

Importance of Design for Safety

VISION ZERO

ZERO Accidents · ZERO Injuries · ZERO Fatalities

Towards Vision Zero

Lessons Learned from Past Incidents

Safe Design Principles



Eliminate Hazards



Engineering Controls



Safety by Design



Chemical Plant Explosion



Construction Falls



Train Collision

Lessons from Past Incidents

Learning from the Past



Root Cause Analysis



Incident Investigations



Case

Building a Safer Future



Risk Assessment



Safety Innovations



Human Factors



Fundamentals of Design for Safety

SAFE WORKPLACE

SAFE SYSTEMS



IMPORTANCE OF DESIGN FOR SAFETY TOWARDS VISION ZERO

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PE(Chem), CEngSpore, SrMAIChE, SrMIES, MACS, CCPS Fellow



Combustible Dust Explosion Seminar
Singapore Chemical Industry Council, SCIC
13 May 2026, SCIC Training Room



Importance of Design for Safety towards Vision Zero

1. Lessons Learnt from Examples / Incidents
2. Facts: MNC versus SME on Process Facility
3. Fundamentals of Design for Safety
4. Design for Safety Professionals

Strive for Operations Excellence and Sustainability

1. Lessons Learnt from Examples / Incidents



Air-con repairman dangles outside 12th storey HDB flat **without harness, risks life for few hundred dollars**

1. Lessons Learnt from Examples / Incidents



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1. Lessons Learnt from Examples / Incidents



Safer Design – Purpose Built Ledge for Air-con Condensing Unit

1. Lessons Learnt from Examples / Incidents

Is This Safe?



Switches are **less than a Foot** away from the Shower and located inside the **Curtain!**

1. Lessons Learnt from Examples / Incidents

Is This Safe?

Unsafe Conditions

Switches are less than a Foot away from the Shower and located inside the Curtain!

1. Lessons Learnt from Examples / Incidents

Is This Safe?



What went wrong?

1. This Power Plug is connected Exactly on the Opposite Side of The Shower
2. Wrong Power Switch is used

1. Lessons Learnt from Examples / Incidents



THE STRAITS TIMES

Saturday, June 04, 2022

Trio electrocuted in flat

Deaths of 3 family members a misadventure: Coroner

Accident involved water heater that had been installed in unsafe manner

Shaffiq Alkhatib
Court Correspondent

A man and his parents were electrocuted in 2020 in a case involving a water heater that had been installed in an unsafe manner. Yesterday, State Coroner Adam Nakhoda found the trio's deaths to be a misadventure.

The tragedy, which took place in the elderly couple's HDB flat in Ho Ching Road in Jurong on Dec 10 that year, claimed the lives of Mr Omar Abdul Manan, 80, his wife Asmah Bujang, 66, and their son Muhamad Ashikin Omar, 45.

State Coroner Nakhoda noted yesterday that the model of the water heater in the case had been approved for use in Singapore.

Describing the case as a "truly tragic accident", he stressed that such appliances should be properly installed according to the specifications of manufacturers.

State Coroner Nakhoda said Mr Omar, who was found in the bathroom, was electrocuted when he was taking a shower.



The accident, which claimed the lives of an elderly couple and their son, took place in the couple's flat in Jurong in December 2020. When investigators checked the flat after the accident, they found that the residual current circuit breaker did not protect the main electricity circuit for the whole unit, but only the utility room. PHOTO: LIANHE ZAOBAO

Madam Asmah suffered a similar fate after she rushed in to help him.

Mr Ashikin, who arrived at the flat later, was also electrocuted when he tried to help his parents.

The couple's daughter told investigators she did not know who had installed the water heater.

In an earlier proceeding, the court heard that a three-pin plug connected to an electrical socket

had been used to supply power to the heater.

Senior associate engineer Goh Chin Fong from the Energy Market Authority testified in March that the heater should have been connected directly to a double-pole switch instead of a wall plug.

Mr Goh, who had given expert testimony, described a double-pole switch as one with an "on-off

switch with an on-off light".

When investigators disassembled the water heater's three-pin plug, they found that the neutral and earth cables had fused together.

This caused the current to flow back to a heating tank in the water heater, energising a metallic hose connected to the tank.

Mr Goh said the cables in the

three-pin plug could have fused together because of overloading.

A double-pole switch is safer as the cables are spaced farther apart, minimising the risk of the cables fusing together.

The court heard that the water heater should have caused a power trip because of the electricity leakage and this would have cut off power to the unit.

But when investigators checked the flat, they found the residual current circuit breaker (RCCB) did not protect the main electricity circuit for the whole unit. Only the utility room was protected.

The couple had lived in that flat since the 1970s. Back then, HDB homes were not installed with RCCBs, said Mr Goh.

He added that HDB installed the circuit breakers only from the 1980s and an RCCB was added to the couple's home during an upgrading exercise about 30 years after they had moved in.

However, in their home, it protected only the utility room.

HDB flats in the 1970s also did not have double-pole switches, said Mr Goh in March, adding that it was because water heaters were not widely used then.

Responding to queries from The Straits Times, HDB said all flats built since 1985 have been installed with the RCCB.

Its spokesman added: "As with all fittings and fixtures, RCCBs can be subject to fair wear and tear over time.

"Hence, as part of their regular home maintenance, flat owners should also test their RCCB regularly to ensure that it is in good working condition.

"Residents who are unsure what an RCCB is or where it is located can contact an HDB branch (office) for advice."

Four family members were in court yesterday but they declined to comment when approached.

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1. Lessons Learnt from Examples / Incidents



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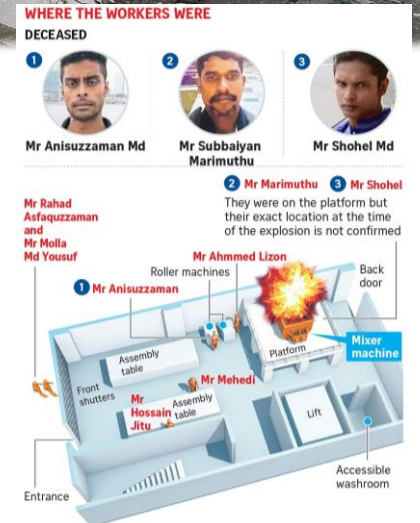
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com.sg

**EMA on Water Heater Safety:
To replace 3-Pin Plug to Double-Pole Switch**

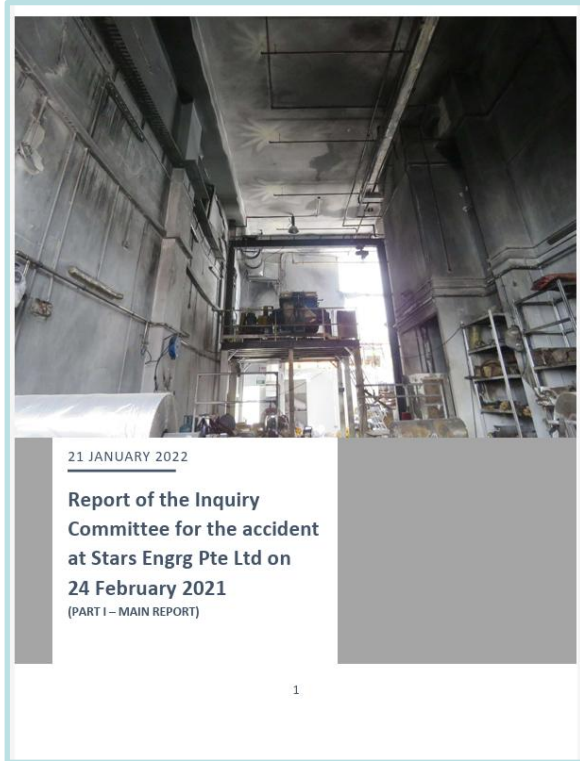
1. Lessons Learnt from Examples / Incidents

Tuas dust explosion incident – 24 February 2021



1. Lessons Learnt from Examples / Incidents

Report of the Inquiry Committee for the accident at Stars Engrg Pte Ltd on 24 February 2021



PART I

Government Accepts Recommendations by the Tuas Explosion Inquiry Committee, 25 March 2022

<https://www.mom.gov.sg/-/media/mom/documents/safety-health/reports-stats/stars-engrg-inquiry-committee-report-part-1.pdf>



PART II Annexes I, II, III, IV

<https://www.mom.gov.sg/-/media/mom/documents/safety-health/reports-stats/stars-engrg-inquiry-committee-report-part2-annex-1.pdf> [Annex I]

1. Lessons Learnt from Examples / Incidents

✓ Tuas dust explosion incident – 24 February 2021

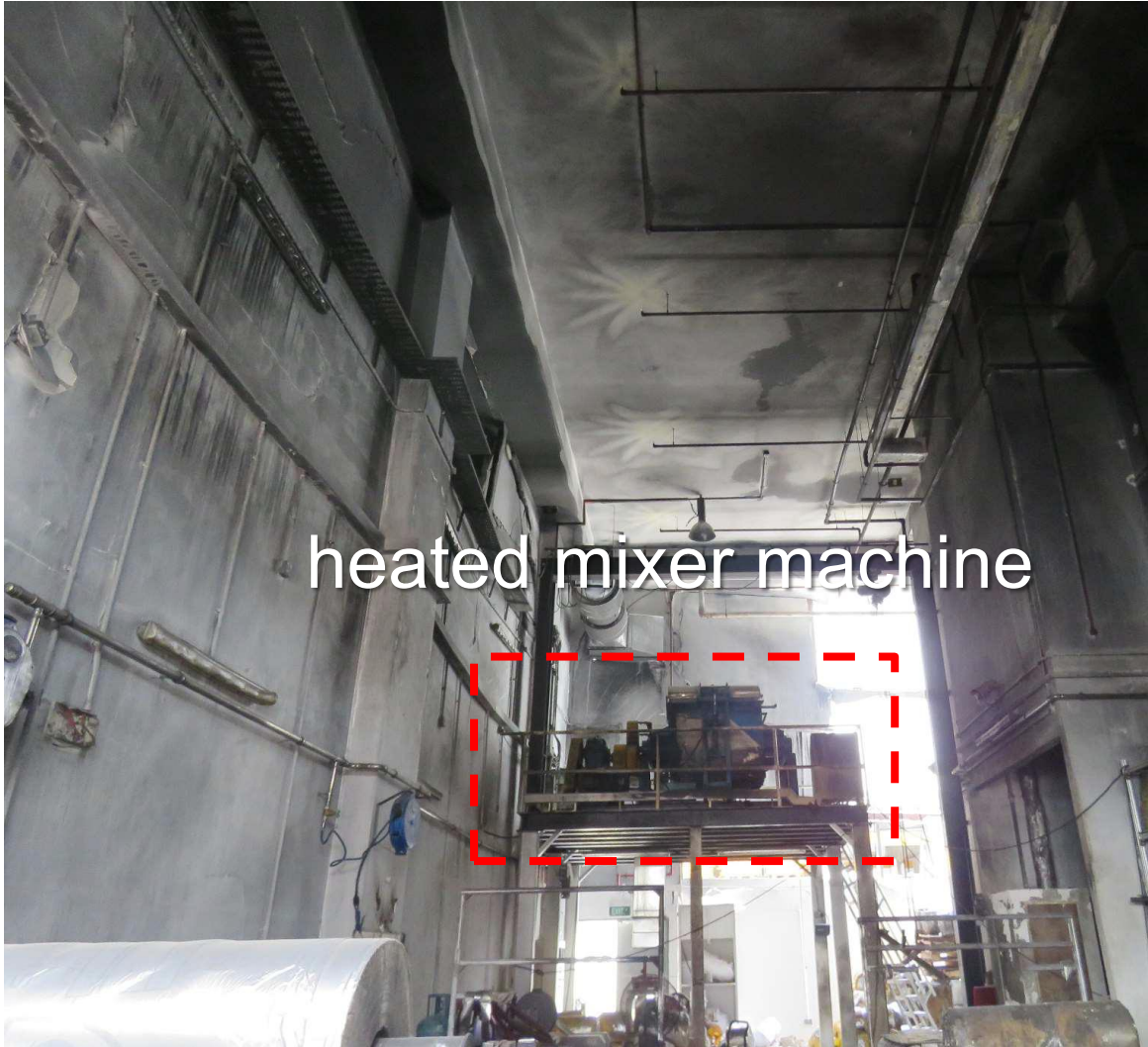
Inadequate Design Considerations

→ Mixer Machine Operated in Unsafe Manner

1. No proper investigation when machine showed signs of failure and risk to safety and health (e.g., oil leaks and instances of fire; simply “repair” as “solution”)
2. The causes were not established for corrective measures
3. Operations continued despite many Red Flags

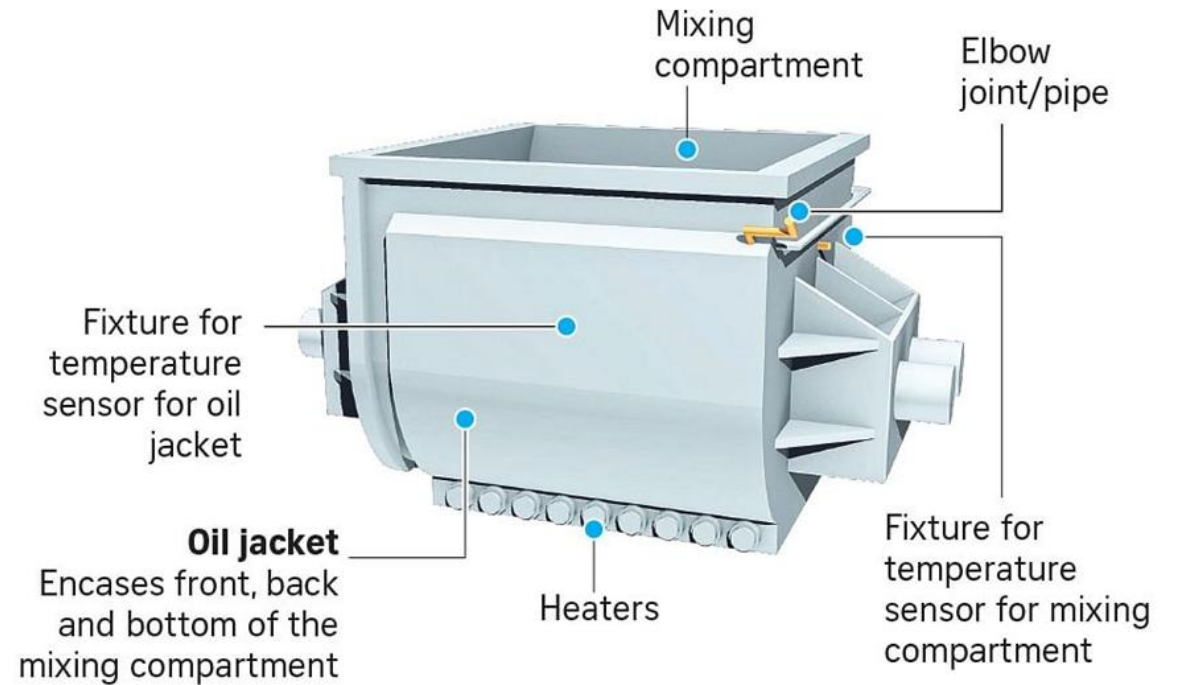
**No proper engineering → Make-shift combination → Shoddy assembly →
Lack knowledge of entire process & operations → Unsafe operations ...**

1. Lessons Learnt from Examples / Incidents



The mixer machine that exploded

The machine – which features a mixing container surrounded by a heated jacket of oil – is used to create a clay-like material used for fire protection in buildings.



Poor safety competence, especially process safety, despite many red flags

Temperature sensor not sensing oil temperature inside jacket

2

3

1 **Temperature sensor was not inserted to oil jacket** to monitor (and “control”) within safe limits, i.e. below oil boiling point so as to minimise oil vapour generation in jacket. The only one temperature sensor used at mixer chamber is not representative of oil temperature

3 There was no proper means to ascertain minimum thermic oil level required before commencement of operations. Insufficient oil level / without submerging heater elements not only resulted in inefficient heating of oil, but also overheating of heaters

Poor safety competence, especially process safety, despite many red flags

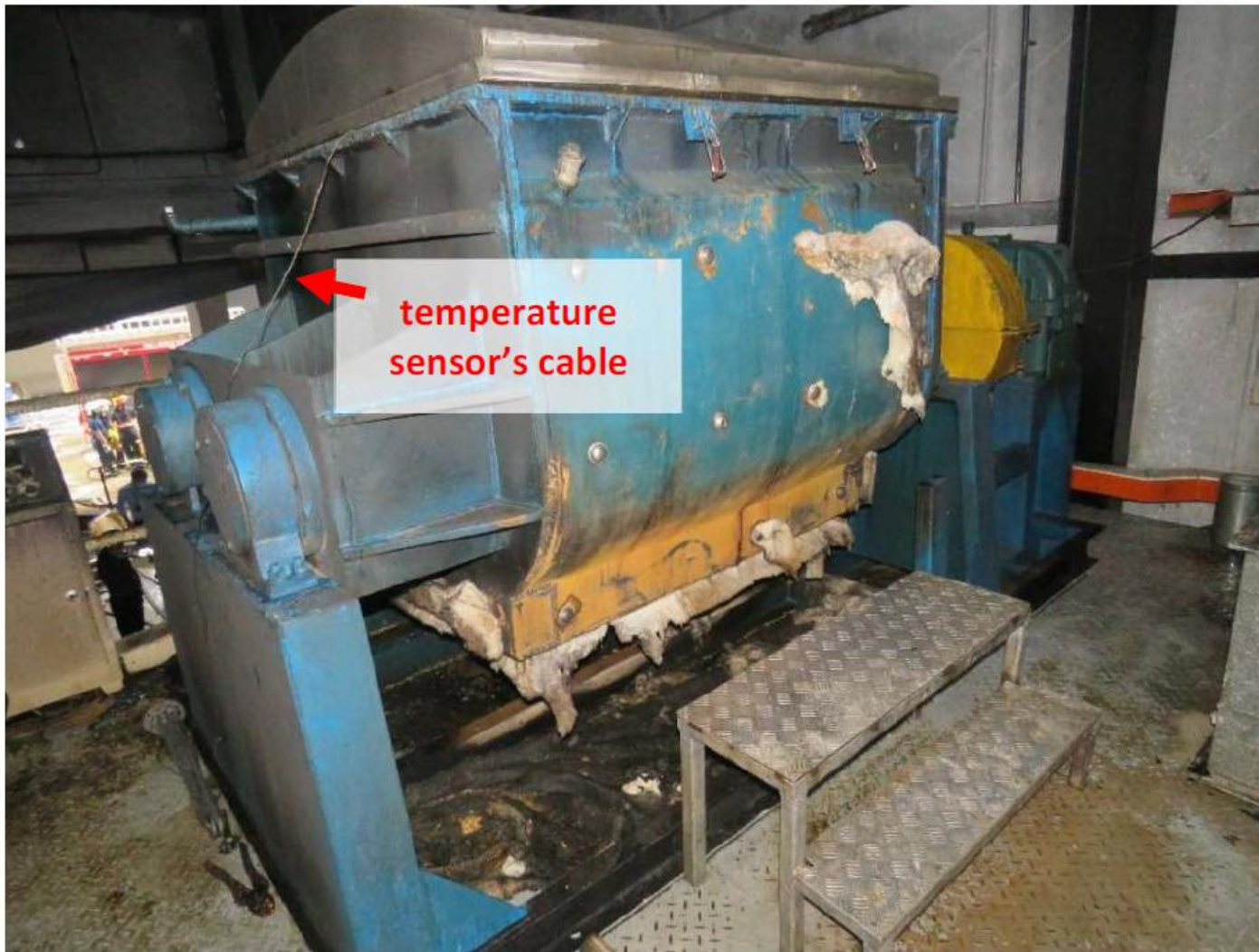


Figure 39: Temperature sensor in mixing chamber

126. A cable from the control panel was found connected to a RTD which was **placed inside the mixing chamber of the mixer machine** (Figure 39)

Poor safety competence, especially process safety, despite many red flags

1

2

Mixer machine oil jacket was operated as a closed system

3

2 **Mixer machine oil jacket vent line was sealed / plug to “minimise” thermic oil loss** without a safety relief valve. This is a deviation (wrong modification) from original equipment manufacturer design without risk assessment

Poor safety competence, especially process safety, despite many red flags



Figure 40: All three openings on the oil jacket circled in red were found closed

126. **All three openings on the oil jacket were found closed post accident.** Both openings at the top of the jacket had end caps that rendered them sealed, while the drain valve was found in a closed position (Figure 40)

Poor safety competence, especially process safety, despite many red flags



3 There was no proper means to ascertain minimum thermic oil level required before commencement of operations. **Insufficient oil level / without submerging heater elements** not only resulted in inefficient heating of oil, but also overheating of heaters

Poor safety competence, especially process safety, despite many red flags

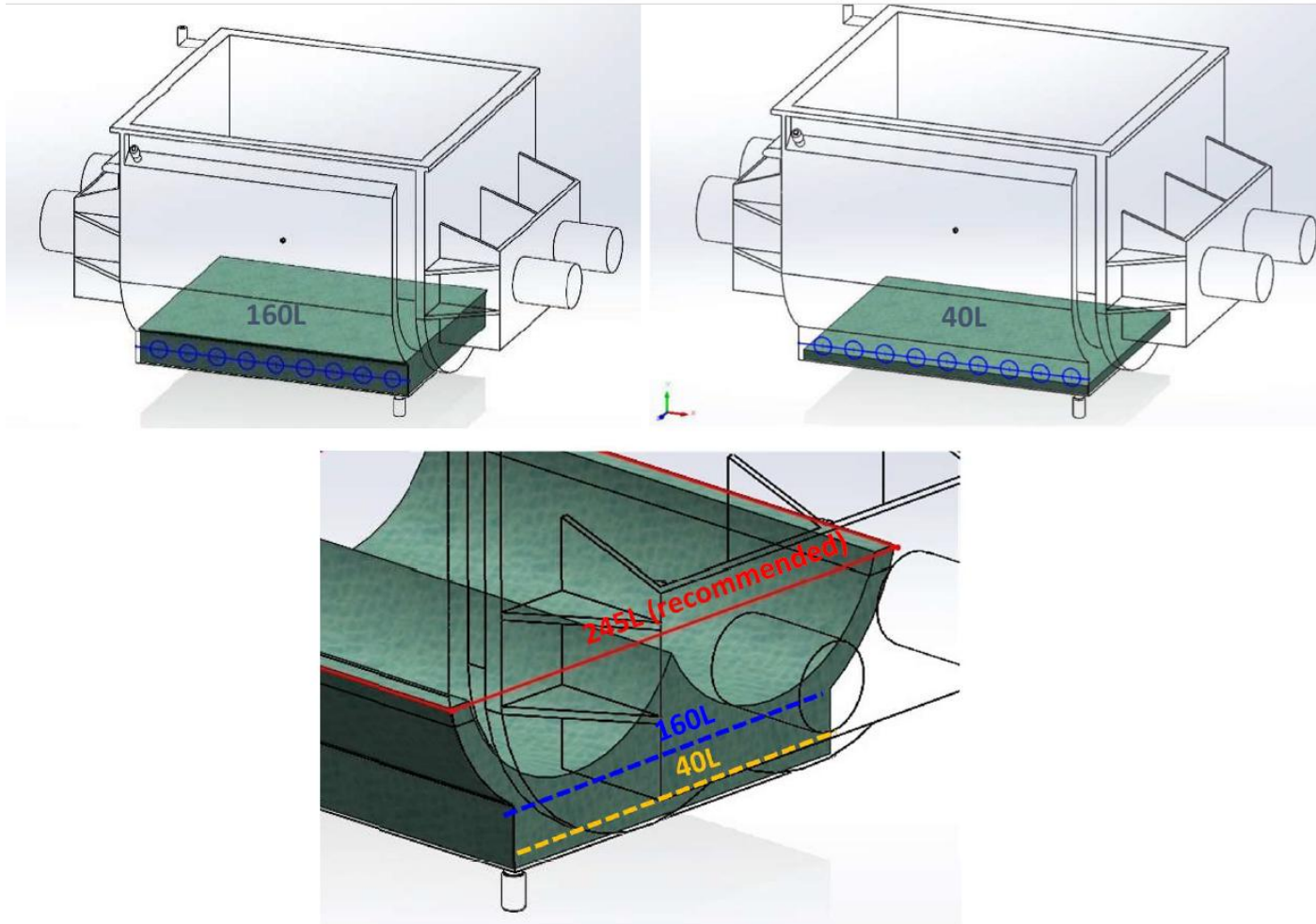


Figure 49: Fill levels corresponding to 40 litres, 160 litres and 245 litres in the oil jacket

141. ...only two buckets, or 40 litres, of oil were added to the oil jacket. As shown in Figure 49, the heaters were not immersed in the thermic oil and there was **a gap between the top of the 40 litres oil level (yellow dotted line) and the lowest point of the mixing chamber...** (Figure 49)

Poor safety competence, especially process safety, despite many red flags

↖ Temperature sensor not sensing oil temperature inside jacket

≈ Mixer machine oil jacket was operated as a closed system

∞ Insufficient thermic oil in mixer machine's jacket

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Poor safety competence, especially process safety, despite many red flags

Temperature sensor not sensing oil temperature inside jacket

Mixer machine oil jacket was operated as a closed system

Insufficient thermic oil in mixer machine's jacket

1 Temperature sensor was not inserted to oil jacket to monitor temperature (to ensure it was within safe limits, i.e. below oil boiling point so as to minimise thermic oil loss) within safe limits. The only one temperature sensor used at mixer machine was used to monitor temperature

2 Mixer machine was modified to "minimise" thermic oil loss with a modification (wrong modification) from original design without risk assessment

3 The proper means to ascertain minimum thermic oil level required before commencement of operations. Insufficient oil level / without submerging heater elements not only resulted in inefficient heating of oil, but also overheating of heaters

Strictly, there were violations of multiple Process Safety elements!

1. Lessons Learnt from Examples / Incidents

Importance of Design for Safety!



Safe design is an important part of risk management

Help prevent accidents and injuries from occurring

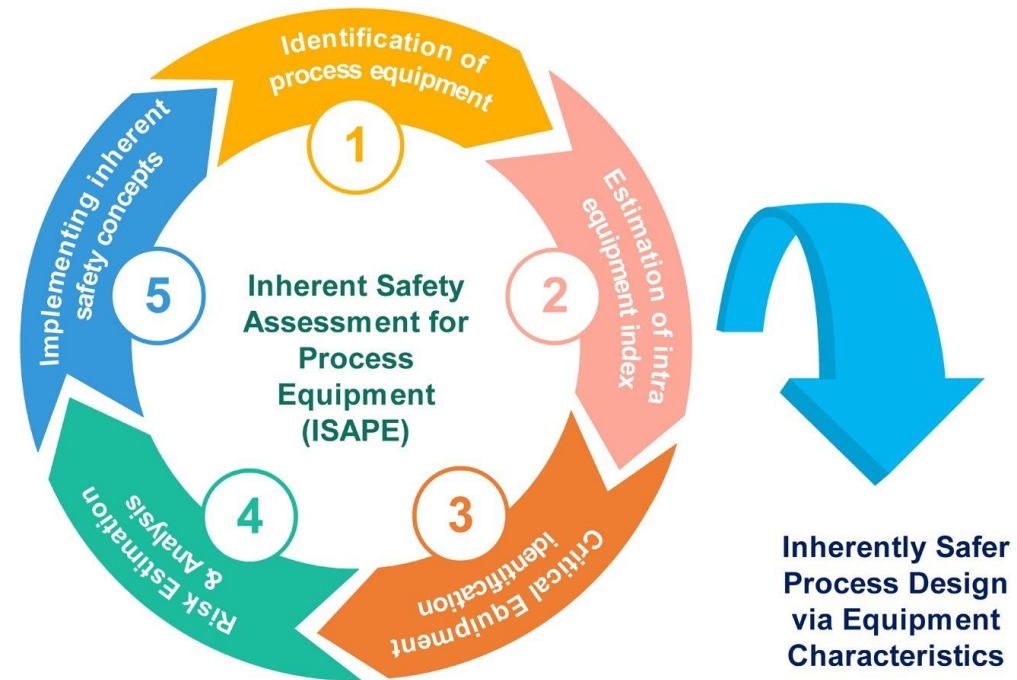
Incorporate features that protect people and property from harm

2. Facts: MNC versus SME on Process Facility

Safe design and operation of process facilities that manufacturing products involving the use of hazardous materials such as fuels and chemicals

→ require process safety design considerations to minimise risks to health and safety throughout lifecycle of product being designed

Inherent Safety Assessment for Process Equipment



Source: ScienceDirect

It can be challenging for Small and Medium Enterprises (SME) to certify their equipment to the machinery safety standard → **seek professional support**

3. Fundamentals of Design for Safety

Process Safety Design Considerations

- ❖ Identify hazards and risks – PHA: **HAZID, HAZOP**, etc.
- ❖ Singapore laws: regulations – WSH: DfS Regulations 2015, Construction Regulations 2007, Risk Management Regulations; WSH guidelines on Design for Safety
- ❖ Process safety management



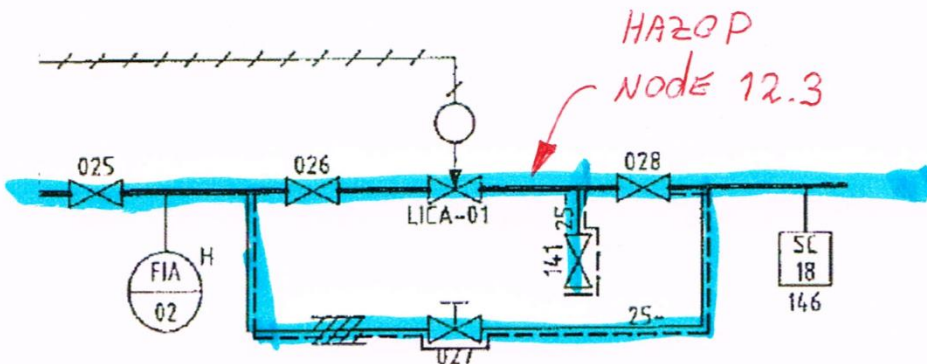
Source: SafetyCulture

3. Fundamentals of Design for Safety

HAZOP Study Process

- 
- 1 Build a HAZOP team
 - 2 Identify processes, P&ID, and HAZOP nodes
 - 3 Define the parameters, determine deviations, and select guide words
 - 4 Identify controls and establish safety monitoring
 - 5 Communicate HAZOP results and improve processes

Source: SafetyCulture



Severity escalation (S) ↑	[1]	4	3	2	1	AC	4: "Critical Risk"
	[2]	3	2	1	AC	AC	3: "High Risk"
	[3]	2	1	AC	AC	NSR	2: "Medium Risk"
	[4]	1	AC	AC	NSR	NSR	1: "Low Risk"
	[5]	AC	AC	NSR	NSR	NSR	AC: "Acceptable"
		[1]	[2]	[3]	[4]	[5]	NSR: "No special risk"
		← Likelihood escalation (L)					

↑ Risk (R) escalation

The integration of HAZOP study with risk-matrix and the analytical-hierarchy process for identifying critical control-points and prioritizing risks in industry

Source: ScienceDirect

3. Fundamentals of Design for Safety

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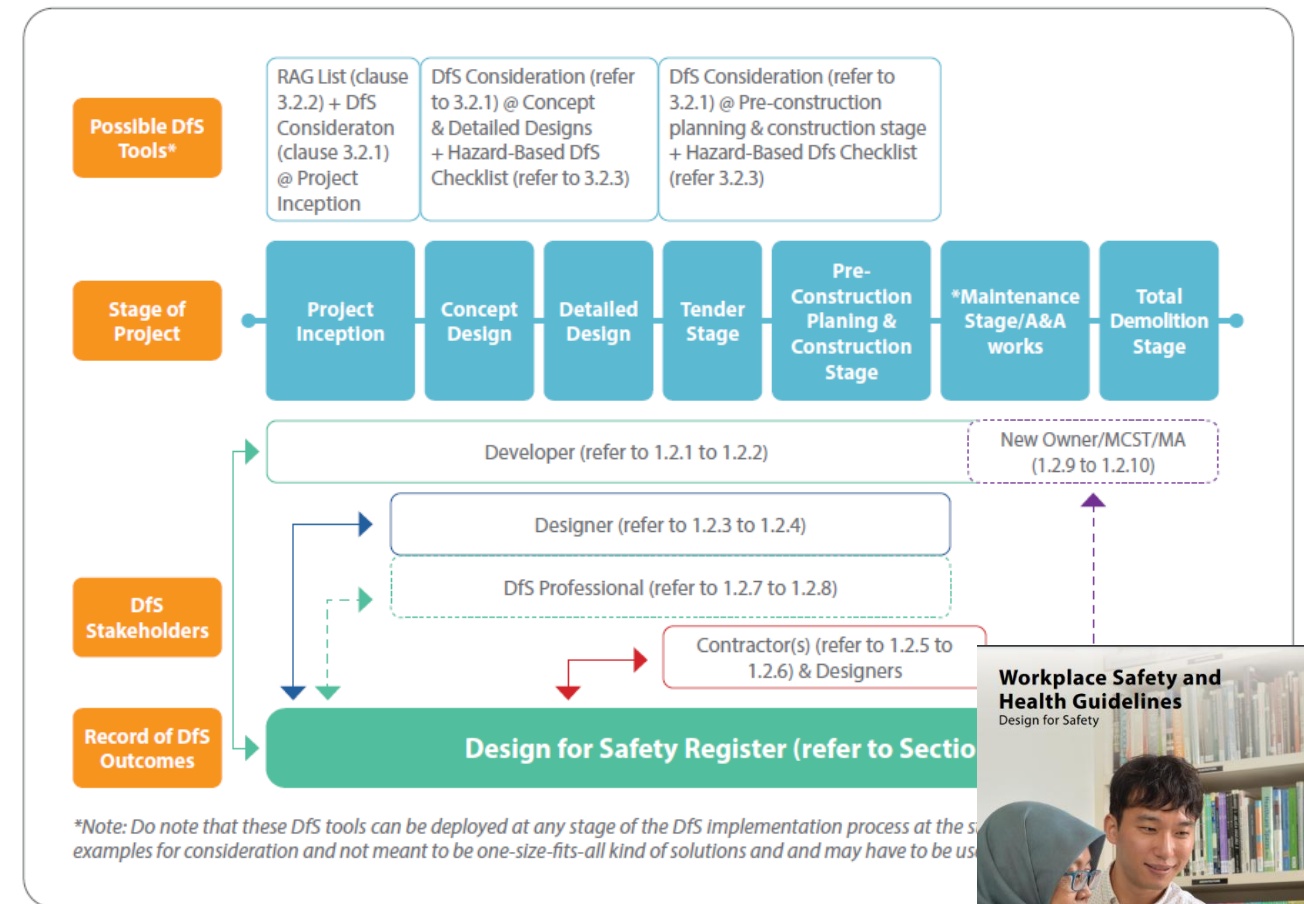


Figure 2: Sample Dfs process for a typical construction project (New Build).

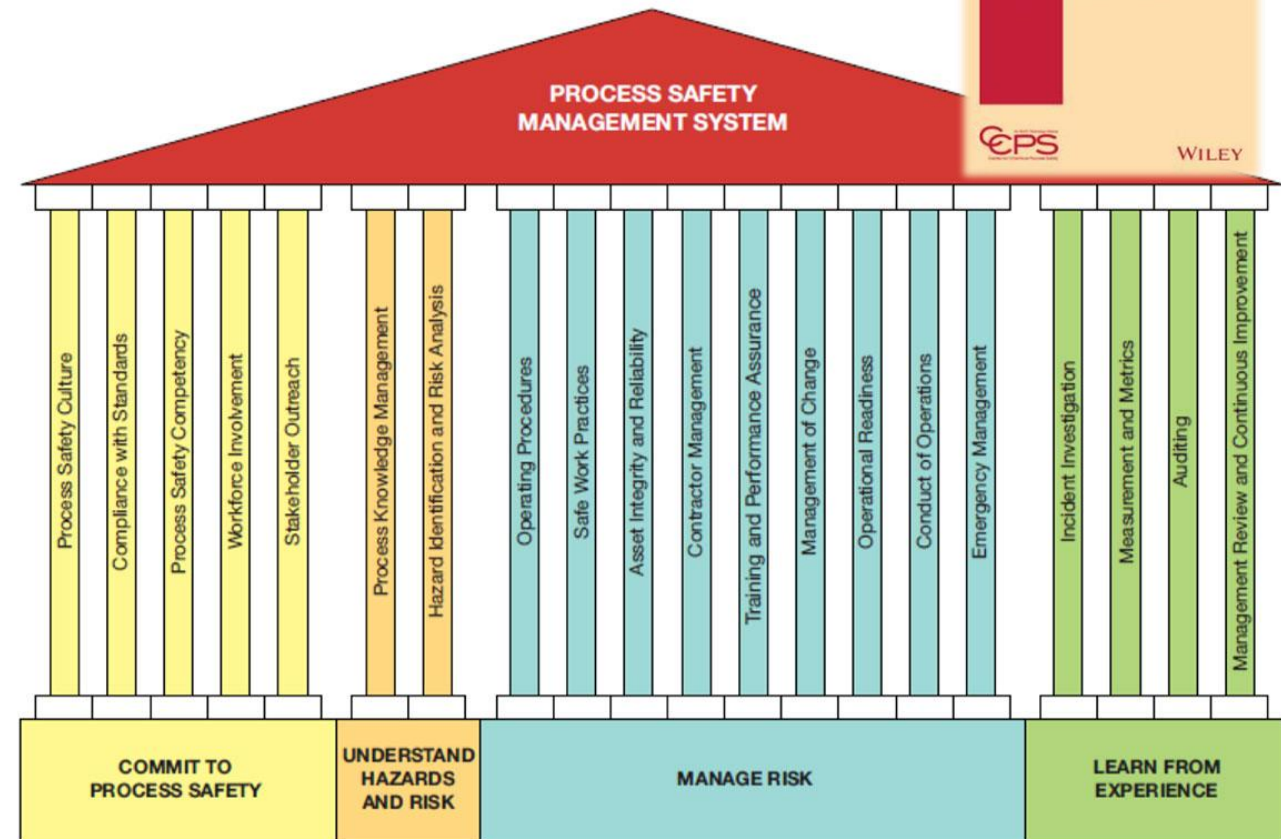


3. Fundamentals of Design for Safety

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- ❖ Singapore laws: regulations – WSH: DfS Regulations 2015, Construction Regulations 2007, Risk Management Regulations; WSH guidelines on Design for Safety
- ❖ **Process safety management**

CCPS Risk-Based Process Safety Management System



4. Design for Safety Professionals



Design for Safety (DfS) Professionals:

- ✓ Convene DfS Review Meetings
- ✓ Keep an updated copy of DfS Register
- ✓ Provide all relevant information on each foreseeable risk identified and its mitigation

Safe Design of Process Facilities

- ✓ Basic engineering – process design
- ✓ HAZOP Study based on Process & Instrument Diagram
- ✓ Convene identified risk mitigation measure meetings to improve inherent design including process equipment
- ✓ Detailed engineering including 3-D model for facility operability
- ✓ Post construction site checks
- ✓ Pre-start-up safety review before commissioning of facility

4. Design for Safety Professionals

Safe use of machineries and combustible dust:

- ✓ Enhanced safety measures for higher-risk machineries and combustible dust
- ➔ From **1 January 2025**, companies will need to comply with additional requirements to strengthen workplace safety and health (WSH) standards for higher-risk machineries and combustible dust.

<https://www.mom.gov.sg/workplace-safety-and-health/safe-measures/sectoral-level/safe-use-of-machineries-and-combustible-dust>

Measures for safe use of machinery

- ✓ The **list of machinery** in the **Fifth Schedule of the WSH Act** will be expanded to include classes of higher-risk machinery
- ✓ Existing duties under sections 16 and 17 of the WSH Act will now apply to manufacturers, suppliers, installers and modifiers of these machineries
 - Manufacturers and suppliers
 - Installers and modifiers

4. Design for Safety Professionals

Measures for safe use of machinery

- ✓ The **list of machinery** in the **Fifth Schedule of the WSH Act** will be expanded to include the following classes of higher-risk machinery:
 1. Sheet benders and sheet rollers
 2. Lathes and milling machines
 3. Machines designed for industrial use for any of the following purposes:
 - Cutting, including table saws and slicing machines
 - Packaging, including palletisers, balers and compactors
 - Mixing by mechanical movement, including paddle mixers and ribbon mixers
 - Handling or processing food, including grinders, mincers, blenders and juicers

4. Design for Safety Professionals

Measures for safe use of machinery

- ✓ Existing duties under sections 16 and 17 of the WSH Act will now apply to manufacturers, suppliers, installers and modifiers of these machineries

Manufacturers and suppliers

You will need to:

- Ensure that your machineries are designed, examined and tested to be safe when properly used
- Provide information about how to use your machineries safely

Installers and modifiers

You will need to ensure that any installation or modification carried out does not compromise the safe use of your machinery

With these new requirements, buyers of the machineries can be more assured that their purchase meets the required safety standards

4. Design for Safety Professionals

Measures for safe use of combustible dust

- ✓ Combustible dust is any finely divided combustible particulate solid that may present a flash fire or explosion hazard when suspended in the air. You may find the list of combustible dust in the Fourth Schedule of the WSH (General Provisions) Regulations
- ✓ From 1 January 2025, the list of hazardous substances in the **Fifth Schedule of the WSH Act** will be expanded to include combustible dust. Duties of manufacturers and suppliers will also be extended to include combustible dust
 - Labelling for combustible dust
 - Notification on use of combustible dust

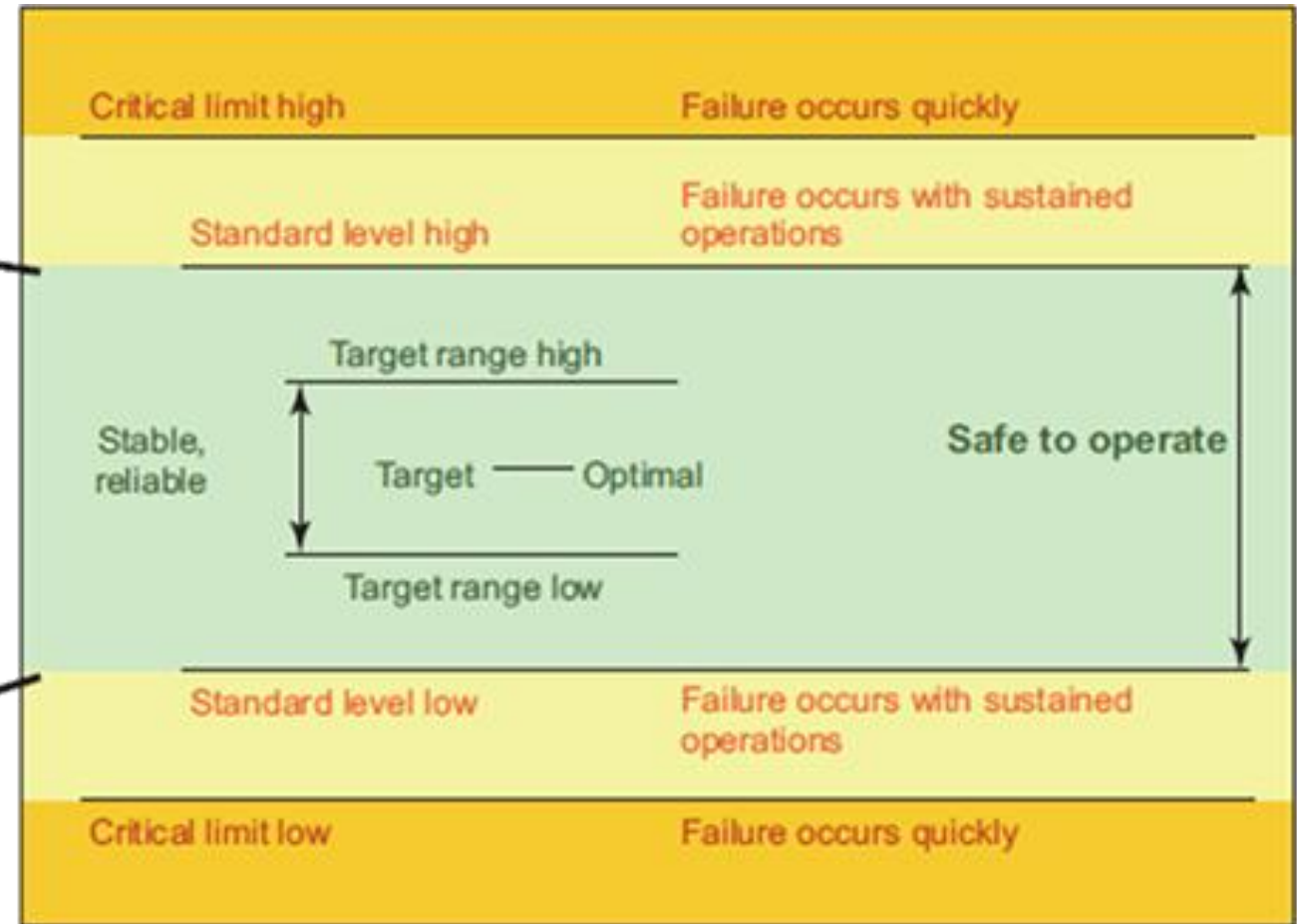
<https://www.mom.gov.sg/workplace-safety-and-health/safe-measures/sectoral-level/safe-use-of-machineries-and-combustible-dust>

4. Design for Safety Professionals

Design for Safety (DfS)

Integrity Operating Windows (IOWs)

Process Safety Management System (PSM)



<https://becht.com/becht-blog/entry/integration-of-integrity-operating-windows-into-process-safety-management/>

Importance of Design for Safety towards Vision Zero

Strive for Operations Excellence and Sustainability



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