Safety Case Regime: Moving the Needle on Process Safety

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Empowered *Workforce*,
Thriving *Workplaces*

Presentation Agenda

1. Overview of Safety Case Regime[#]
   - ✓ Key components of Safety Case
   - ✓ Top Focus Area covered for Safety Case in 2017 - 2025

2. Enhancing MHI's Process Safety Performance through Safety Case

3. Case Study: Success of Safety Case

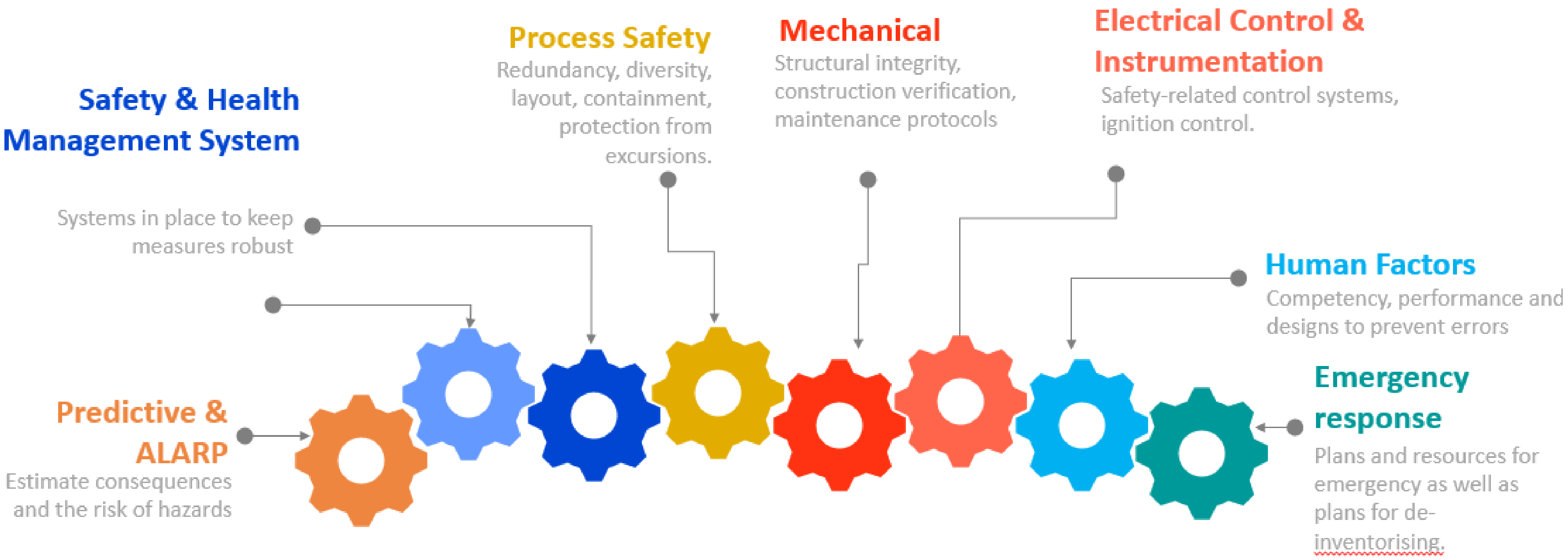
Singapore implements a Safety Case Regime to manage the Major Hazards Installations (MHIs) industry. MHIs process, manufacture or store large quantities of dangerous substances that are flammable or toxic. Examples of MHIs include oil refineries, petrochemical plants, chemical specialty companies, bulk storage terminals and warehouses.

Overview of Safety Case Regime for Major Hazards Installation (MHI)

Workplace Safety and Health (MHI[1]) Regulations, a performance-based approach for MHIs to implement the Safety Case regime

- A **Safety Case** is prepared by an MHI to demonstrate how to prevent and mitigate the consequences of major accident throughout the lifecycle of the facility.
- Focused on putting in place proportional measures to manage Major Accident risks to As Low as Reasonably Practicable (ALARP), rather than mere compliance

Shifting away from a prescriptive, one-size-fits-all regulatory approach, to allow ***greater flexibility*** for MHIs to tailor risk mitigating measures to best suit needs



[1] *Premises that process, manufacture or store large quantities of dangerous substances exceeding threshold quantities are regulated under the WSH (Major Hazard Installations) Regulations.*

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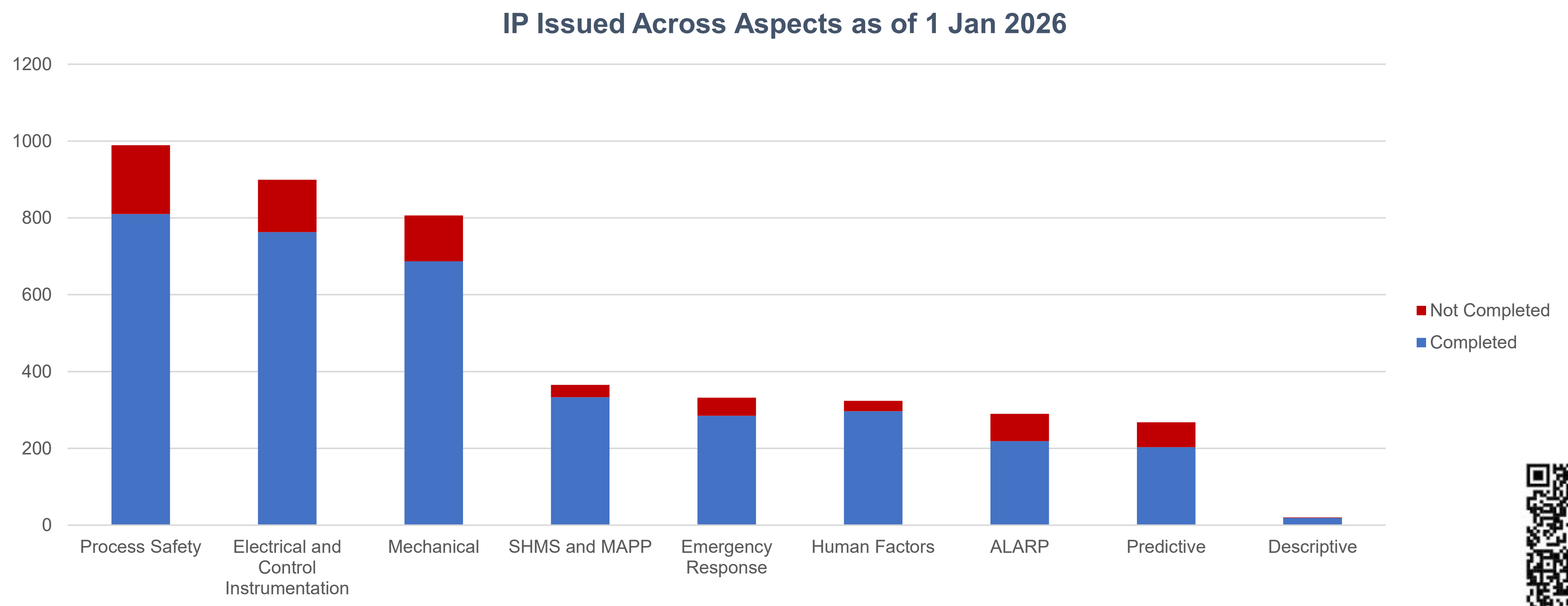
From 2017 to 2025, MHD assessed 119 Safety Cases. Top focus areas included Process Safety, Mechanical Integrity, and EC&I*.

- Intervention Plan (IP) items are issued to MHIs, to address potential deficiency in an MHI's measures for prevention and mitigation of major accidents.



Key IP Findings (2017-2021)

Electrical, Control, & Instrumentation

Key focus topics for Process Safety, Mechanical Integrity, and EC&I since the start of the Safety Case regime

Key Focus Topics	Process Safety	Mechanical Integrity	EC & I
Risk assessments are appropriate and comprehensive to identify necessary measures to reduce risk to ALARP • Chemical Reactive Hazard Demonstration • Process Hazard Analysis, LOPA assessment	✓		✓
Overpressure protection philosophy and design basis	✓		
Ex-Equipment for hazardous zone • Hazardous area classification (HAC) study and selection of equipment suitable for hazardous zone • Installation and Inspection of Ex-rated equipment	✓		✓
Design specifications of safety critical equipment and systems		✓	
Maintenance Regime for safety critical equipment and Inspection at appropriate intervals by competent persons		✓	✓
Overall ECI control strategy, including alarm management			✓

Enhancing Process Safety Performance through Safety Case

Risk Tolerability Targets: Enabling MHIs to systematically demonstrate major accident risks have been reduced to ALARP


ALARP Demonstration Guidelines: Single Scenario Risk Tolerability Target and Adequacy of Barriers

June 2020

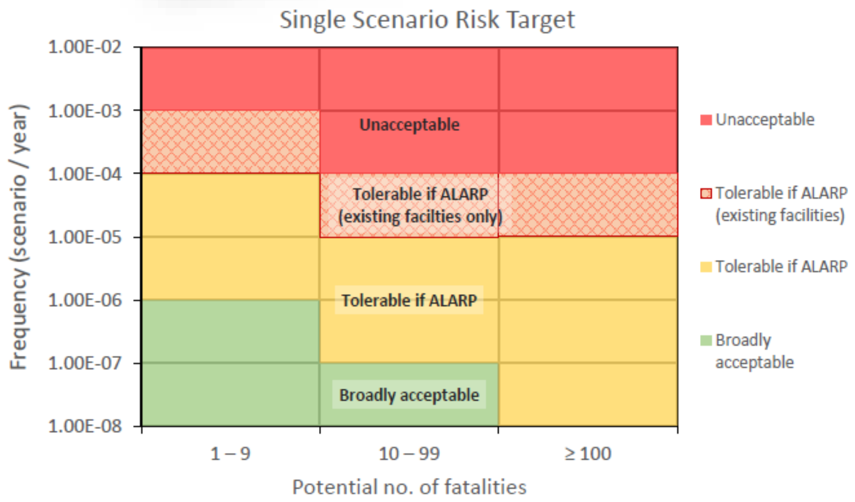
Revision 0

About this set of Guidelines:

Under the Workplace Safety and Health (Major Hazard Installations) Regulations 2017, Major Hazard Installations (MHIs) are required to demonstrate that their risks are identified and managed to as low as reasonably practicable ("ALARP").

This document, "ALARP Demonstration Guidelines: Single Scenario Risk Tolerability Target and Adequacy of Barriers", is intended to provide guidance to MHIs on:

- Risk tolerability targets, so that residual risks of Safety Critical Events (SCEs) are within the ALARP region of the risk tolerability target, taking into consideration the available barriers.
- The methodology for MHIs to assess whether adequate barriers have been provided to manage the risk of the identified major accident scenarios to ALARP.
- A list of references to guide MHIs in assessing the adequacy and robustness of their barriers.
- An implementation roadmap, specifying the target dates for phased implementation of the risk tolerability target and adequacy of barriers assessment.



- Publication of "ALARP Demonstration Guidelines" in 2020 to guide MHIs in assessing the adequacy of independent and effective barriers for risk reduction to ALARP

<u>Improvements</u>

\>> Protection against reactor overpressure.

- SIS was installed to add additional layers of protection to the reactor. Previously, the reactor relied solely on BPCS interlocks for overpressure protection, with the PSV not adequately sized to handle excessive gas generation.

\>> Protection against tank overfill

- SIS or BPCS automated overfill protection system were implemented to reduce reliance on human intervention.
- Alarm system was enhanced to introduce an additional layer of human response.

\>> Protection against escalation of events to safety critical events

- Gas detectors or leak detection software systems were installed to provide early detection of leaks.
- Isolation valves were installed to improve emergency shutoff and contain releases onsite instead of direct discharge to sea.

Pressure Relief System Revalidation: Strengthening MHIs' knowledge and compliance with industry standards

- Discussion on overpressure protection philosophy and the design basis of pressure relief valves (PRVs) have proven valuable in helping MHIs identify additional initiating events not captured in their HAZOP studies, and deepening their understanding of their overpressure protection systems.

- MHIs are advised to reference API 520/521 (Pressure-Relieving and Depressuring Systems) to demonstrate that the PRVs installed are adequate for the scenarios of concern.

<u>Improvements</u>

>> Identification of additional overpressure scenarios

- One MHI identified eight (8) additional credible overpressure scenarios for the distillation column and determined that the existing PRV was inadequately sized to handle the controlling case, necessitating replacement or resizing.

>> PSV replacement and piping modification

- Several MHIs replaced their PRVs to ensure the equipment could handle the controlling case for overpressure relief, and or modified the pipe sizing to manage pressure drop and back pressure across the overpressure protection system.

>> Enhanced external insulation of vessel designed to limit external fire heat input.

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Management of Ex-Equipment: Driving MHIs towards robust installation and inspection standards, and enhancing competency assurance

- MHIs are advised to reference the IEC 60079 series (Parts 14, 17 and 19) for the selection, installation, inspection and maintenance of Ex-equipment.
- The standard prescribes a structured initial and periodic inspection regime, to be carried out by competent persons, to ensure that equipment and its associated wiring remain in good condition and safe for use in hazardous zones.

MHD ECI FAQ


Unused entries must be sealed with certified plugs


Water Ingress into Ex-rated lighting

Improvements

>> Replacement or removal of unsuitable equipment in hazardous zones

- Unsuitable equipment were identified either by MHD during Safety Case inspections or by MHIs through their Hazardous Area Classification (HAC) revalidation studies

>> Implementation of structured Ex-inspection regime

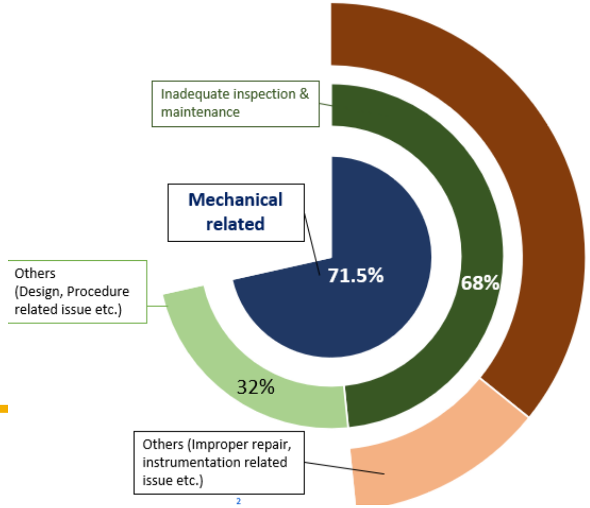
- MHIs identified actionable findings through the structured Ex-inspection.
- One MHI identified several defects such as exposed armoured wires at cable glands, incorrect cable gland used, damaged earth lug, and unsealed pipe cable entry holes.

>> Enhanced competency assurance

- Ex-inspections were carried out by suitably skilled and competent personnel certified under international certification schemes or who had completed the relevant WSQ courses.

Mechanical Maintenance Regime: Driving MHIs conformance with international codes and standards, beyond prescribed regulatory requirements

- Maintenance regime should be established for all safety critical vessels handling dangerous substances. The Mechanical Integrity Programme should account for the damage mechanisms applicable to the equipment, with inspection results thoroughly assessed to determine the appropriate next inspection interval.



MHD Process Related Incident analysis (2018 - 2024)

CUI at insulation support ring

Tank Internal Inspection

Improvements

>> Aligning inspection scope with relevant API standards such as API 571 and API 653

- MHIs identified damage mechanisms associated with safety-critical equipment, with inspections conducted/ planned to detect applicable failure modes.
- Internal Inspections conducted to assess the equipment condition.
- UTG thickness measurement utilised to assess corrosion rates and calculate the remaining life of equipment.

>> Investigation of failures based on inspection results. Next inspection interval brought forward where necessary

- Commonly seen for PRVs and corrosion-related inspections

EC & I Maintenance Regime: Surfacing management and maintenance gaps to drive MHI reliability improvements

- All EC&I equipment, including safety interlocks, has potential for failures. Intervention plans were issued to MHIs that had failed to implement a suitable maintenance and inspection regime for safety-critical EC&I equipment, or where the scope of the regime was inadequate to detect all potential failures.

- Discussion on Functional Safety Management helped uplift MHI's competency in IEC 61511 and deepened their understanding on the adequacy of their Safety Instrumented System (SIS).

Guidelines on SIS in MHIs

Improvements

>> Enhanced reliability and availability of safety critical EC&I equipment

- Suitable maintenance and inspection regime implemented for safety-critical BPCS interlocks and gas detection system.
- Proof testing procedures updated to adequately reveal all dangerous failure modes, including end-to-end loop tests to check against design specification.

>> Better alignment of SIS management with IEC 61511

- Safety Requirements Specifications (SRS) and SIL verification reports reviewed and improved.
- System implemented to identify, investigate, and track SIS failures.
- Functional safety assessments conducted, with further areas for improvement identified.

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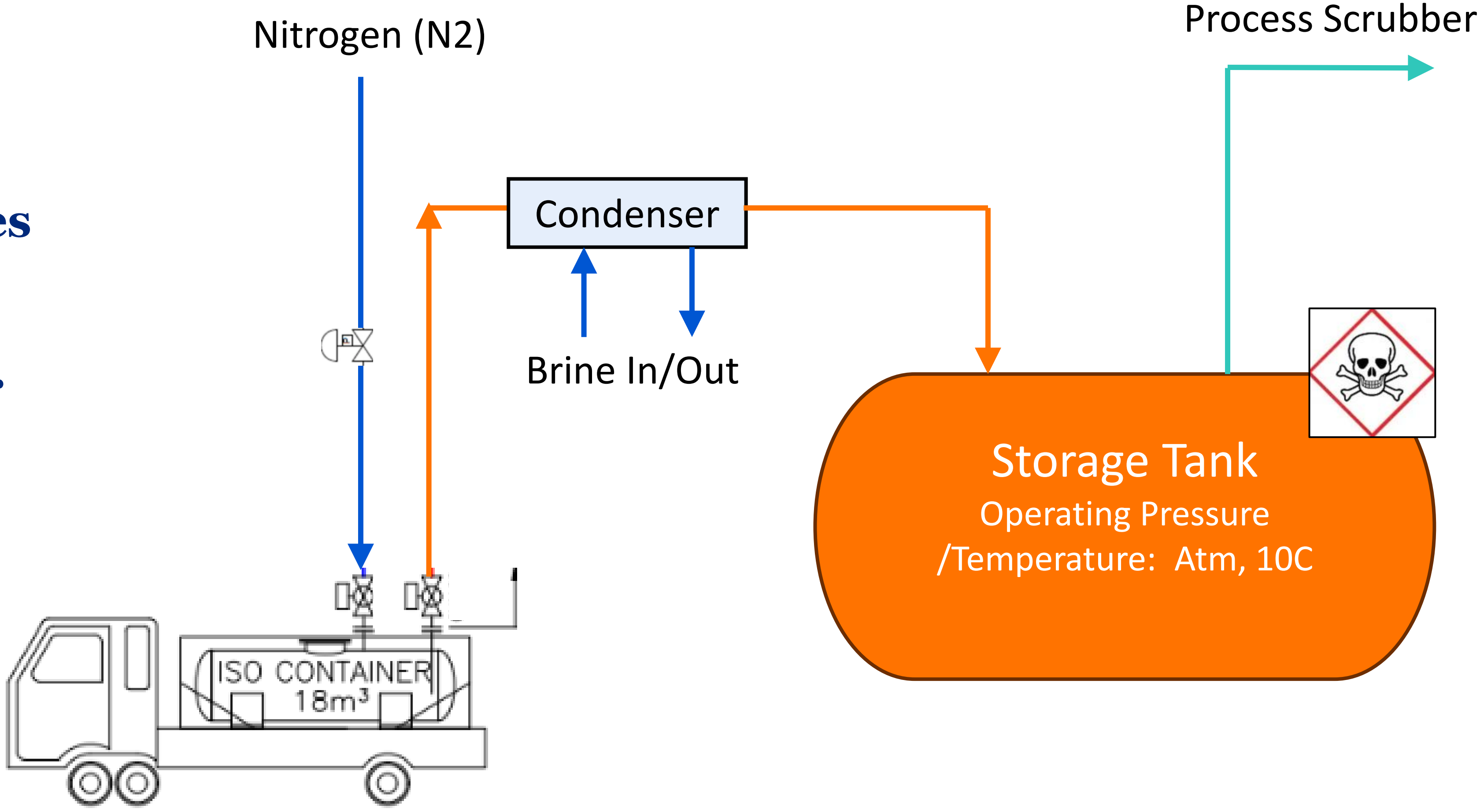
Case Study:
Success of Safety Case

Safety Critical Event (SCE) Scenario: Rupture of a Toxic Substance Storage Tank

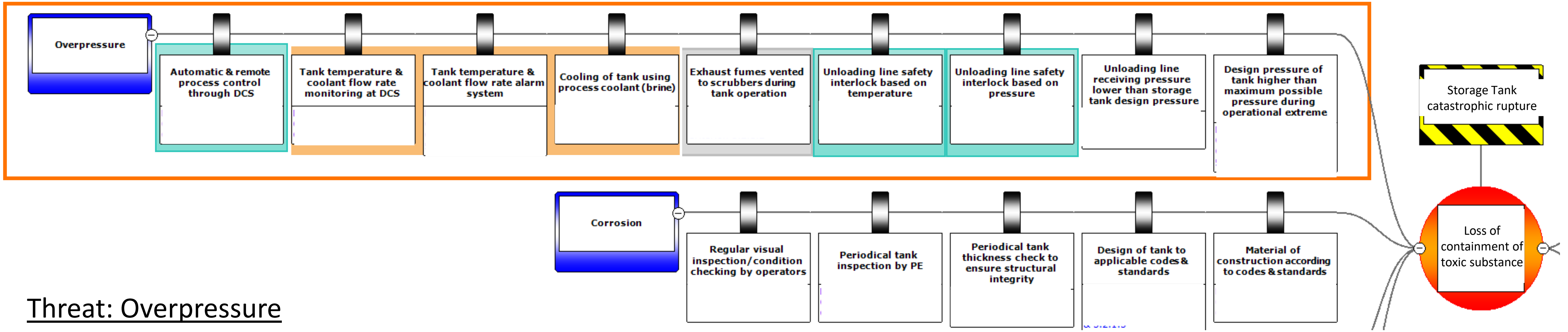
Jurong Island

> 100 Fatalities

~ 8 E - 6/ year



MHI unable to demonstrate adequate risk reduction measures for major toxic release scenario to ALARP



<u>Threat: Overpressure</u>

- Bowtie representation of hazards and barriers could be strengthened to show the linkage.

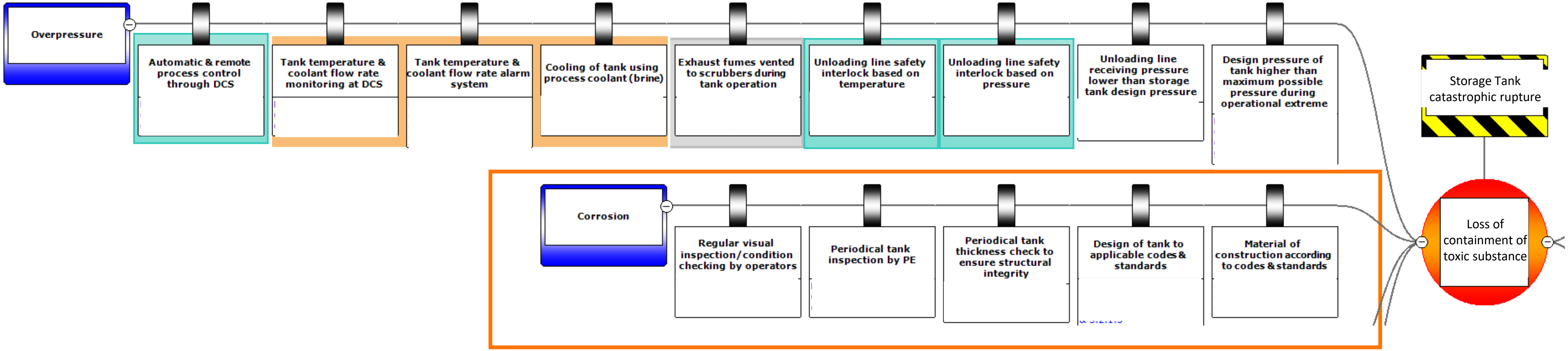
  >> The initiating event leading to overpressure required clearer identification (i.e. What cause the overpressure?)

  >> A review of the barriers presented was needed to ensure their effectiveness and independence from one another (i.e. common mode of failure)

  >> The adequacy of protection should be assessed based on the quality rather than the quantity of measures

- The storage tank had no Pressure Relief Device. Further demonstration was needed to confirm whether the open system connected to the process scrubber could adequately relieve pressure.

MHI unable to demonstrate adequate risk reduction measures for major toxic release scenario to ALARP



<u>Threat: Corrosion</u>

- Documentation to demonstrate compliance with recognised mechanical standards (e.g. ASME) was not available
- Mechanical inspections on the tanks had not been carried out since commissioning in 2000

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Safety Case Intervention Plans (IPs) to drive MHIs to demonstrate that the toxic risk has been reduced to ALARP

- Carry out hazard identification using a quantitative method
- Review effectiveness of all existing measures and identify new measures where necessary
- Certify the storage tank based on recognised mechanical standards (e.g. ASME) and institute an appropriate maintenance strategy for the tank
- Review operator’s reliability in emergency situations, using established methodology (e.g. human reliability assessment)
- Review the design basis of existing emergency scrubber
- Over the Safety Case submissions, the MHI has progressed and made improvements. See next slide for more details.

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Safety Case interventions yielded improvements across multiple areas following sustained engagements

Engineering Controls

Preventive Measures

Hazard Identification
MHI carried out quantitative risk analysis

Design Documentation
MHI engaged TUV SUD to perform design calculations and the tank design was 3 times more than what was known.

Preventive Measures
- Installed an additional pressure relief valve on the inlet line

Operator's Response to Alarms
- Reviewed alarm setpoint of tank
- Safety critical task analysis (in progress)

Mitigative Measures

Gas Detectors
Installed additional toxic gas detectors

Water Deluge System
- Installed water sprinkler around the storage tank

Emergency Scrubber
- Activated via two different types of toxic gas detectors
- Increased emergency scrubber capacity to 5 hrs

Administrative Controls

Maintenance Strategy
- Instituted maintenance programme for storage tank
- Engaged API inspector to conduct external inspection, welding inspection and ultrasonic thickness gauging

Emergency Response
Reviewed ERP to ensure toxic scenario is included

Looking Back, Moving Forward

- The Safety Case Regime provides MHIs with a structured means of demonstrating the adequacy and robustness of their risk management measures.

- MHIs have deepened their understanding of major hazards and risks, and developed more robust measures to manage them

- MHIs should continue to manage risks to ALARP based on the principles of proportionality, striving beyond regulatory compliance.

- MHD and MHIs to sustain the 2-way engagement to translating discussion into tangible improvements in process safety performance across the industry.

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Thank you

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