Safety Aspects of Floating LNG: Preliminary Inherent Safer Design Selection of Liquefaction Process

Picture Source : http://www.shell.com/about-us/major-projects/prelude-flng.html

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Outline

- What is Inherently Safer Design (ISD)?
- General Principles of ISD.
- Need for ISD in Current industry and FLNG
- Hazards associated with FLNG
- Application of step-wise methodology for selection of Inherently Safer Design of Natural Gas liquefaction process
- Discussion and Result
- Conclusion
- Future Scope for application

What is Inherently Safer Design?

- What is “Inherent”?
- Inherently Safer Design is to eliminate or minimize hazards rather than control hazards

- This is best done at the very beginning of a project

Hazard Reduction Strategy (Principles of ISD)

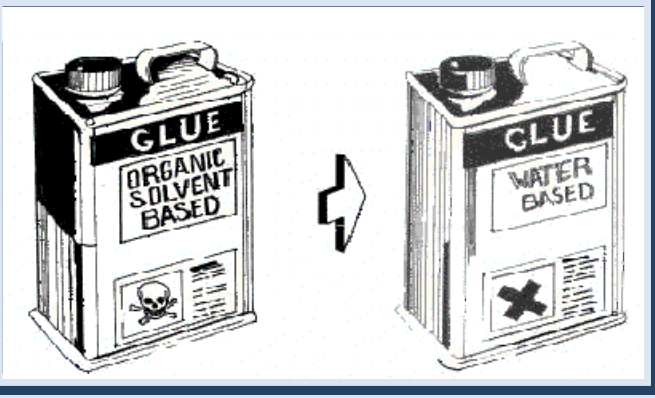
Minimization

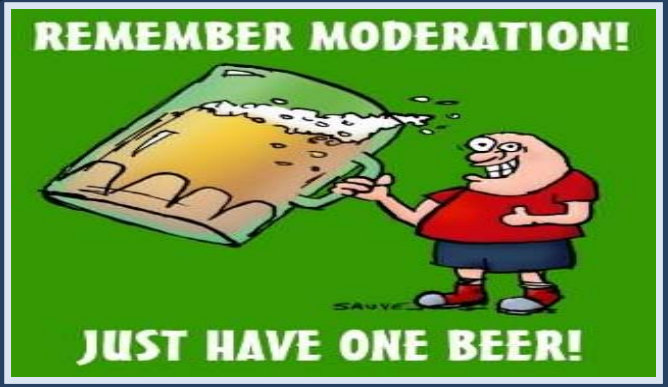
Simplification

Strategy

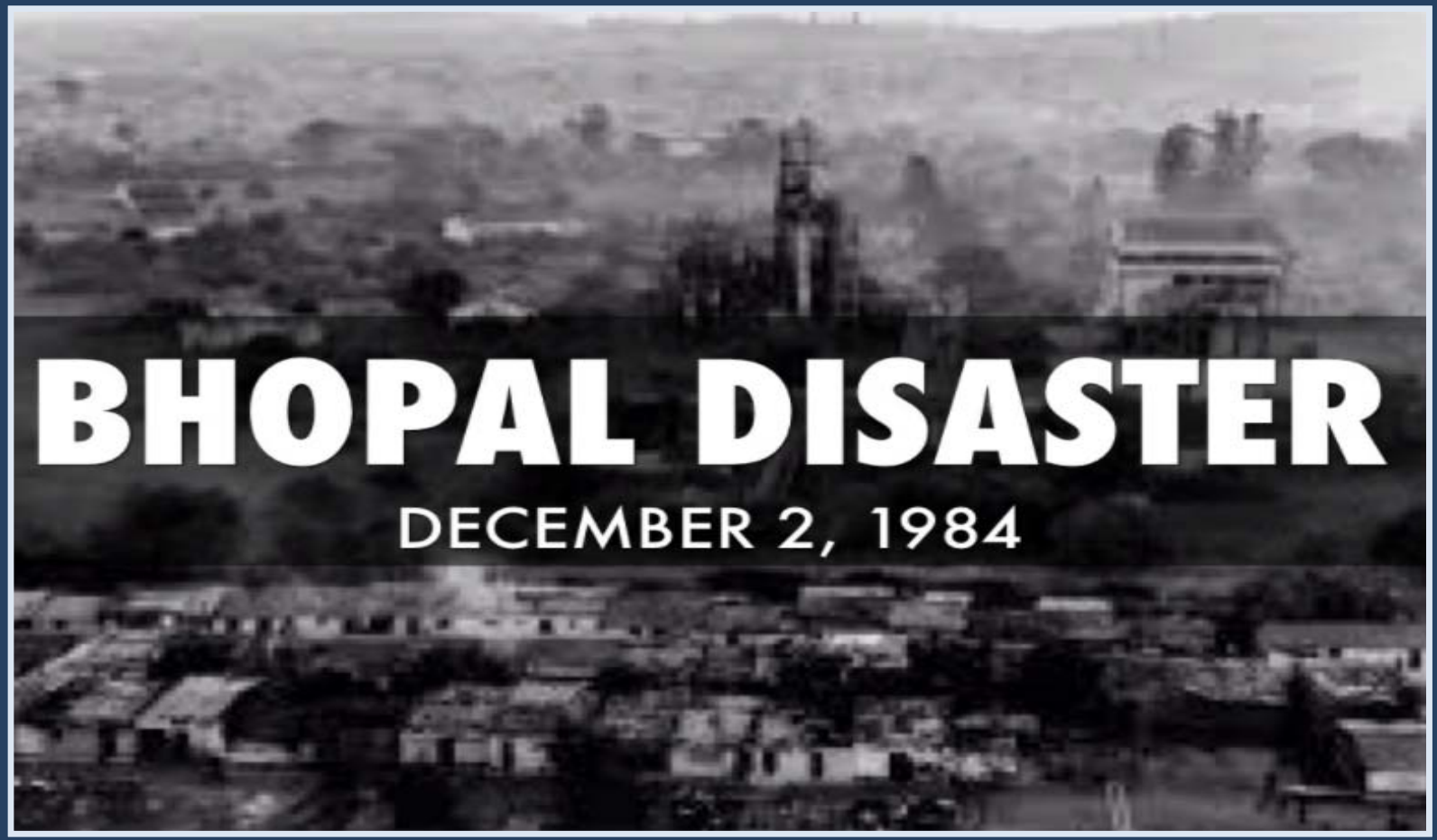
Moderation

Substitution





Need for ISD in Current industry



Bhopal Disaster in 1984

Need for ISD in Current industry

Flixborough Disaster in 1974

Need for ISD in Current industry

Piper Alpha in 1988

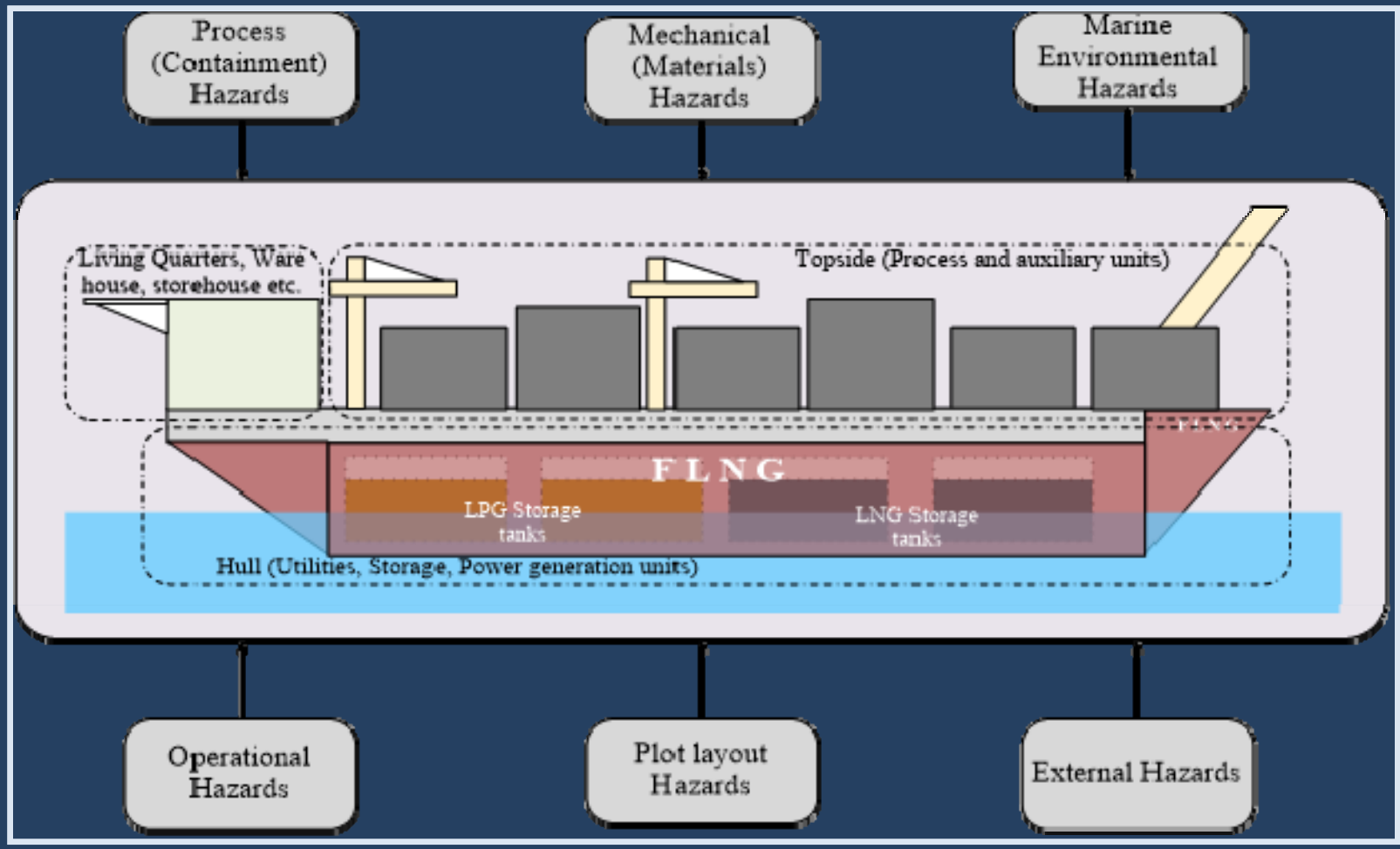
Need for ISD in Current industry

Fukushima Incident in 2011

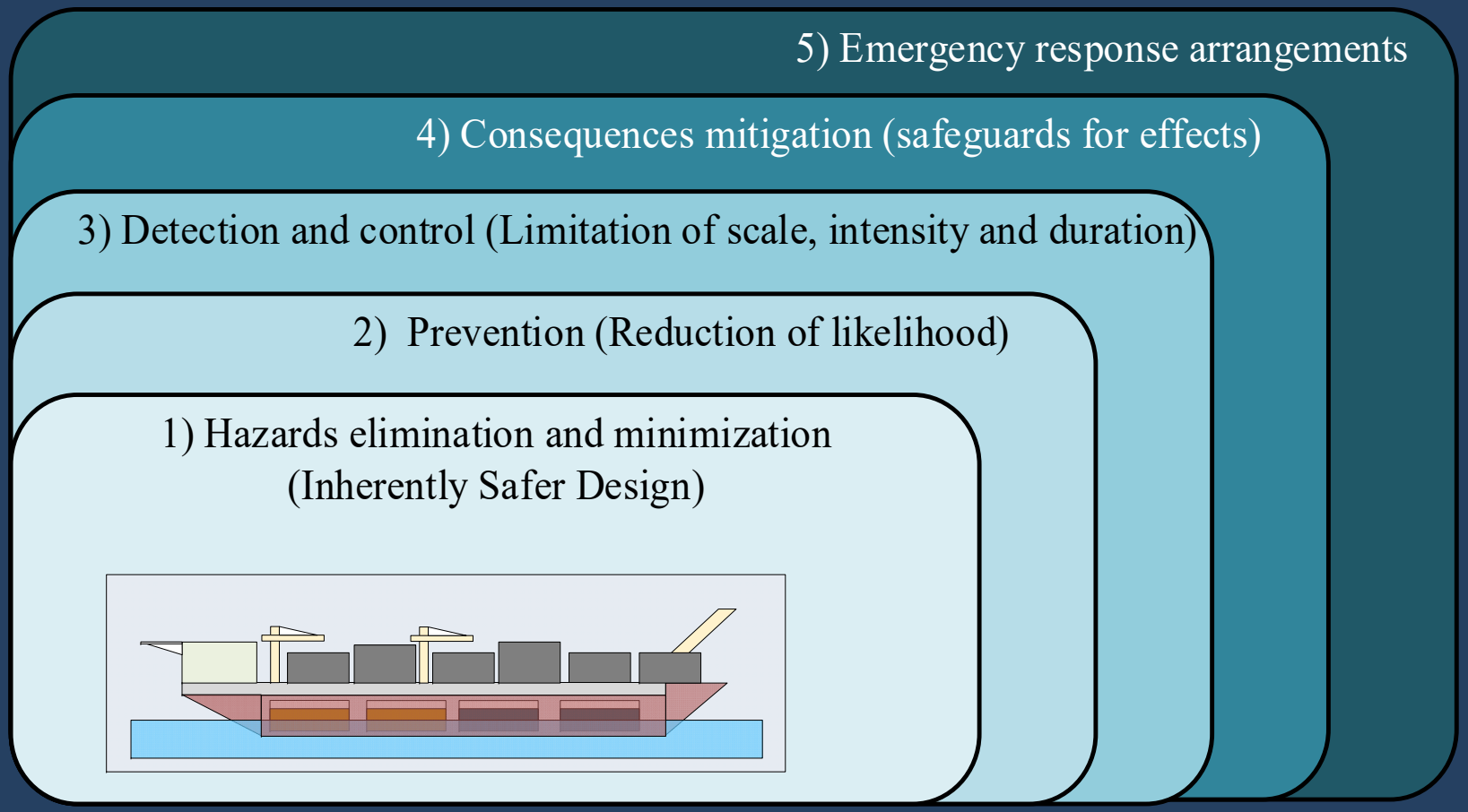
Need for ISD in FLNG Structure

- Offshore structure
- Limited escape space
- Limited plot area
- Complexity
- Not much operational experience
- Remote location
- Many Hazards involved

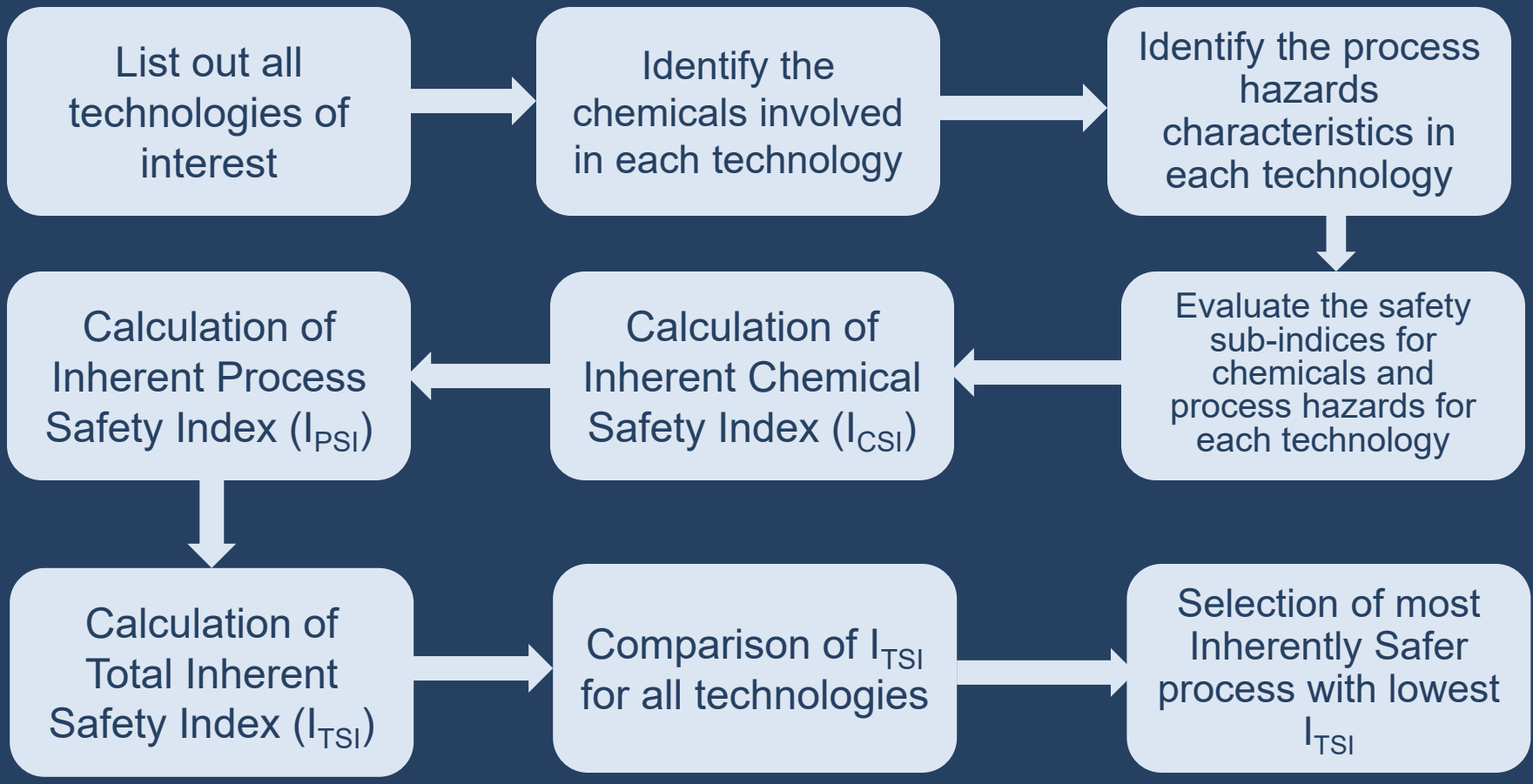
Need for ISD in FLNG Structure (Hazards Associated)



Layer of protection analysis (LOPA) for FLNG

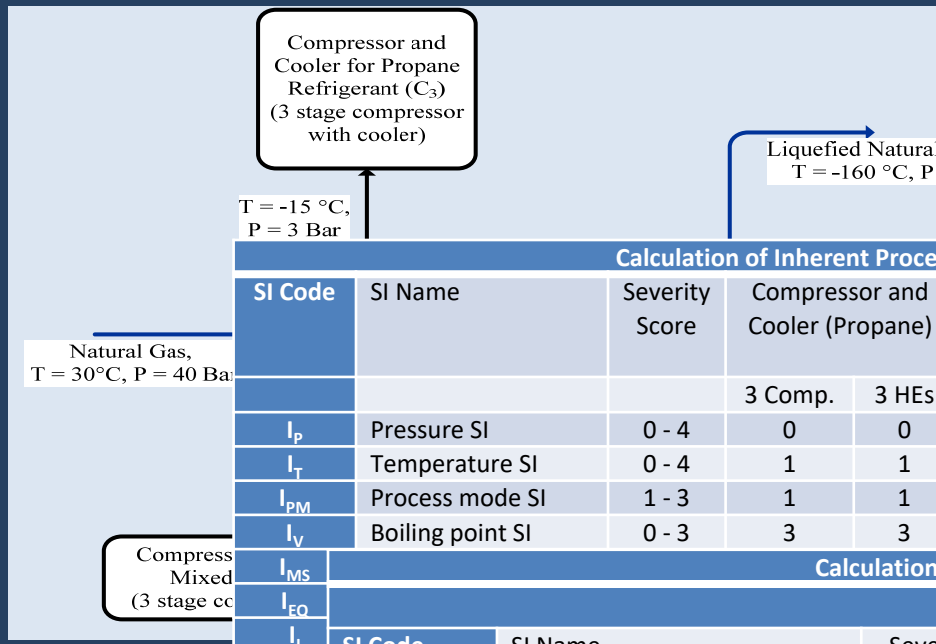


Step-wise Methodology for ISD



ISD Application to Natural Gas Liquefaction Processes

Propane Mixed Refrigerant (C3MR) Process



Calculation of Inherent Process Safety Index (I_{PSI})

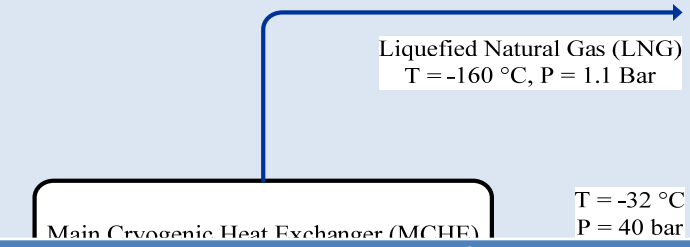
SI Code	SI Name	Severity Score	Compressor and Cooler (Propane)		Pre-cooling System	Compressor and Cooler (MR System)		MCHE	MR Vessel
			3 Comp.	3 HEs	3 HEs	3 Comp.	3 HEs		
I_P	Pressure SI	0 - 4	0	0	2	2	2	2	2
I_T	Temperature SI	0 - 4	1	1	4	4	4	4	4
I_{PM}	Process mode SI	1 - 3	1	1	1	1	1	1	1
I_V	Boiling point SI	0 - 3	3	3	3	3	3	3	3
I_{MS}									
I_{EQ}									
I_I									
Inherer									
Total In									

Calculation of Inherent Chemical Safety Index (I_{CSI})

			Natural Gas		Propane	Mixed Refrigerant		
SI Code	SI Name	Severity Score	(95% Methane)	(5% Ethane)	Propane	(70% Propane)	(20% Ethane)	(10% Methane)
I_C	Corrosiveness SI	0 - 2	0	0	0	0	0	0
I_{EL}	Exposure limit SI	0 - 4	2	1	1	1	1	2
I_T	Toxic SI	0 - 4	1	1	1	1	1	1
I_R	R-phrases SI	0 - 4	0	0	0	0	0	0
I_F	Flammability SI	0 - 4	4	4	4	4	4	4
I_{RM}	Chem. React. SI	0 - 4	0	0	0	0	0	0
	Total Chemical severity index		7	6	6	6	6	7
Inherent chemical safety index			6.65	0.3	6	4.2	1.2	0.7
Total Inherent Chemical Safety Index (I_{CSI})			19.05					

ISD Application to Natural Gas Liquefaction Processes

Single Mixed Refrigerant (SMR) Process



Calculation of Inherent Process Safety Index (I_{PSI})

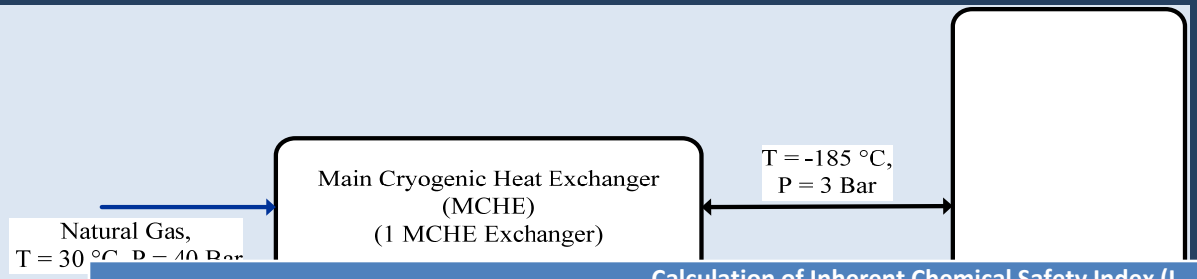
SI Code	SI Name	Severity Score	MCHE	Compressor and Cooler (MR System)		Cooled MR Vessel	Warm MR Vessel
				3 Comp.	3 HEs		
I_P							
I_T							
I_{PM}							
I_V							
I_{MS}							
I_{EQ}							
I_I							
Inherent proces							
Total Inherent P							

Calculation of Inherent Chemical Safety Index (I_{CSI})

			Natural Gas		Mixed Refrigerant		
SI Code	SI Name	Severity Score	(95% Methane)	(5% Ethane)	(70% Propane)	(20% Ethane)	(10% Methane)
I_C	Corrosiveness SI	0 - 2	0	0	0	0	0
I_{EL}	Exposure limit SI	0 - 4	2	1	1	1	2
I_T	Toxic SI	0 - 4	1	1	1	1	1
I_R	R-phrases SI	0 - 4	0	0	0	0	0
I_F	Flammability SI	0 - 4	4	4	4	4	4
I_{RM}	Chemical reaction SI	0 - 4	0	0	0	0	0
	Total Chemical severity index		7	6	6	6	7
Inherent chemical safety index			6.65	0.3	3.6	1.8	0.7
Total Inherent Chemical Safety Index (I_{CSI})		13.05					

ISD Application to Natural Gas Liquefaction Processes

Nitrogen Refrigerant Process



Calculation of Inherent Chemical Safety Index (I_{CSI})

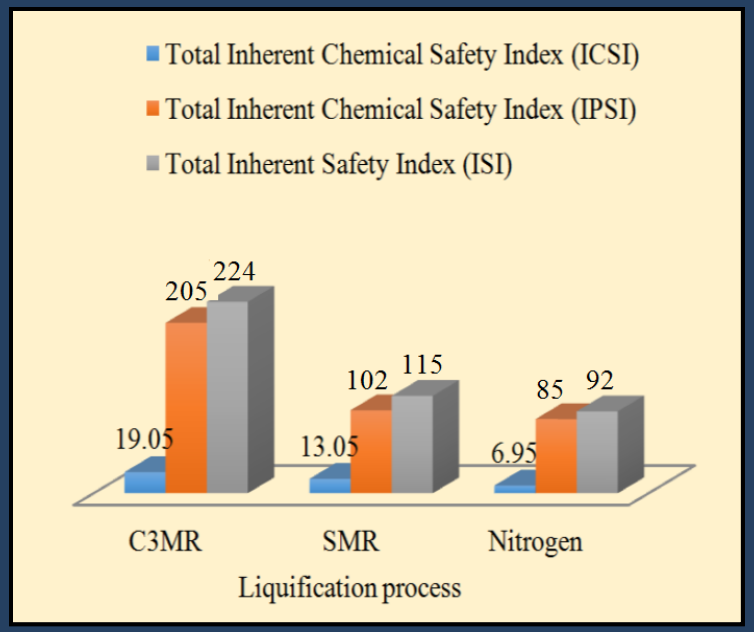
SI Code	SI Name
I_C	Corrosiver
I_{EL}	Exposure l
I_T	Toxic SI
I_R	R-phrases
I_F	Flammabil
I_{RM}	Chemical r
	Total Cher
Inherent chemical safety index	
Total Inherent Chemical Safety Index	

Calculation of Inherent Process Safety Index (I_{PSI})

SI Code	SI Name	Severity Score	MCHE	Nitrogen Cold Box		Sub-cooler (HE)
				2 Comp.	2 HEs	
I_P	Pressure SI	0 - 4	2	1	1	2
I_T	Temp. SI	0 - 4	4	4	4	4
I_{PM}	Pro. mode SI	1 – 3	1	1	1	2
I_V	Boiling point SI	0 – 3	3	3	3	3
I_{MS}	Material phase SI	1 – 3	2	2	2	2
I_{EQ}	Eq. safety SI (ISBL)	0 – 4	1	3	1	1
I_I	Inventory SI	0 – 5	1	1	1	1
			14	15	13	15
Inherent process safety index			14	30	26	15
Total Inherent Process Safety Index (I_{PSI})			85			

Discussion and Result

Comparison of Total Inherent Safety Index (I_{SI}) FLNG liquefaction technologies			
FLNG liquefaction technologies	C_3MR	SMR	Nitrogen
Total Inherent Chemical Safety Index (I_{CSI})	19.05	13.05	6.95
Total Inherent Chemical Safety Index (I_{PSI})	205	102	85
	224.05	115.05	91.95
Total Inherent Safety Index (I_{SI}) (Round figure)	224	115	92



Conclusion

- FLNG is offshore structure and hence very crucial from safety point view.
- ISD methodology is a good approach for the upcoming projects to select the preliminary inherently safer design amongst many technologies available.
- It generally applies at the pre-design stage and hence many later cost and safety concerns can be avoided in advance.
- Mathematical evaluation
- Nitrogen Refrigerant Process is the most inherently safer process comparatively for Natural Gas Liquefaction for FLNG.

Future Scope for application

- ISD can be implemented to any field
- A software can be developed to help performed this evaluation at research stage with ease
- Safety indices can be customized based on need as they are limited to relative comparison amongst alternatives

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- Prevention is better than Cure… Similarly Inherently Safer Design is always better than operating and managing hazards…

Thank you &

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