assessment prior to any work involving hazardous chemicals and develop safe work procedures to include all control measures used to address the identified risks. Control measures to be put in place to ensure that risks are kept to a level as-low-as-reasonably-practicable (ALARP).

- Ensure any deviation from the standard operating procedures, such as opening of the pit cover, as mentioned in this case, is subjected to management of change and risk assessment before implementation.

- Ensure all workplaces, including outdoor work areas are adequately lighted, especially at night.

- Paint the disposal hatch in a different colour to make sure it is clearly visible.

- Equip workers with suitable PPE like safety goggles, face shield, long sleeved chemical-resistant aprons, rubber gloves and safety shoes. Ensure that they are worn correctly for protection against chemical splash during sampling and disposal.

- Use sealed containers instead of open buckets to transfer hazardous chemicals if manual transfer is absolutely required. Where possible, eliminate the need for manual transfer by redesigning the sampling line to include in-line or closed loop flushing system direct to disposal pit.
CASE 2
CHEMICAL BURNS DURING BLENDING OPERATION

Description of Incident
After carrying out a chemical blending operation, a worker felt severe pain in the fingers of his left hand. As the pain did not subside, he was sent to the hospital for treatment and was warded for one day. He was also given a total of 16 days of medical leave.

Possible Causes and Contributing Factors

Mission
- The blending operation involved a highly corrosive substance, hydrofluoric (HF) acid.

Man
- The worker removed his impervious gloves and replaced them with cotton gloves during the blending operation as he thought that the cotton gloves would provide sufficient protection.
Management
• The management only gave verbal instructions to the workers. There was no documentation of safe work procedures developed for the chemical blending operation.

• There was insufficient training on proper handling of corrosive substances for the worker.

• No supervision was provided to workers handling the corrosive substance.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One worker injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Contact with corrosive substance (HF acid)</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Use of inappropriate PPE (cotton gloves)</td>
</tr>
</tbody>
</table>
| Basic cause(s)    | • No documented Safe Work Procedures  
|                   | • Lack of training and supervision |
| Failure of OSHMS  | • Process safety information  
|                   | • Operating procedures and safe work practices  
|                   | • Training, awareness and competence  
|                   | • Control of hazardous substances  
|                   | • Emergency preparedness and response (first aid treatment) |

Recommendations and Learning Points

• Use the correct equipment for storage and handling of corrosive substances. Equipment used for storing or handling corrosive substances must go through a preventive maintenance programme to ensure that the equipment remains fit for use.

• Ensure all chemical containers are labelled clearly. The relevant SDS for each chemical should be made easily available to the workers so that they can quickly identify the hazardous properties of the chemical being handled.

• Provide workers with proper documentation of the safe work procedures specifying the correct PPE (e.g., face shield, chemical protective suits, chemical resistant gloves) to be used during the chemical blending operation. Specifically to this incident, impervious gloves must be provided for basic hand protection and properly fitted for firm grip.
• Organise sufficient training in hazard communication and conduct safety briefings so that workers are fully aware of the hazards and risks associated with the chemical(s) in use.

• Supervise all workers including new workers that are at risk of coming into contact with corrosive substances to ensure proper use and maintenance of appropriate PPE and familiarity with the safe work procedures.

• Provide local exhaust ventilation and/or respiratory protection for the chemical blending operation to prevent or minimise inhalation of toxic and/or corrosive vapours.

• Put in place appropriate spill control measures (e.g., use of secondary containment and availability of suitable absorbents) for immediate response to any spillage during chemical handling.

• Include appropriate first aid treatment guidelines in the safe work procedures and make sure the correct antidote for accidental skin contact with corrosive substances (e.g., calcium gluconate gel for dermal exposure to HF acid) are easily available to the workers.

• Provide SDS to the doctor and/or medical professional attending to the injured worker exposed to the hazardous substance so that the correct treatment could be correctly identified and administered.

• Install signs at worksites to remind workers on the appropriate use of PPE.
CASE 3
HYDROGEN SULPHIDE POISONING DURING PLANT SHUTDOWN OPERATION

Description of Incident
Two workers deployed by a contractor were overcome by hydrogen sulphide (H₂S) gas which leaked from a relief valve when they were trying to remove it. One of the workers fell to the ground from a five-storey scaffold but survived, while the other worker on the scaffold became unconscious due to inhalation of the leaked gas. The latter worker subsequently died of H₂S poisoning.

Scene of the accident – the deceased was found on the scaffolding platform on the left.

Close-up view of the relief valve which leaked.
Possible Causes and Contributing Factors

Man
- Both workers unscrewed the flange bolts of the wrong relief valve and failed to:
  - Check the name/label on the relief valve before starting work; and
  - Obtain a copy of the Permit-to-Work (PTW) before commencing work.
- The foreman did not show the workers the location of the relief valve to be removed and assumed that they knew where it was as they acknowledged the location of the relief valve.

Medium
- \( \text{H}_2\text{S} \) gas was released from the relief valve.

Machine
- The name/label on the relief valve was not legible.
- The relief valve was not isolated as the workers were not supposed to work on it.

Management
- The safe work procedures did not specify the step of identifying the correct valve prior to removal.
- The management allowed the workers to carry out the work unsupervised.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>One fatality and one worker seriously injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Contact with toxic gas, ( \text{H}_2\text{S} ) due to inhalation</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Work carried out on wrong relief valve</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Miscommunication</td>
</tr>
<tr>
<td></td>
<td>No safe work procedures for the task</td>
</tr>
<tr>
<td></td>
<td>Failure to obtain PTW</td>
</tr>
<tr>
<td></td>
<td>Lack of supervision</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Operating procedures and safe work practices</td>
</tr>
<tr>
<td></td>
<td>Training, awareness and competence</td>
</tr>
<tr>
<td></td>
<td>Consultation and communication</td>
</tr>
<tr>
<td></td>
<td>Contractors</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

- Workers must obtain a copy of the PTW to ensure that the work is authorised and conditions were met before commencing work.

- Workers should verify the equipment to be worked on by matching the equipment name/label that was stated on the PTW. Report immediately to the permit issuer if the equipment cannot be verified.

- Ensure that all equipment labels are legible at all times.

- To prevent miscommunication, the foremen should physically bring the workers to the site to make sure that there is no confusion on the equipment to be worked on.

- Provide workers with a written document of the safe work procedures for the task and ensure that they undergo sufficient training for the assigned work. The safe work procedures should include checks to ensure that all the correct lines are isolated and lock-out tag-out (LOTO) measures are in place.

- Occupier and contractor management should supervise workers to ensure workplace safety especially during first breaks and verify that all safe work procedures are adhered to.
**CASE 4**

**EXPOSURE TO CHLORINE GAS DURING ELECTROLYSER SHUTDOWN**

**Description of Incident**
During the shutdown of an electrolyser in a chloralkali process, an abnormal situation occurred when the manifold was seen emitting fumes. As the pressure in the manifold dropped, the safety interlock was activated which resulted in an electrical trip throughout the plant. An electrician went into the electrolyser room to reset the trip. While doing so, he was injured due to inhalation of chlorine (Cl₂) gas.

View of the electrolyser manifold metallic end plate. The end plate was previously clamped with an acrylic sight glass which gave way during the incident.

Side view of the electrolyser.
Possible Causes and Contributing Factors

Machine
- The broken acrylic sight glass was found to be single-layered as compared to the sight glass on the other end of the manifold which was double-layered.

- The malfunction of the sight glass could be the result of wear-and-tear due to the cyclic fluctuations in temperature and pressure, or even aging.

Man
- All except the electrician have attended the Oil/Petrochemical Safety Orientation Course.

- The electrician did not wear PPE to protect himself against chlorine exposure.

Management
- The management did not anticipate the possible failure of the acrylic sight glass when conducting risk assessment.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>One worker injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Contact with toxic gas, Cl₂ due to inhalation</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Presence of chlorine in the workplace</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Defective sight glass</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Hazard identification, risk assessment and risk control (Failure to identify the risk of sight glass malfunction)</td>
</tr>
<tr>
<td></td>
<td>Training, awareness and competence</td>
</tr>
<tr>
<td></td>
<td>Emergency preparedness and response</td>
</tr>
</tbody>
</table>
**Recommendations and Learning Points**

- Anticipate all possible risks during risk assessment and implement suitable control measures such as implementing a replacement programme for the sight glass as per manufacturer’s recommendation.

- Use a double-layered sight glass that can withstand the cyclic fluctuations in process temperature and pressure.

- Install an on-site chlorine gas detector for leak detection and/or require workers to perform gas check before entering/re-entering the area.

- Train and ensure that the plant personnel wear the appropriate PPE during the course of their work. In this case, workers would need to be equipped with a full-face respirator, a chemical protective suit, safety boots and gloves before entering the hazard zone where chlorine gas is present.

- Develop procedures to ventilate the affected area and contain the hazard in the event of an emergency.
CASE 5
CONTACT WITH HYDROFLUORIC ACID DURING DECOMMISSIONING OF PRESSURISED TANK

Description of Incident
Liquefied propane with traces of hydrofluoric (HF) acid was passed through a pressurised tank for treatment. The tank contained solid potassium hydroxide which is being consumed during the treatment had to be periodically replaced. A process technician was isolating the tank to replace the potassium hydroxide. After depressurising the tank, he connected a rubber hose from the nitrogen gas supply valve to the utility connector valve of the tank to initiate nitrogen purging. He then opened the utility connector valve without verifying that the tank had been fully depressurised. The rubber hose burst and contents from the tank gushed out. The technician suffered chemical burns and later succumbed to his injuries.

Photographs showing the burst rubber hose used to connect the tank utility connector valve to the nitrogen gas supply valve.
1. Utility connector valve.
3. Rubber hose.
4. Utility connector.
5. Utility connection valve.
Possible Causes and Contributing Factors

Man

• The worker opened the valve located at the bottom of the tank to depressurise the tank. However, this method caused the sludge to choke the pipeline and hinder the depressurising process.

• The worker failed to ensure complete depressurisation of the tank before opening the bottom valve.

• The worker wore a lower-class HF suit which did not provide sufficient protection for the task in the event of a chemical splash.

• He proceeded to purge the tank without authorisation from his supervisor.

Management

• Safe work procedures have not been documented specifically for tank decommissioning.

• The management failed to ensure that the workers wore the appropriate class of chemical protective suit.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>One fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Contact with corrosive substance, HF acid</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Rubber hose became defective due to incomplete depressurisation of the tank</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Did not adhere to work instructions</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Operating procedures and safe work practices</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

• Install a non-return valve on the tank utility connector line to prevent backflow of tank contents.

• Ensure that flexible hoses are compatible with the contents being conveyed, and the system temperature and pressure.

• Check all flexible hoses and their couplings regularly for leaks, and ensure that they are periodically checked and replaced when required.

• Ensure that the tank is completely depressurised by using appropriate instruments (e.g., pressure indicators and alarm/interlock system) before starting work.

• Ensure that the importance of checking the tank pressure prior to connecting hoses for nitrogen purging operation is clearly indicated in the safe work procedures.

• Supervise the workers on-site to make sure they comply with safe work practices.

• Replace flexible hoses with fixed piping where possible.

• Conduct periodic risk assessment reviews for high risk activities.
The potential of fire and explosion is always present in the refining and petrochemical industry. Good design, sound operation and diligent maintenance of the plant are critical in preventing fire outbreaks and reducing the risk of an explosion.

Some process safety design considerations include operating within design limits, preventing loss of containment, need for positive isolation, adequate pressure relief, suitable instruments and controls for managing upsets, and emergency conditions. For flammable atmospheres, the control of ignition sources is essential along with proper inerting, bonding and grounding of equipment and piping.

Importantly, a plant must be designed with safety in mind, it is also critical that the plant can be operated safely. Besides providing workers with training in operations and occupational safety and health, other key measures include the need for rigorous process hazard analyses, development of procedure on management of change (MOC), and implementation of a robust PTW system. To ensure maximum process uptime, a regular inspection and maintenance regime should be implemented to assure the mechanical integrity of the plant.

The following cases will provide some insight on how things can easily fail if some of the proper measures are not put in place.
**CASE 6**

**LOSS OF CONTAINMENT AT ELEVATED FLARE TOWER**

**Description of Incident**
An overflow of hot liquid hydrocarbon from the top of a flare tower had caused a small fire at the elevated platform and bottom of the flare tower. No workers were injured in this incident.

Simplified block diagram of the process.
Possible Causes and Contributing Factors

Machine
A process upset caused the following sequence of events.

- A trip in the gas compressor resulted in the diversion of liquid feedstock to a downstream process vessel which caused it to experience levels higher than usual.

- The absorber column was flooded as the critical control valve was not isolated which allowed backflow from the downstream process vessel.

- The high flow from the knockdown drums was due to the reverse flow from the absorber column.

- High flow from the upstream knockdown drums together with undersized pumps at the drain tank outlet led to an overflow of the common drain tank.

- The overflow of liquid hydrocarbon from the top of the flare tower was a result of the overflow from these vessels in the following sequence: common drain tank → flare drum → seal drum → flare tower.

Man
- The plant operators failed to isolate the critical control valve to prevent backflow into the absorber column as stipulated in the emergency procedure.

- The plant operators were slow in reacting to the high-level alarm triggered for the absorber column.

- The plant operators were unsure how to handle the unusual high level conditions in the knockout drums as they could not figure out why the drum levels were so high. (NB: Specific Gravity (S.G.) fluctuations may have caused the control system to report inaccurate level indications)

- The plant operators did not follow the proper flow diversion procedures for common drain tank as they failed to recognise that the drain tank was filled with hydrocarbon and the tank level was above the normal level.

Management
- There was a lack of automatic control and management of overflow condition, and other critical process safety conditions.

- The management failed to conduct a thorough process hazard analysis which could have identified the worst case scenario.
## Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>Property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Loss of containment</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Overflow of hot liquid hydrocarbon from the top of the flare tower</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Failure to anticipate operating problems/hazards due to compressor trip</td>
</tr>
<tr>
<td></td>
<td>Inadequate response by plant operators to abnormal conditions</td>
</tr>
<tr>
<td></td>
<td>Lack of instrumentation and controls for automatic management of abnormal conditions</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Hazard identification, risk assessment and risk control</td>
</tr>
<tr>
<td></td>
<td>Training, awareness and competence</td>
</tr>
<tr>
<td></td>
<td>Operating procedures and safe work practices</td>
</tr>
</tbody>
</table>

## Recommendations and Learning Points

- Carry out periodic process safety review including a thorough process hazard analysis to identify and anticipate all possible worst case scenarios. In particular for this incident, it is important to review the design of the process and carry out a Hazard and Operability (HAZOP) study ‘NO FLOW’ condition caused by a compressor failure.

- Recognise that S.G. fluctuations may cause the control system to report inaccurate level indications which will lead to sounding off the alarms at the wrong level. Employ alternative method (e.g., sonic or ultrasonic level measurement) to ensure accurate liquid level indications whenever possible.

- Install safety instrumentation and safety interlocks for overflow detection and automatic isolation of the critical control valve, and a control system for automatic handling of overflow condition and liquid relief. Replacing the critical control valve with a proper safety barrier such as emergency shutdown valve should also be considered.

- Emphasise to the plant operators the importance of promptly adhering to standard operating procedures including the flow diversion procedure and the emergency procedure.

- Use process simulators to provide plant operators with realistic training in process troubleshooting and handling abnormal as well as emergency conditions.

- Allow the senior plant personnel to authorise a safe shutdown if there are uncertain or sustained unstable plant conditions.
CASE 7
FIRE DUE TO SIGHT GLASS LEAK

Description of Incident
A leak originating from a cracked level sight glass led to a fire at a flash tower of an oil refinery. The fire damaged part of the side of the flash tower and melted the insulation material on some of the pipe fittings. No workers were injured in this incident.

Possible Causes and Contributing Factors

Machine
• The oil leaked from the level sight glass as it had cracked due to thermal fatigue. The sight glass was subjected to severe temperature fluctuations each time the plant was shut down and re-started.

Medium
• The temperature of the oil leaking from the flash tower was above its auto-ignition temperature.

Management
• The sight glass was neither regularly inspected nor maintained.

1. Location of oil leak.
Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• Property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Fire</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Oil leak from cracked level sight glass</td>
</tr>
</tbody>
</table>
| Basic cause(s)     | • Sight glass cracked due to thermal fatigue  
|                     | • No regular inspection and maintenance for the sight glass |
| Failure of OSHMS   | • Mechanical integrity and reliability |

Recommendations and Learning Points

- Glass components are susceptible to damages once installed. Therefore, an appropriate material that is able to handle operational conditions such as fluctuating temperature and pressure must be selected at the design stage.

- Implement a risk-based inspection and maintenance programme for all fixtures that are part of the process including sight glasses.

- Set up a replacement programme for all sight glasses based on manufacturer recommendations, and/or after going through a fixed number of operational cycles.

- Where feasible, put in place engineering measures (e.g., excess flow check valve) in the sight glass assembly to prevent leakage of vessel contents through the sight glass in the event of glass breakage.

- Explore deploying longer cycles of ramped heating and ramped cooling to avoid extreme temperature fluctuations. It is important to know that while glass is generally able to withstand high temperatures, it may be weakened when it is prone to severe temperature fluctuations.

- Establish an emergency response plan, and carry out periodic drills and exercises for employees to practice preliminary fire control, leak containment, evacuation, rescue and first aid.
CASE 8
FLASH FIRE DURING CHARGING OF FLAMMABLE POWDER

Description of Incident
An operator was pouring a sack of chemical powder manually into the hopper of a blending machine. The charging process took place while a welder was installing a product specification board (sign board) within the vicinity of the hopper. When the welder started a test spark, a spark fell into the hopper and a flash fire occurred. The operator who was loading the chemical powder suffered burns and sustained cuts while escaping from the fire.

Possible Causes and Contributing Factors

Medium
• The chemical powder being charged into the hopper was flammable.

Management
• There was no PTW issued for this hot work to ensure that the necessary checks were made before commencing the welding works.

• There was no enclosure to isolate the welding sparks from the hopper.

• Proper means of communication (e.g., via walkie-talkies) were not provided to the workers.

Accident location at the top of the blending machine.
1. Product specification board.
2. Hopper of the blending machine.
3. Position of the welder.
4. Position of the injured.
Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One worker injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Flash fire</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Introduction of sparks into a flammable atmosphere</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>• Failure to conduct risk assessment</td>
</tr>
</tbody>
</table>
| Failure of OSHMS            | • Hazard identification, risk assessment and risk control  
                                • Operating procedures and safe work practices  
                                • Consultation and communication  
                                • Control of hazardous substances |

Recommendations and Learning Points

• Conduct a general workplace risk assessment to identify all sources of flammable material.

• A PTW must be issued to ensure that the necessary worksite checks are made, a gas test is performed and the work has been authorised before any hot work is allowed to proceed.

• Set up a fire blanket enclosure around the hopper opening to shield against sparks generated from any nearby welding works.

• Improve communication and coordination between different teams of workers by providing walkie-talkies or portable radio handsets to the workers.

• Equip all workers handling flammable substances with suitable PPE (e.g., a fire retardant uniform) for basic protection against fire.
Description of Incident
An explosion involving a highly reactive and flammable substance occurred at the discharging area of a chemical plant. The explosion caused a heavy tote bin to topple and fall on a worker, pinning him to the ground. The worker eventually succumbed to his injuries. Another worker who managed to escape from the scene sustained burn injuries as a result of the ensuing fire.
Possible Causes and Contributing Factors

Mission
• The work involved a substance that reacted violently with water to form flammable vapours.

Medium
• The reactive substance in fine powder form was potentially explosive when dispersed.

• The pressure in the hopper vessel was very low causing the breather valve to open and admit atmospheric air into the vessel.

• The reactive substance was mixed with moist air when the breather valve opened.

• The air that entered the hopper vessel was extra moist as it had rained in the day.

Man
• The inert gas supply was cut off by the control room operator, causing an abnormally low negative pressure within the hopper vessel.

Machine
• When the inert gas supply was cut off, the breather valve opened to protect the vessel from collapsing.

• The breather valve was connected directly to the atmosphere instead of the inert gas supply. This was a major flaw in the design of the breather valve.

• An oxygen analyser was installed in the hopper vessel but it failed to detect the air ingress as its sampling point was located too far from the breather valve.

• There was no low pressure alarm to alert the workers that the vessel pressure had reached a critical level.

• There was no flow transmitter to detect inert gas supply.

Management
• The management failed to ensure proper design of the inerting system as air ingress was possible since the breather valve was connected directly to the atmosphere.

• There was no procedure for Management of Change as management had given permission for the inerting system to be switched from an automatic to manual mode without any impact assessment.
Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One fatality, one worker injured and property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Struck by falling object (deceased) and fire (injured)</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Reactive substance exploded when mixed with moist atmospheric air</td>
</tr>
</tbody>
</table>
| Basic cause(s)     | • Flaw in the design of the inerting system in that the breather valve was connected directly to atmosphere  
                      • Inadequate management of change |
| Failure of OSHMS   | • Hazard identification, risk assessment and risk control  
                      • Management of change |

Recommendations and Learning Points

• Consider whether an inherently safer design could be adopted by eliminating the breather valve and replacing it with a full vacuum rated equipment.

If the above recommendation is not possible:
• Carry out a process hazard analysis to ascertain the risks associated with the continuous use of the highly reactive and flammable substance, the impact of air ingress, and develop control measures to mitigate the risks.

• Change the design of the breather valve so that it is connected to an inert gas supply, instead of direct to the atmosphere.

• Include routine checks on the status of inert gas supply and the system pressure in the safe work procedure.

• Install transmitters to monitor the flow of inert gas into the system.

• Locate the oxygen analyser sampling point near to the breather valve for a more accurate and faster detection of air ingress into the vessel.

• Install a low pressure alarm to warn plant operators of a dangerous negative pressure condition.

• Set up a management of change procedure for all process changes (whether for temporary or permanent) and deviations from standard operating procedures.
CASE 10
EXPLOSION OF REACTOR AND SETTLER TANK DURING PROCESS TROUBLESHOOTING

Description of Incident
Several workers were carrying out troubleshooting on process line no. 1. The pump supplying hydrogen peroxide (H$_2$O$_2$) to process line no. 1 was still in operation. The same pump supplied hydrogen peroxide to process line no. 2 as well. There was a valve located after the pump that controlled the supply of hydrogen peroxide to a reactor via process line no. 2. As the valve was not fully isolated, the hydrogen peroxide reacted with the remnants inside the reactor and downstream settler tank which then caused an explosion. The explosion ripped off the shell of the reactor and the top of the settler tank. None of the workers were injured in this incident as they were working at the other end of the production building.

The explosion caused severe damage to the reactor with the top of the reactor, indicated by (1), completely blown off.
Possible Causes and Contributing Factors

Medium
- Hydrogen peroxide reacted exothermically with the remnants (concentrated sulphuric acid, $\text{H}_2\text{SO}_4$, and isopropanol, $(\text{CH}_3)_2\text{CHOH}$ in both the reactor and settler tank, resulting in an increase in the system pressure.

Machine
- The cooling water jacket of the reactor was not in operation as the reactor was shut down. As such, the temperature increase in the reactor could not be controlled.
- The relief vents for both the reactor and settler tank were inadequately sized to relieve the rising pressure in each vessel.

Man
- The workers failed to ensure that the isolation valve was fully closed.
- Some of the workers involved in the troubleshooting were unaware that the same pump supplied hydrogen peroxide to the reactor via process line no. 2 as well.
- The workers did not know that sulphuric acid and hydrogen peroxide were incompatible and should not be mixed.

Management
- The management failed to carry out a thorough Hazard and Operability (HAZOP) study and a Quantitative Risk Assessment (QRA) on the reactor and associated process lines.
- There was a lack of instrumentation for the monitoring of key process parameters like process temperature, system pressure, vessel liquid level, etc.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>Property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Explosion</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Over-pressurisation of process vessels</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Failure to ensure positive isolation of critical valve</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Process safety information</td>
</tr>
<tr>
<td></td>
<td>Hazard identification, risk assessment and risk control</td>
</tr>
<tr>
<td></td>
<td>Operating procedures and safe work practices</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

• Conduct process hazard analysis and implement suitable layers of protection to mitigate all identified risks.

• Review all the existing operating procedures and safety checklists to ensure they are written clearly and all the identified risks (e.g., chemical incompatibility) have been highlighted and sufficiently addressed.

• Provide competency training to ensure that the workers understand the process flow and the risks associated with mixing of incompatible chemicals.

• Ensure positive isolation of process lines through the use of double block valves and bleed with spading to prevent accidental mixing of incompatible chemicals.

• Implement process instrumentation, control and alarm systems so that key operating parameters like process temperature and pressure can be easily monitored.

• Re-design the relief vents for the worst-case pressure relief scenario.

• Establish and implement procedure on the steps and measures to be taken in the event of a runaway reaction.
CASE 11
EXPLOSION OF CONDENSER DURING CHEMICAL PROCESS

Description of Incident
An explosion occurred during the production of acetylated lanolin in a batch process plant. The explosion was a result of a runaway reaction and subsequent over-pressurisation of the condenser (during condensation of acetic acid (CH$_3$COOH) vapours which passed through it from a reactor). The front cover and related components of the condenser were blown away causing minor damages to the building and other equipments. There was no injury to the plant personnel in this incident.
**Possible Causes and Contributing Factors**

**Mission**
- Significant revisions (versus previous batches) were made to the operating procedure for the current batch. The revised operating procedure led to the formation of excess acetic acid which ended up in the condenser.

**Medium**
- Acetic acid is a flammable substance with a low flash point.
- Runaway reaction between hydrogen peroxide (H$_2$O$_2$; used as a bleaching agent) and excess acetic acid in the condenser resulted in the generation of large volumes of oxygen via an exothermic reaction.

**Man**
- The operator had misread the operating instructions and charged excessive acetylant into the reactor. This led to more acetic acid formed as by-product.
- The operator failed to check for presence of excess acetic acid prior to starting the new batch.

**Management**
- The operating instructions were inadequate.
- The management had failed to conduct process hazard analysis of the revised operating procedure prior to commencement of the new batch.
- The plant personnel were unaware of the strong reactivity between acetic acid and hydrogen peroxide.

**Causal Analysis**

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>Property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Explosion</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Failure to remove excess acetic acid produced during the lanolin acetylation process</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Management did not conduct a process hazard analysis prior to implementing the revised operating procedure</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Hazard identification, risk assessment and risk control, Operating procedures and safe work practices, Management of change, Training, awareness and competence</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

- Provide operating instructions that are simple, clear and easy-to-understand.

- Ensure critical process safety checks are included in the operating procedure, e.g., checking for excess acetic acid.

- Subject all revisions to management of change procedures and carry out a process hazard analysis to identify and evaluate potential hazards due to the revisions prior to implementation.

- Communicate the changes to all plant personnel so that they are aware of the revisions and provide necessary training to help the workers understand the operational risks.
CASE 12
BOILER EXPLOSION DURING PLANT COMMISSIONING

Description of Incident
Three workers were trying to restart a steam utility boiler during night shift when an explosion occurred inside the furnace of the boiler. The explosion ripped open the boiler, causing damage to the water tubes and subsequent release of high pressure steam. Two workers eventually died due to severe burns and the third worker was badly injured.

The steam utility boiler after the explosion.
Possible Causes and Contributing Factors

Man
• The workers allowed a large amount of flammable gas into the boiler furnace.

• Investigations revealed that the workers used unauthorised bypass method to restart the boiler.

• The workers had learnt the bypass method from the pioneering boiler start-up team and thought that it could be used again (just like they had done a few times before) to overcome the unsuccessful firing situation they were facing.

• The workers, however, failed to adhere to the safe work procedures as they did not apply for management of change approval before implementing the bypass method, and removed the bypass valve security seal without authorisation.

• The workers also failed to carry out risk assessment prior to implementing the bypass method. They had applied the bypass method successfully a few times before and thought it would be alright to continue with the method.

Medium
• The furnace walls were very hot as the boiler had been in operation before it tripped.

Management
• Workers were not specifically advised against carrying out the bypass method practiced by the pioneering boiler start-up team.

• Safe work procedures were not adequately enforced and effectively communicated to the workers.
Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• Two fatalities and one worker badly injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Explosion followed by contact with high pressure steam</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Presence of flammable gas-air mixture and ignition source in boiler furnace</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>• Failure to adhere to safe work procedures</td>
</tr>
<tr>
<td></td>
<td>• Lack of risk assessment for deviations from safe work procedures</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>• Hazard identification, risk assessment and risk control</td>
</tr>
<tr>
<td></td>
<td>• Operating procedures and safe work practices</td>
</tr>
<tr>
<td></td>
<td>• Management of change</td>
</tr>
</tbody>
</table>

Recommendations and Learning Points

- Emphasise the importance of adhering to safe work procedures at all times.

- Conduct periodic safety briefings and refresher training for all workers involved in boiler operations so that the safe work procedures are clear to all.

- Highlight all deviations from safe work procedures to management for approval prior to any implementation.

- Ensure that all deviations (i.e., changes) from safe work procedures are subject to risk assessment prior to implementation.

- Nurture a strong safety culture where workers understand that process changes (whether major or minor) need to be properly managed to prevent a process safety incident.
CASE 13
FURNACE EXPLOSION DURING TEMPERING PROCESS

Description of Incident
An explosion occurred at a furnace used for tempering tubular metal components. Each piece of metal component had earlier been masked with a layer of liquid chemical (a flammable substance) at both its ends. The masking and subsequent drying was carried out by a contractor at his premises prior to delivering it to the client’s furnace location. The explosion occurred 25 minutes after the metal components were loaded into the hot furnace. The explosion blasted away the furnace door and caused damages to the sides, top and rear parts of the furnace. No worker was injured in this incident.

The furnace without its door after the explosion.
1. Side shells damaged and exposed the furnace insulation.
2. Door blasted open.
Possible Causes and Contributing Factors

Mission
- The work involved tempering of metal components partially masked with a layer of flammable chemical.

Medium
- There was an accumulation of flammable vapour in the furnace due to evaporation of the residual masking chemical from the metal components.

Machine
- The furnace in use was meant specifically for the tempering process and not suitable for drying the metal components as there was no internal ventilation system to clear away the accumulated vapour.

Management
- The management failed to communicate to the workers and contractors on the safe work procedures and the importance of checking for sufficient air drying time prior to loading metal components into the furnace.
- The management had approved the use of the furnace as it was larger and could accommodate more metal components in line with growing business demand.
- As there was a lack of procedure for management of change, no risk assessment was carried out to determine the impact of shortening the air drying time, switching to a larger furnace, and increased metal component loading on the furnace operation.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>Property damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Explosion</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Ignition of the flammable vapour accumulated inside the furnace</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Insufficient air drying time for the masked metal components prior to loading into the furnace.</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Hazard identification, risk assessment and risk control, Operating procedures and safe work practices, Management of change, Contractors</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

- Communicate the importance of critical safety checks such as sufficient air drying time or level of dryness to all workers and contractors, and clearly indicate the need for such checks in the safe work procedures. Implement system (e.g., via regular audit) to ensure compliance by all parties.

- Ensure that all changes to the process workflow (e.g., shortening the air drying time, switching to a larger furnace and increased metal component loading) are subject to management of change procedure and process hazard analysis before implementing.

- Select and use the right equipment for the task – in this case, a furnace with an internal ventilation system should have been used so that residual vapours emitted from the heated metal components can be removed effectively.
CONTACT WITH HOT SUBSTANCES/OBJECTS
CASE 14
SCALDED BY STEAM CONDENSATE IN PROCESS PLANT AREA

Description of Incident
While returning from a site check on an erected scaffold at a heat exchanger, a worker fell into an uncovered 1.4 m deep pit containing 0.6 m depth of hot steam condensate. The worker’s trousers and shirt (up to the chest level) were soaked and the worker died of severe and extensive scald burns three days later in the hospital.

Possible Causes and Contributing Factors

Medium
- The pit contained high flow of hot steam condensate and half of the pit was uncovered and not barricaded.

Management
- The management did not fully cover or barricade the pit as they failed to address the hazard introduced by drainage of hot condensate through the pit.

Close-up view of the pit (barricaded after the accident).
1. Concrete slab covering the downstream portion of the pit.
2. Uncovered portion of the 1.4 m deep pit.
### Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Contact with hot substance</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• Pit was not covered</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>• Failure to identify hazard of hot condensate at downstream location</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>• Hazard identification, risk assessment and risk control</td>
</tr>
</tbody>
</table>

### Recommendations and Learning Points

- Carry out a general workplace risk assessment to identify all uncovered pits and open drains, and install permanent covers or proper barricades to prevent workers from falling into them.

- Conduct periodic inspections to ensure all covers are in place and check for damages or corrosion.

- Provide clearly demarcated walkways for workers’ access and ensure a thorough risk assessment is conducted for each walkway.

- Install safety signs at suitable locations along the designated walkway to alert workers of dangers in the vicinity (e.g., barricaded pit ahead with steam condensation release point) especially during plant start-up and shutdown events.

- Ensure that a water gel blanket is easily available during installations where there is potential for contact with hot substances. The water gel blanket will provide immediate pain relief, help to reduce trauma and slow down the burn progression for the injured worker.
CASE 15
SCALDED BY HOT LIQUID FROM INCINERATOR

Description of Incident
Solid waste cakes were fed into the rotary kiln of an incinerator through a supply nozzle. After combustion, the ashes formed would be channelled into a slab box. When the control panel indicated an abnormal drop in the temperature within the kiln, two workers decided to carry out a site inspection. Fog and liquid deposits were observed at the base of the kiln. When they opened the slab box for inspection, the two workers came into contact with the discharged hot liquid. One worker succumbed to burn injuries while the other ended up being hospitalised for more than four months.
Possible Causes and Contributing Factors

Man
• The workers opened the door of the slab box without assessing the risks posed by the abnormal drop in temperature within the kiln.

Machine
• The supply nozzle could have cracked due to thermal stress causing the cooling water to leak into the kiln. The presence of cooling water in the kiln led to a drop in the temperature within the kiln.

Management
• The management failed to identify the impact of thermal stress on the supply nozzle during process hazard analysis.
• A safe work procedure was not available for slab box inspection under abnormal conditions.
• There was no maintenance regime for the supply nozzle.
• The workers were not provided with specialised PPE for the task.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>• One fatality and one worker seriously injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>• Contact with hot substance</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>• A crack in the nozzle which caused the cooling water to leak into the kiln</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>• Inadequate process hazard analysis.</td>
</tr>
</tbody>
</table>
| Failure of OSHMS     | • Hazard identification, risk assessment and risk control.  
                        • Operating procedures and safe work practices  
                        • Mechanical integrity and reliability (of the supply nozzle) |
**Recommendations and Learning Points**

- Review the process hazard analysis to determine if there are more or new hazards and implement suitable risk control measures to address each identified risk.

- Conduct a proper root cause analysis to determine the actual cause of nozzle failure (e.g., due to thermal stress, inadequate material of construction, poor nozzle/joint design, etc.)

- Establish a regular inspection and maintenance regime for the supply nozzle.

- Allow the workers to stop the incinerator operation in the event of process abnormality.

- Develop safe work procedures and train the workers for slab box inspection under abnormal conditions. In general, equipment under operation should not be opened for inspection without establishing the cause of the abnormal condition. To minimise the risk to workers, all hazards must be identified and control measures put in place before inspecting the equipment.

- Equip the workers with suitable fire retardant PPE when working with hot substances.
FALLS FROM HEIGHT
CASE 16
FALL FROM HEIGHT WHILE CLIMBING ROPE LADDER

Description of Incident
After helping to dismantle a metal scaffold inside a reactor, a worker was at the base of the reactor getting ready to exit through the overhead reactor manhole. While the worker was on the way up the vertical rope ladder, he fell and landed at the base of the reactor. The worker was immediately rescued but he died on the way to the hospital.

Metal scaffold that was inside the reactor before dismantling.
1. Manhole.

Close-up view of the reactor manhole.
2. Fall arrester.
3. Life line.
4. Rope ladder.
Possible Causes and Contributing Factors

Mission
- Upon dismantling the scaffold inside the reactor, the workers were required to climb up 14 m to exit via the overhead reactor manhole.

Man
- The worker did not attach his body harness to the provided fall arrestor and retractable life line.

- The worker lost his grip when climbing up the rope ladder.

Management
- There was a lack of supervision to ensure that each worker attached their body harness to the provided life line before climbing up the rope ladder.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>One fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Falling from height</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Did not attach body harness to life line</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Not following safe work procedure</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Operating procedures and safe work practices</td>
</tr>
</tbody>
</table>

Recommendations and Learning Points

- Prior to working in a confined space (i.e., the reactor in this case), the entry permit must be obtained and the necessary gas checks are carried out by a Confined Space Safety Assessor. The confined space must be adequately ventilated and lit for the task to be carried out.

- Ensure that the workers are well-rested and medically fit for strenuous work activities such as using the rope ladder for access to and egress from the designated work area.

- Implement a Fall Prevention Plan to address all risks associated with working at height.

- Emphasise the need to properly secure the body harness before using the rope ladder during worker training and/or toolbox meetings, and highlight its importance in the safe work procedures.

- Introduce a buddy system to verify that each worker has attached his body harness to the life line before climbing the rope ladder.

- For safer means of access and egress, explore the use of a fixed ladder instead of a rope ladder.
CAUGHT IN/BETWEEN OBJECTS
CASE 17
TRAPPED IN/BETWEEN PRIME MOVER CABIN AND CABIN DOOR

Description of Incident
A prime mover driver (a contractor) delivered a 20-foot long empty container to a factory for loading drums of chemical. When the Operations Manager failed to contact the driver via walkie-talkie, he sent a co-worker to look for him. The prime mover driver was found unconscious and trapped between the driver’s side of the cabin and the cabin door of his prime mover parked at the factory. The prime mover had surged forward causing the cabin door to be wedged against the open leaf of the factory main gate. The driver was pronounced dead by the ambulance crew.

Scene of the accident.

1. The driver was found trapped between the driver’s side of the cabin and the cabin door.
2. This leaf gate was originally fully opened and beside the kerb. Its hinges had to be cut and the gate shifted to this position in order to extricate the driver.
Possible Causes and Contributing Factors

Medium
- The prime mover/trailer/container was parked in the factory driveway which was sloping 2 degrees downwards towards the main gate.

Man
- The driver parked the prime mover in parallel to the open leaf of the main gate at the factory entrance.
- The driver parked the prime mover with its front wheels turned towards the main gate.
- The driver was trying to get into the prime mover cabin when it suddenly surged forward.

Machine
- The prime mover was left connected to the trailer/container during the loading operation. Although the handbrake was engaged, the prime mover surged forward as the weight of the drums that were being loaded into the inner end of the container caused the trailer to press on the tail end of the prime mover. This created sufficient force to push the prime mover forward.

Management
- The management did not provide a designated work area for safe loading/unloading operation.

Causal Analysis

<table>
<thead>
<tr>
<th>Evaluation of loss</th>
<th>One fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contact</td>
<td>Caught between prime mover cabin and cabin door</td>
</tr>
<tr>
<td>Immediate cause(s)</td>
<td>Insufficient clearance between prime mover and main gate</td>
</tr>
<tr>
<td>Basic cause(s)</td>
<td>Prime mover moved during loading operation</td>
</tr>
<tr>
<td>Failure of OSHMS</td>
<td>Hazard identification, risk assessment and risk control</td>
</tr>
<tr>
<td></td>
<td>Operating procedures and safe work practices</td>
</tr>
<tr>
<td></td>
<td>Contractors</td>
</tr>
</tbody>
</table>
Recommendations and Learning Points

- Designate and clearly demarcate a proper work area for safe loading/unloading operation.

- The prime mover should be disconnected from the trailer/container during loading/unloading.

- Position wheel clamps under the trailer and prime mover to prevent any unexpected movement during loading/unloading.

- Highlight in the Safe Work Procedures for prime mover drivers (including contractors) the dangers of parking:
  i. On a slope;
  ii. Next to an obstruction;
  iii. With front wheels turned towards the obstruction; and
  iv. With the prime mover and trailer/container connected during loading/unloading operation.
Unlike safety-related hazards, the consequences posed by occupational health hazards are usually less obvious. In some cases, the adverse health effects may manifest after many years of exposure. Absenteeism due to occupational ill health decreases productivity and increases the cost of healthcare. Early proactive measures to prevent or minimise exposure to occupational health hazards will reduce the potential of developing ill health due to workplace conditions.

In this section, let’s look at interventions on either the process or the equipment that could drastically reduce worker exposure to noise, ergonomic hazards from manual handling, corrosive acid and toxic dust.
CASE 18
PREVENTING NID: ACOUSTIC ENCLOSURE FOR SHREDDER MACHINE

Problem
A shredder machine was used to shred polymer. Bales of polymer were manually fed into the machine which was powered by a 37 kW motor. Excessive noise of 94 dBA was generated from the motors and gears located at the lower section of the shredding machine. The machine operator and workers working nearby were usually exposed to the loud noise from the machine.
**Solution**
The machine was fully enclosed within removable acoustic panels supported by a stainless steel frame. The inner surface of the panels was lined with a sound absorption material. The enclosure was specially designed to allow for easy removal of the panels to facilitate regular maintenance of the machine.

**Results**

<table>
<thead>
<tr>
<th>Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before control</td>
</tr>
<tr>
<td>After control</td>
</tr>
<tr>
<td>Total reduction</td>
</tr>
</tbody>
</table>

- Before control: 94 dBA
- After control: 84 dBA
- Total reduction: 10 dBA

AFTER: The same shredder machine fully enclosed with removable acoustic panels supported by a stainless steel frame.
CASE 19
IMPROVING WORK ERGONOMICS: PUSH-PULL ATTACHMENT FOR FORKLIFT

Problem
Bags of dry solid chemical (25 kg per bag) had to be manually loaded into shipping containers. Two workers were required to load 640 to 680 bags into each shipping container. Approximately 140 containers were loaded each day. It was an extremely strenuous and repetitive task for the workers who were at risk of injuring their wrists, shoulder and lower back in the long run.

Solution
A custom-built push-pull contraption was attached to the forklifts to facilitate lifting and proper placement of the bags into the shipping container.

With the new push-pull attachment, forklift drivers could load the same number of bags in less than half the time as compared to manual loading. It used to take two workers to load one container in 45 minutes. With the mechanical aid, one forklift driver needed only 15 minutes to load the same container.

Results

Before control
Lifting Index = 4.2 (based on NIOSH Lifting Equation).

After control
Manual handling completely eliminated.

BEFORE: Manual loading by workers.

AFTER: The use of a mechanical aid helped increase productivity whilst protecting worker health.
CASE 20
ELIMINATING EXPOSURE TO HAZARDOUS CHEMICAL: AUTOMATIC DOSING SYSTEM

Problem
The waste solvent in a storage tank at a pharmaceutical plant had to be neutralised by periodic manual charging of concentrated sulphuric acid into the tank. Workers had to work at height, and exposed themselves to acid vapour as well as acid splash while carrying out the work. Full body, hand and face protection was required to carry out this task.

Solution
An automatic dosing system was installed to eliminate the need for manual charging of concentrated sulphuric acid. The system is operated by a process control system. This eliminated the risk of exposure to acid and working at height.

Results
Elimination of risk of exposure to concentrated sulphuric acid.

Cost savings $32,000/year
Time savings 210 hrs/year
CASE 21
ELIMINATING EXPOSURE TO HAZARDOUS CHEMICAL: INFLIGHT SOLID SAMPLER

Problem
Employees were required to move drums of Active Pharmaceutical Ingredient (API) powder from the milling process to the dispensary for manual sampling. During sampling, employees were exposed to API powder when they scooped it from the drums into sample bottles for laboratory testing.

Solution
An inflight solid sampler was designed to automatically extract a representative sample from two positions in the chute of the milling process. Employees were no longer exposed to API powder as manual sampling was eliminated.

Results
Before control
API concentration = 0.16 mg/m³ = 13.33% of the Permissible Exposure Limit

After control
No exposure.

$120,000 saved from PPE (gown and respirators), sample bottles and disposal cost of waste API as manual sampling was no longer required.
## ACKNOWLEDGEMENTS

<table>
<thead>
<tr>
<th>Supporting Organisations</th>
<th>Contributors</th>
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Antidote – a remedy substance which, when given or taken in the correct dose, can be used to counteract or neutralise the effects of poisoning.

Auto-Ignition Temperature – the lowest temperature at which a substance will spontaneously ignite in a normal atmosphere without an external source of ignition, such as a flame or spark.

Confined Space – any chamber, tank, pit, pipe, flue (or any other similar space) in which dangerous airborne substances are liable to be present to such an extent as to involve risk of (a) fire or explosion occurring, (b) persons being overcome through exposure to toxic substance, and (c) persons being asphyxiated due to inadequate supply of air.

Control Measure – any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level.

Corrosive Substance – one that will destroy or irreversibly damage another surface or substance with which it comes into contact. The main hazards to people include damage to the eyes, skin, and tissue under the skin; inhalation or ingestion of a corrosive substance can cause damage to the respiratory and gastrointestinal tracts. Exposure to a corrosive substance could result in chemical burn.

Double Block Valves and Bleed – a special T-configuration along a pipeline involving two block valves (one upstream, one downstream) for dual isolation and a bleed valve (between the block valves) for cavity venting and depressurisation. A double block valves and bleed configuration is typically used to facilitate maintenance, repair or replacement work.

Exothermic Reaction – a chemical reaction that is accompanied by the release of energy, usually in the form of heat.

First Break – refers to the first time any equipment or pipeline containing a hazard (e.g., a chemical, a hot liquid or a gas under pressure) is opened to facilitate work. Opening the line, in this case, may refer to the act of disconnecting flanges, opening dead-end valves, breaking pipe joints, removing blinds, etc.
Hazard – any possible source of harm or any situation with the potential to cause bodily injury or ill-health.

Hazard Communication – the means through which employers inform their workers about hazards in the workplace, including training, labelling of hazardous substances and provision of Safety Data Sheets.

Hazard and Operability (HAZOP) Study – a structured and systematic qualitative examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to workers or equipment, or prevent efficient operation. The HAZOP technique is based on a set of guidewords and is carried out by a multi-disciplinary team over a series of meetings.

Inherently Safer Design – a design approach that aims to avoid hazards instead of controlling them, particularly by reducing the amount of hazardous material present at any time, replacing a hazardous material with one of lower hazard, designing out problems instead of adding additional layers of protection, and reducing the number of hazardous operations in the plant (e.g., by lowering the temperature and pressure of operation).

Local Exhaust Ventilation – a mechanical exhaust system (typically comprising a hood, duct, exhaust fan, air cleaning device, exhaust stack) used to control air quality by capturing airborne contaminants (e.g., fine particles, toxic gases, vapours or fumes) at or very near its source of generation in an industrial setting. Examples of common hood types include fume hood, canopy hood and welding hood. The captured air stream may be exhausted outside once it is rendered safe.

Lock-out Tag-out (LOTO) – a safety procedure used to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. LOTO requires that hazardous power sources be “isolated and rendered inoperative” before any repair procedure is started. “Lock and tag” works in conjunction with a lock usually locking the device or the power source, and placing it in such a position that no hazardous power sources can be turned on. The LOTO procedure requires that a tag be affixed to the locked device indicating that the hazardous power source should not be turned on.

Loss of Containment – refers to the release or escape of material, usually a gas or liquid normally designed to be contained within plant equipment or pipelines, to the environment. Loss of containment can vary from small releases (e.g., minor emissions or leaks) to very large release (e.g., vessel or pipeline rupture) and the release could be deliberate or accidental.
**Negative Pressure** – a partial vacuum condition in a room, vessel or specific location where the pressure is below that of the surrounding atmospheric pressure.

**Permit-to-Work** – a formal document which specifies the work to be done and the precautions to be taken. Permits-to-work form an essential part of safe systems of work to control work activities that are potentially hazardous. Examples of potentially hazardous work are entry into confined spaces, hot work and pipeline breaking. A permit-to-work allows work to commence only after safe work procedures have been defined and implemented. The permit also provides a clear record that all foreseeable hazards have been addressed and confirms that suitable control measures have been put in place to mitigate the risk(s).

**Personal Protective Equipment (PPE)** – refers to protective clothing, helmets, goggles, respirators, gloves, boots, or other garment or equipment designed to protect the wearer’s body from injury (e.g., by blunt impacts, electrical hazards, heat, chemicals, etc) for job-related occupational safety and health purposes. The use of PPE is to reduce worker exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

**Preventive Maintenance** – a proactive maintenance strategy based on servicing, replacing or overhauling an item at a periodic interval.

**Process Upset** – an abnormal plant condition where operating parameters (e.g., flow, level, temperature or pressure) severely deviate from the design intention.

**Runaway Reaction** – generally refers to a thermal runaway situation where an exothermic reaction releases more heat as its temperature increases leading to an uncontrollable exponential temperature climb, often resulting in an explosion.

**Container Label** – a label on a chemical container or package providing a summary of the chemical’s hazards with warnings to the user to take the necessary precautions. A typical label would include the following information: Product Identifier, Hazard Pictogram, Signal Word (“Danger” or “Warning”), Hazard Statement, Precautionary Statement, Supplementary Information, Supplier Information.

**Safety Data Sheet** – source of information on the physical, chemical and hazardous properties and the necessary precautions to undertake to safeguard worker safety and health.
Safety Interlock – a device used to help prevent a process from harming its operator or damaging itself by stopping the process when tripped. The interlock may comprise any electrical, electronic, or mechanical sensor or switching device, which detects the unsafe situation and automatically activates to prevent the undesired process condition.

Secondary Containment – the use of a secondary outer container to catch and limit the spread of leaking or spilt hazardous liquids from a primary inner container into the environment.

Spading/Blinding – the use of a flat metal disc plate (commonly referred to as a “spade” or a “single blind”) to positively isolate (or permanently blank off) a pipeline so that no flow is possible. Spading / blinding is usually deployed to ensure that contact with hazardous materials is prevented so that maintenance work on a pipe system can be carried out safely.

Worst Case Scenario – a simulated planning exercise to cater for situations where “things go wrong”, potentially leading to negative impact on worker safety, health or environment. Identifying the worst case scenario would enable facilities and safety systems to be designed to handle the worst foreseeable situation should it arise.
The following aspects of process safety are extracted from Singapore Standard SS 506: 2006 Occupational Safety and Health (OSH) Management System - Part 3: Requirements for the Chemical Industry. Readers are advised to purchase the standard for details.

**Process Safety Information** – includes information pertaining to the (i) hazards of chemicals used or produced by the process, e.g., toxicity information and chemical incompatibility data, (ii) technology of the process, e.g., process flow diagram and process chemistry, and (iii) equipment used in the process, e.g., piping and instrumentation diagram and design codes and standards employed.

**Hazard Identification, Risk Assessment and Risk Control** – includes the (i) ongoing proactive identification of physical, chemical and biological hazards, (ii) assessment and evaluation of OSH risks, and (iii) implementation of control measures to address the risks and mitigate them to as low as reasonably practicable. Examples of recognised methodologies to aid identification and assessment of risks are: What-If Checklist, Risk Assessment Matrix, Job Safety Analysis, Hazard and Operability (HAZOP) Study, Failure Mode and Effect analysis (FMEA), Fault Tree Analysis.

**In-house OSH Rules and Regulations** – used to regulate OSH activities and behaviours at the workplace. The rules should cover training requirement, safe work practices, use of personal protective equipment, housekeeping, incident reporting, etc. The rules and regulations need to be documented and communicated to all workers (including contractors) in the workplace.

**Training, Awareness and Competence** – all workers must possess sufficient OSH knowledge to enable them to recognise potential hazardous situations and understand their role in creating safe working conditions. Competency may be defined in terms of appropriate education, training and/or relevant experience. Training may comprise a combination of formal courses and on-the-job training. Awareness may be achieved through campaigns, tool box meetings, OSH signs and posters, OSH talks and videos, emergency response drills, etc.
Consultation and Communication – a procedure for ensuring that OSH information is communicated to and from (i) employees at various levels in the organization, and (ii) externally with interested parties. Employees should be involved in the development and review of OSH policies and procedures and be consulted whenever there are changes affecting workplace safety and health.

Operating Procedures and Safe Work Practices – Operating procedures describe the operating tasks to be performed (for normal operation, start-up, shut-down and emergency operations), operating conditions to be maintained, records of operating conditions, samples to be collected, OSH precautions to be taken, etc. Safe work practices are for ad-hoc and non-routine work to ensure safe conduct of operating and maintenance activities by employees as well as contract workers. Examples of ad-hoc and non-routine work include opening of process equipment and piping, lockout and tagout of energy sources, hot work, entry into a confined space, use of a crane, excavation work, etc. The permit-to-work system is commonly deployed as an important element of safe work practices.

Management of Change – a procedure to address all hazards or concerns that may be introduced by any changes (whether permanent or temporary) in process technology and in facilities. Changes in process technology can result from changes in production throughput, materials used, equipment unavailability, new equipment, new chemicals used, changes in operating conditions, etc. Changes in facilities include changes in materials of construction, modification of equipment, piping re-configuration, changes in alarms and interlocks, etc.

Pre-start-up Safety – a procedure to ascertain the readiness of the operating function and the technical safety and integrity of the new facility under construction prior to the introduction of hazardous substances. The pre-start-up procedure typically includes checks to confirm that the construction and equipment is in accordance with specifications, risk assessment has been performed and control measures implemented, safety, operating, maintenance and emergency procedures are in-place and adequate, etc before plant commissioning.

Contractors – a procedure to ensure that contractors meet the OSH requirements consistent with that required of employees when providing services for the organization. The contractor’s OSH performance is often used as a key parameter for contractor selection and evaluation. Only contractors who can meet the organization’s OSH performance standards and requirements are permitted to work in the workplace.
**Mechanical Integrity and Reliability** – a procedure to ensure ongoing mechanical integrity and reliability of all equipment, electrical system and instrumentation to reduce unplanned shutdowns and process upset conditions. The procedure includes establishment of written maintenance procedures, implementation of a hardware inspection and testing programme, setting up a quality control and assurance programme for maintenance materials, parts and equipment, etc.

**Control of Hazardous Substances** – a procedure for the proper use, storage, handling, movement and disposal of hazardous substances. The procedure includes the set up of a register of hazardous substances used or produced, the storage of hazardous substances in designated areas secured against unauthorised access, training on hazard communication to all employees and contractors, etc.

**Occupational Health** – scope includes medical surveillance, hearing conservation and respiratory protection. To prevent occupational diseases, medical surveillance involves procedures to monitor the health of employees exposed to (i) excessive noise through audiometric examinations, and (ii) specific toxic chemicals through biological monitoring. Hearing conservation involves a procedure to ensure that employees and contractors are adequately protected from exposure to noise levels exceeding the permissible exposure levels. Respiratory protection involves provision and proper use of suitable respirators to ensure that workers are effectively protected from airborne contaminants like toxic dust, fumes, gases and vapours.

**Emergency Preparedness and Response** – includes the implementation of an emergency response plan and the establishment of an emergency command centre, an emergency response team and the procedure for emergency response notification and initial response. A programme of drills and exercises may be used to periodically test the emergency response plan and procedures.

**OSH Inspection** – a detailed inspection programme conducted at planned intervals to verify compliance with applicable legal requirements, in-house safety rules and regulations and safe work practices.
APPENDIX B
OVERVIEW OF 5M (MISSION, MAN, MANAGEMENT, MACHINE, MEDIUM) MODEL

Mission refers to the task that has to be achieved, including the objectives and the aspects of planning, preparation, operating area and contingencies. For example, in Case 2, a worker was tasked to carry out chemical blending operation involving a highly corrosive substance known as hydrofluoric acid. His fingers were burnt while handling the chemical with cotton gloves instead of impervious gloves.

Man refers to the specific individual(s) directly involved in the operation’s execution, taking into account his/their reliability (attitude, discipline, psychological factors and physical health) and proficiency (knowledge, judgement and hands-on skills) that led to the occurrence of the incident. For example, in Case 4, the electrician had failed to wear PPE to protect him against chlorine exposure. As a result, he was injured due to the accidental exposure to chlorine.

Management refers to all who can influence the control of the operations. Management includes the scheduling of work activities and supervision of field operations. It also concerns the provision of training, instructions and the management of risks associated with the operation. For example, in Case 8, Management had failed to put in place a hot work permit-to-work system to ensure that the environment was safe for welding. As a result, a flash fire occurred when a spark fell into the hopper containing flammable chemical powder.

Machine refers to the tools for the operation and its reliability (failure rate, accuracy and dependability) and capabilities (its suitability to the task, degree of automation, and ability to provide for the needs of the human). For example, in Case 10, the relief vents for both the reactor and settler tank were found to be inadequately sized. When the pressure rose, there was insufficient relief and this led to the explosion.

Medium refers to the physical environment of an operation. It includes visibility, weather conditions, density of events, the degree of real-time supervision or control and support and the nature of the terrain. For example, in Case 17, the factory driveway where the prime mover/trailer/container was parked was sloping down 2 degrees towards the main gate. The sloping nature of the driveway was a contributing factor that led the prime mover to move towards the main gate when it surged forward, causing the cabin door of the prime mover to be wedged against the open leaf of the factory main gate.
### APPENDIX C
CASE LISTING BY OSHMS PROCESS SAFETY COMPONENT

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<td>Management of Change</td>
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<td>Training, Awareness and Competence</td>
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<td>Consultation and Communication</td>
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<td>Control of Hazardous Substances</td>
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<td>Mechanical Integrity and Reliability</td>
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