Empowered *workforce*, Thriving *workplaces*

Major Hazards Department: Operational Updates and Strategic Overview: Findings from Thematic Inspections

SCIC Safety Case Seminar 2026

Ministry of Manpower

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15 July 2026

Contents

Source: Wall Street Journal, 19 June 2026

Ageing chemical plants is a cause of concern in the United States

There were 131 serious chemical accidents in 2025, the government data show, up 20% from the year before. Of these, 89 resulted in at least one death or serious injury. All told, chemical accidents killed 48 people in 2025—almost double 2024's toll—and seriously injured 142.

So why is this happening? Former CSB and Environmental Protection Agency officials, as well as industry safety experts, attribute much of the rise in accidents to years of deferred safety maintenance on aging plants. The average U.S. chemical plant is 46 years old, and the average petrochemical and refining infrastructure is 61 years old in North America. Meanwhile, typical equipment has a useful life of about 20 years.

Thematic inspections introduced in 2025 to improve our regulatory oversight on emerging threats/concerns to MHIs

Emerging threat

↓

Adverse Weather Events (AWE)
(May 2025 – Mar 2026)

- Conducted AWE inspections for over 60 MHIs
- Focused on measures associated with adverse weather events

Analysis of reported process-related incidents

↓

Mechanical Integrity Programme (MIP)
(Jul 2025 – Mar 2026)

- Conducted MIP inspections for over 40 MHIs
- Focused on management of corrosion, flange and ageing plant-related issues

Owing to global climate change, extreme weather events was identified as one of the top risks in the global risks severity ranking

Global Risks Severity Ranking

Risk categories
- Economic
- Environmental
- Geopolitical
- Societal
- Technological

	2 years	10 years
1st	Misinformation and disinformation	Extreme weather events
2nd	Extreme weather events	Biodiversity loss and ecosystem collapse
3rd	State-based armed conflict	Critical change to Earth systems
4th	Societal polarization	Natural resource shortages
5th	Cyber espionage and warfare	Misinformation and disinformation
6th	Pollution	Adverse outcomes of AI technologies
7th	Inequality	Inequality
8th	Involuntary migration or displacement	Societal polarization
9th	Geoeconomic confrontation	Cyber espionage and warfare
10th	Erosion of human rights and/or civic freedoms	Pollution

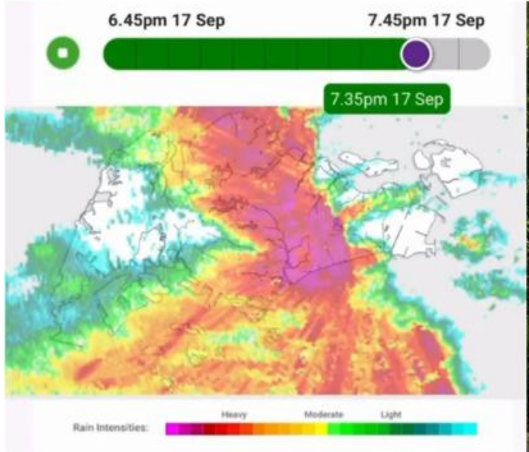
Source
World Economic Forum Global Risks Perception Survey 2024-2025.

Adverse Weather Event in Singapore in 2024

This was the Sumatra Squall that swept across S'pore from west to east on Sep. 17 night

Wet and windy evening.

Matthias Ang | September 18, 2024, 09:45 AM
mothership



While adverse weather events (AWE) in Singapore may be infrequent, this relative rarity can create a false sense of security, leaving MHIs unprepared and vulnerable when such events do occur

- Adverse weather conditions such as strong winds, floods, and storms can impact installations that process, store, or handle hazardous substances, potentially resulting in the release of hazardous substances, fires, or explosions

- Frequency and intensity of natural hazards linked to climate change are expected to worsen in coming decades
  - May occur in locations where they have not previously been observed

- Singapore's geographical location protection from tropical cyclones creates false sense of security
  - On 30 Apr 2022, a container office was blown off by strong wind during heavy rain proved that unexpected weather events can occur

AWE linked to Criterion 2.8 and Criterion 10.1 of SC. For 10.1, MHI has the general duty to ensure that all SCE risks are reduced to ALARP

2.8 The safety case shall describe the vicinity of the installation in sufficient detail to allow the consequences of a major accident to be assessed.

Information on external factors which may lead to or exacerbate major accidents such as:

a) the topography, if it could have an effect on the dispersion of toxic or flammable gases or combustion products. This should include buildings or other structures where appropriate;

b) local weather records, including wind speed, wind direction and atmospheric stability and the relevance of this information to the behaviour of releases of dangerous substances;

c) history of the land on which the installation is located, together with its vicinities, may be significant when considering major accident causes. For example, land subsidence could be considered in reclaimed industrial land like Jurong Island as this is a threat to equipment integrity (i.e. contributing to stress and strain on piping and equipment);

d) historical evidence of other external events that might cause accidents such as flooding, extreme weather conditions including temperature, rain, wind and lightning; and

e) transport activities that may have an impact, including shipping, major transport routes and dangerous substance movements.

AWE linked to Criterion 2.8 and Criterion 10.1 of SC. For 10.1, MHI has the general duty to ensure that all SCE risks are reduced to ALARP

Safety Cases are expected to:	So, ask yourselves…	What to do…
Present options	What more can MHIs do to reduce the risks?	• Look systematically at each SCE • Draw up, in proportionate way, a list of control measures that have been implemented and which could be implemented to further reduce the risks of SCE
Make reasoned arguments	What further risk reduction measures (RRM) are "reasonably practicable"?	• Qualitative or quantitative • Sacrifice grossly disproportionate to benefits? Justify why the additional RRM is rejected • If the control measure is 'reasonably practicable' based on sound logical considerations, implement that measure
Explain why the risk reduction measures put in place reduced risks to ALARP		
Conclude	What is a reasonable implementation timeline and who is responsible to see through its implementation?	• Develop action plan

AWE ops was launched to proactively address emerging threat that could potentially lead to major accident in MHIs if left unchecked

May 2025 – Mar 2026
Programme Period

62
MHIs inspected

Educate MHIs

- Raise awareness of possible adverse weather conditions in Singapore and emphasise the importance of planning for such eventualities

Identify and Assess

- Ensure that the risk of adverse weather conditions is appropriately assessed and mitigated in the design and operation of their installations to As Low As Reasonably Practicable (ALARP)

Take Action

- Incorporate adverse weather risks into the Safety Case and demonstrate that risks to Safety Critical Events (SCE) and Major Accident Scenarios (MAS) arising from adverse weather events have been reduced to ALARP

AWE inspections focused on adverse weather risk management and emergency response plan

- What were the Safety Critical Events (SCE)/Major Accident Scenario (MAS) risks associated with adverse weather events?
- Has MHIs prepared adequate response and emergency plans to tackle such risks?
- Has MHIs addressed longer-term risks in their plans and managed SCE/MAS risks to as low as reasonably practicable (ALARP) ?

Although AWE is relatively new for most MHIs, almost 70% of MHIs inspected have conducted risk assessments (RA) on AWE

RA further considered SCE/MAS due to natural hazard induced disruption (e.g. loss of safety critical utilities)

Control measures to be implemented / actions to be taken are identified (e.g. using portable flood barriers to divert water flow)

RA conducted to evaluate SCE/MAS risks associated with AWE

** Strong winds was identified as the top adverse weather hazard of concern followed by heavy rainfall/flooding and lightning*

Other AWE-specific conditions considered that resulted in some change to the outcome of SCE/MAS (e.g. flooded containment dikes)

Main damage modes identified for the equipment were associated with SCE/MAS

While most existing emergency response plans (ERPs) and recovery systems were sufficient, AWE management could be better integrated into Safety Case for demonstration

Emergency Response

Reviewed site-specific emergency response plans (ERP)

Personal protective equipment for emergency response are available and in good condition

Staff are trained on adverse weather risks and response procedures

Recovery

Means to assess damage to equipment, contamination risks, and potential failures are identified

Documentation

Information on adverse weather conditions that could potentially contribute to accidents incorporated into the Safety Case

Assessed SCE/MAS risks due to adverse weather effects have been reduced to ALARP in the Safety case

Example of Adverse Weather RA (1)

Site screening for natural hazards				
Natural hazards	**Applicable to site**		**Reference/ sources**	**Actions**
	Yes	**No**		
Meteorological				
Flood/Storm Surge	✓		Flash foods have been observed in Singapore in recent years	To update the risk assessment
Hurricane/Tropical Cyclone		✓	No huricane of tropical cyclone reported in Singapore Tropical Cyclones.pdf	NA
Extreme Temperature	✓			Update the Risk assessment table
Snow/Ice Storm		✓		NA
Wildfire		✓	So far no reports of wildfire in Singapore	NA
Straight-line Winds	✓		Strongest statight line winds was recorded at Tengah, on Apr 25, 1984. Mar 30, 2018, A storm with winds reaching 133 km/h in Tengah caused damage to farms in Lim Chu Kang, The Straits Times strongest gust recorded since 2010.	Update the Risk assessment table
Geological				
Earthquake		✓	Singapore is located in a region with low seismic activity, meaning it's far from active tectonic plate boundaries and major earthquake zones.	NA
Landslide		✓	As Singapore is located next to the equator, where rainfall is abundant, frequent and intense downpours are the most common causes of landslides here, said Associate Professor Darren Chian from the National University of Singapore's department of civil and environmental engineering. With Singapore's relatively flat topography, he said, landslides are smaller in scale, less damaging and generally less common here than in other countries in the region.	NA
Tsunami		✓	While Singapore is surrounded by water and could theoretically be affected by a tsunami, it's generally considered to be at low risk due to its location and the protection provided by the Indonesian archipelago. The 2004 Indian Ocean tsunami did not significantly impact Singapore, although it did trigger minor tremors felt in some areas.	NA
Volcanic Eruption		✓	Singapore does't sit atop any volcanoes, nor is it on tectonic plate boundary that would make eruptions likely.	NA
Dam Rupture		✓	There is no documented or histprical evidence of dam failure in Singapore. The dams are engineered and maintained by PUB with robust design and monitoring protocols aligned to international standards.	NA

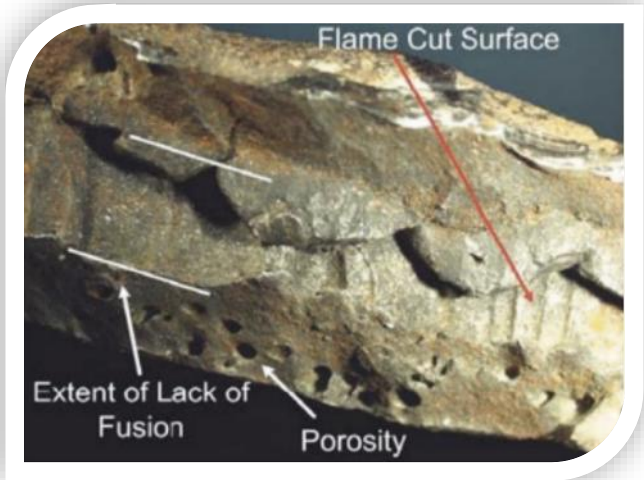
Example of Adverse Weather RA (2)

Hazard	Damage	Consequence	Existing safeguards	Likelihood	Onsite risk	Offsite risk
Heavy rain leading to flood	Few inches of water into the buildings	- Fire pumps damage - Water ingress to chemical warehouse	- Drain system is available. - Inspection for leaves at drain line - Warehouse are installed with hump - Solvents are stored in IBC. Heavy items are stored at lower levels. - Drums are secured with the pallets - fire Pumps are installed above 200mm - Main switch borad is located at 100mm above the ground.	L	M	NA
	Water in the secondary containment (Retention tank)	Loss of secondary containment due to flooded containment dikes	- Storm water retention capacity of 120M3	L	H	NA
Extreme temperature	- Heat stress to the staff - Warehouse temp go high	- Heat exhaustion - Fire hazards due to ambient temperature above flash point.	- WGBT monitoring twice in a day - Equipment in the flammable area is ex-proof and designed for Hazardous class 2.	M	M	NA
Straight-line Winds	- empty containermay fly off - Scrubber may collapse	- Property damage - Chemical leakage (residue)	- IBC with chemiclas are stored within the sheltered place. - Fire pumps, chollers and cooling towers are mounted on the concrete plinth.	M	M	NA
Lightning	- Lightning strikes on employees while working out door - Lightning strikes on building	- Fatality - Fire - Property damage	- Employee are not allowed to work when there is thunder storm - Lightning arrestors are installed on the building - Yearly resistance check for earthing conductor	L	M	NA

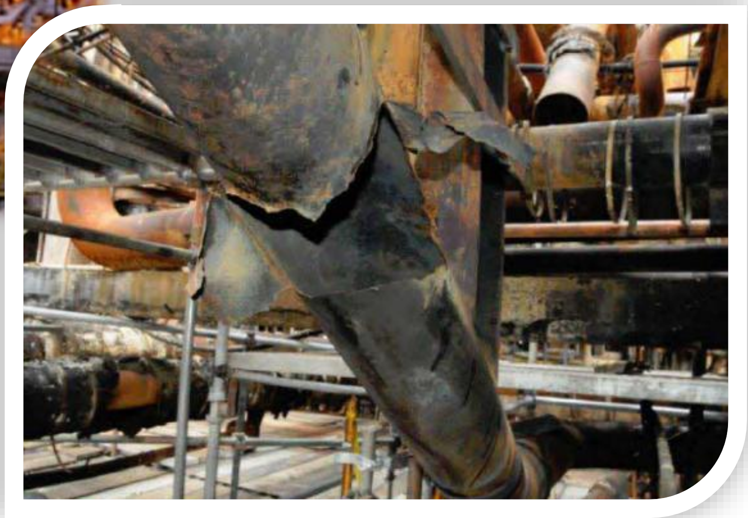
Example of Adverse Weather RA (3)

Hazard	Damage Mode	Consequence	Existing Safeguard	Severity	Likelihood	Overall Risk Rating
High wind speeds	Infrastructure affected - tanks fail in high wind speeds	High winds buckle tank shells causing LOC. Tank contents may ignite causing pool fire/flash fire/BLEVE	• Storage tanks constructed in accordance to API 650 & API 653 to withstand high wind speeds	Very High	Low	Low
		High winds overturn near-empty tanks causing LOC. Tank contents may ignite causing pool fire/flash fire/BLEVE	• Tanks are anchored down to prevent overturning • Floating roof tanks have wind girders to prevent buckling • Emergency Response	Very High	Very Low	Low
		High winds turn unsecured objects into projectiles, damaging equipment and causing LOC. Process materials may ignite causing pool fire/flash fire/BLEVE	• Generally no trees in tank farm area. • Tank structures (e.g. railings and staircases) are secured to tanks per approved code and standards • Emergency Response	Very High	Low	Low
Heavy rain	Tilting of tank's external floating roof	Heavy rain and poor roof drainage tilt external floating roofs, causing LOC and potential tank surface fires.	• Roof buoyancy/drainage follows API 650. • Post-rain operator rounds verify drain flow and function. • Electrical grounding	High	Very Low	Low
	Tanks lifting off foundations	Flood buoyancy may lift tanks off foundations, resulting in potential LOC.	• Tank weight and deep foundation anchoring prevent flood buoyancy displacement	High	Very Low	Low

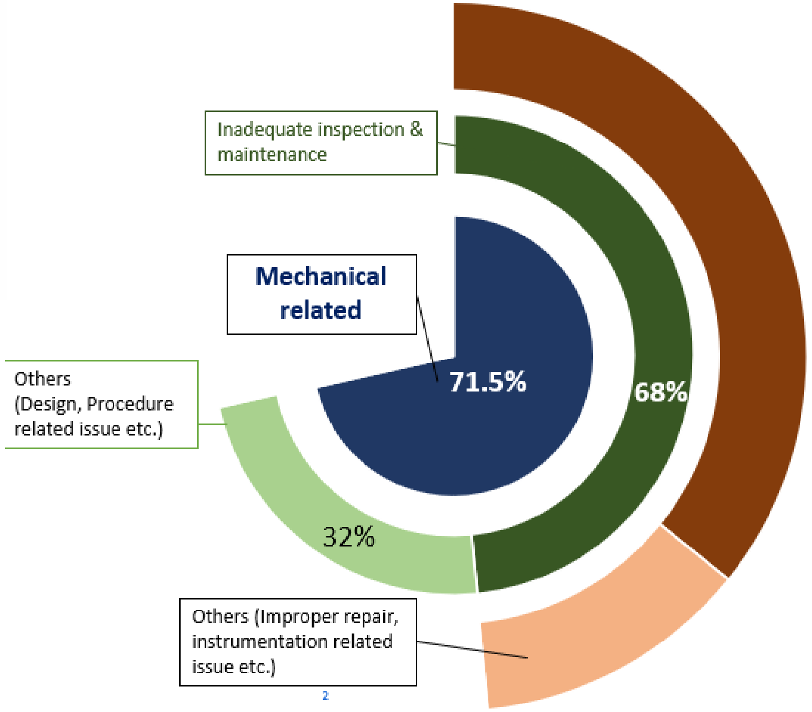
Why focus on mechanical integrity?



Marcus Oil and Chemical Tank Explosion, (2004)



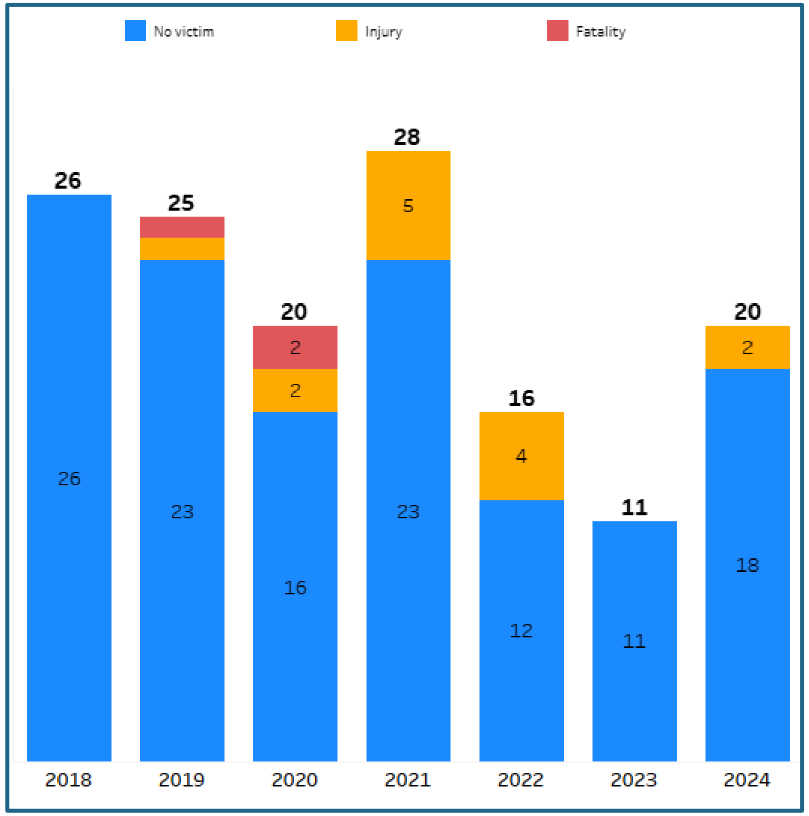
Chevron Richmond Refinery Fire (2012)



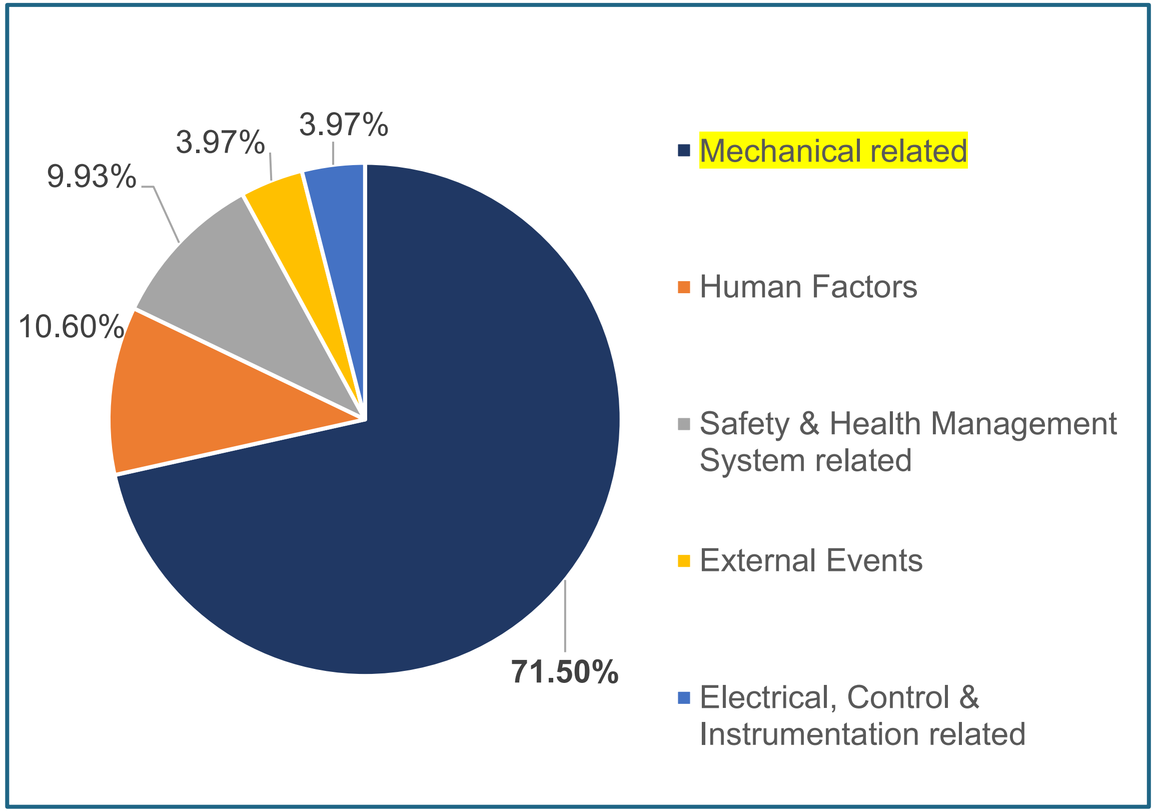
MHD Process Related Incident (PRI) analysis (2018 - 2024)

Top contributor (72%) of Process-Related Incidents (PRIs) in Singapore

PRIs Reported from 2018 – 2024



Breakdown of PRI Cause



Mechanical integrity programme (MIP) was launched to harpen MHD's inspection efforts relating to flange, corrosion, and ageing plant issues

Jul 2025 – Mar 2026
Programme Period

46
MHIs inspected

1) Flange Management

- Pipe specification records
- Flange tightening procedures
- Flange assembly checklist
- Identification of critical flanges
- Training

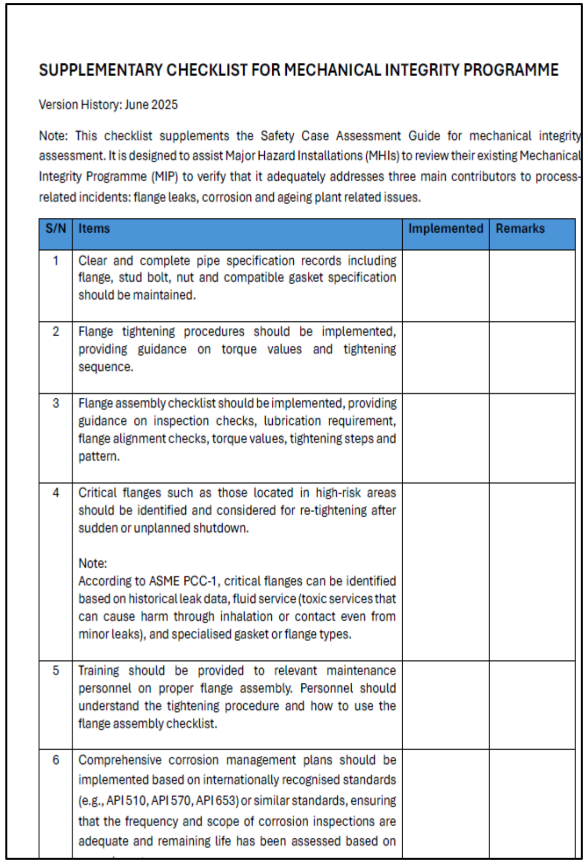
2) Corrosion Monitoring

- Inspection and maintenance programme/SOP
- Inspection of PVs, atmospheric tanks, piping

3) Ageing Plant Related Issues

- Identification of ageing equipment (<10 years remaining life)
- Inspection of ageing equipment
- Fitness For Service (FFS)

85% of MHIs inspected have established in-house flange tightening procedures but more could be done for better assurance of flange assembly on-site

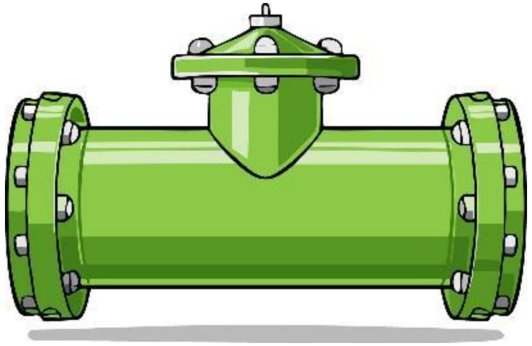


SUPPLEMENTARY CHECKLIST FOR MECHANICAL INTEGRITY PROGRAMME

Version History: June 2025

Note: This checklist supplements the Safety Case Assessment Guide for mechanical integrity assessment. It is designed to assist Major Hazard Installations (MHIs) to review their existing Mechanical Integrity Programme (MIP) to verify that it adequately addresses three main contributors to process-related incidents: flange leaks, corrosion and ageing plant related issues.

S/N	Items	Implemented	Remarks
1	Clear and complete pipe specification records including flange, stud bolt, nut and compatible gasket specification should be maintained.		
2	Flange tightening procedures should be implemented, providing guidance on torque values and tightening sequence.		
3	Flange assembly checklist should be implemented, providing guidance on inspection checks, lubrication requirement, flange alignment checks, torque values, tightening steps and pattern.		
4	Critical flanges such as those located in high-risk areas should be identified and considered for re-tightening after sudden or unplanned shutdown. Note: According to ASME PCC-1, critical flanges can be identified based on historical leak data, fluid service (toxic services that can cause harm through inhalation or contact even from minor leaks), and specialised gasket or flange types.		
5	Training should be provided to relevant maintenance personnel on proper flange assembly. Personnel should understand the tightening procedure and how to use the flange assembly checklist.		
6	Comprehensive corrosion management plans should be implemented based on internationally recognised standards (e.g., API 510, API 570, API 653) or similar standards, ensuring that the frequency and scope of corrosion inspections are adequate and remaining life has been assessed based on		



Availability of pipe specification record

Established flange tightening procedure

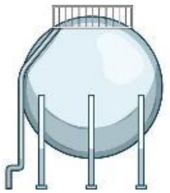
Training provided to relevant maintenance personnel and contractor

Availability of flange assembly checklist

- MHIs believed that flange tightening procedure is sufficient
- MHIs opined the practicality of developing individual checklists for every flange

Corrosion Management: Satisfactory for Pressure Vessels and Storage Tanks, but Piping Requires Improvement

Pressure Vessel (PV)

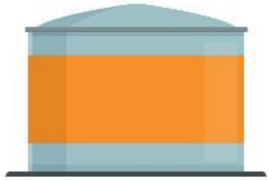


Inspection conducted for PVs

Inspection done in accordance with recognised standards

Calculated vessel remaining life based on thickness gauging and corrosion rate

Storage Tank



Inspection conducted for storage tanks

Inspection done in accordance with recognised standards

Calculated tank remaining life based on thickness gauging and corrosion rate

Piping

Inspection conducted for piping

Inspection done in accordance with recognised standards

Calculated vessel remaining life based on thickness gauging and corrosion rate

Within 5 to 10 years, more MHIs are expected to have equipment with less than 10 years of remaining life. Proactive management of ageing equipment required

Proper management of ageing plant can:

1) **Prevent loss of containment** of equipment that could potentially lead to major accident scenarios

2) **Extend** equipment **lifespan** and **increases reliability**

3) **Reduce unplanned downtime** and **maintenance cost**

According to studies done by Association of Materials Protection and Performance (formerly known as NACE), corrosion costs over **US$2.5 trillion globally (3.4% of 2013's global GDP)**, but **implementing proper corrosion control measures** could save US$375-875 billion annually (i.e. **15 – 35% cost savings**).

Importantly, ageing plant is not just related to the chronological age of the plant

- A plant that is chronologically 'old', but the equipment is well inspected and maintained, and remains fit for service may not be considered ageing plant

- A new plant can experience accelerated ageing or early ageing (due to corrosion, erosion etc) even though its chronological age is ‘young’

API standards applicable to ensuring MI

Equipment Strategy	Reference
Identification of damage mechanism.	API 571- Damage mechanisms affecting fixed equipment in the Refining Industry
Atmospheric Tanks	API 653 – Tank Inspection, Repair, Alteration, and Reconstruction
Pressure Vessel System, including Pressure Relief Devices	API 510 – Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration
Piping System	API 570 - Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems
Flange Management	ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly
Ageing Plant	API 579 – Fitness for Service

Key takeaway: Importance of incorporate aspects of adverse weather elements and mechanical integrity into your Safety Case

- <u>Adverse Weather Elements</u>
  - Novel topic for most MHIs
  - For those not engaged by MHD, to begin identifying relevant hazards and risks and implementing the necessary precautions in response to the impacts of climate change
  - For those who have been engaged, stay up-to-date on changes and learn from past accident cases

- <u>Mechanical Integrity</u>
  - Most MHIs already have systems in place for flange integrity assurance and mechanical integrity for pressure vessels, piping, and storage tanks.
  - However, continual improvement needed as more MHIs are expected to have ageing equipment within next 5 – 10 years,
  - MHD will incorporate checks on MHIs' ageing equipment management as part of our Safety Case intervention visits

Thank you

Ministry of Manpower