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EPSC

Hazardous Material Transportation
Whose Risk is it Anyway ?

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EPSC Maastricht Process Safety Congress
Wednesday December 13, 2023

Speaker Bio

Background:

- Agrochemical and Industrial Chemicals production
  - Chlorine, Phosgene, Carbon Monoxide, Di-azo blowing agents
  - Design, process troubleshooting, plant management
- Lithium chemistry
  - Lithium organometallics, pyrophoric catalysts, lithium metal, battery precursors
  - Capital projects, technology management, safety auditing and training
  - Global safety responsibility for supply chain operations
- Pharmaceutical manufacture
  - Process safety management, new product implementation, high potency APIs and antibody-drug conjugates
  - Anaerobic digestion systems
- BakerRisk
  - Process Hazard Analysis (HazID, Hazop, LOPA), Regulatory Compliance, Process Safety Management Systems, Biofuels (Anaerobic Digestion).
- IChemE Hazards Conference – Technical Committee 2013-23

James Birch
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PgDip CEng MIChemE

Outline

- The Isotank
  - Their development, purpose and the regulations
- Their Usage Cycle – Hazards and Risks Along the Way
  - Prevention / Mitigation examples
  - Finite Element Analysis (FEA)
  - Consequence Analysis
- Those in Peril on the Sea
  - Risks at Sea – Fatalities & Fires
  - On a lighter note…
- Whose Risk Is It Anyway ? – Conclusions
- Any Questions ?

The Isotank

Key player – The Isotank

- ISO tank / ISOtank / ISO tankers / Isotainer / Isocontainer
- ISO = International Standards Organisation
- Commercial production began in 1966, followed by standardization in the early 1970s. Typically 20 ft long (also available as 30 ft and 40 ft)
- Standard ISO 1496-3(2019) for transport of gases, liquids and solids

Evolution

Simple tank

On-board chiller (reefer)

Self-powered temperature control system

Vacuum-insulated / Cryogenic

- **Automated valves, level measurement, GPS tracking, payload monitoring…**
- **No longer “a simple tank in a frame”**

Design Standards - T Codes

T-Code	Minimum Test Pressure (bar)	Minimum Shell Thickness	Pressure-Relief Requirements	Bottom Opening Requirements
T1	1.5	> or = 6mm	normal	2 shut-off devices (Int + Ext)
T2	1.5	> or = 6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T3	2.65	> or = 6mm	normal	2 shut-off devices (Int + Ext)
T4	2.65	> or = 6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T5	2.65	> or = 6mm	normal + rupture disc	Not Allowed
T6	4	> or = 6mm	normal	2 shut-off devices (Int + Ext)
T7	4	> or = 6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T8	4	> or = 6mm	normal	Not Allowed
T9	4	6mm	normal	Not Allowed

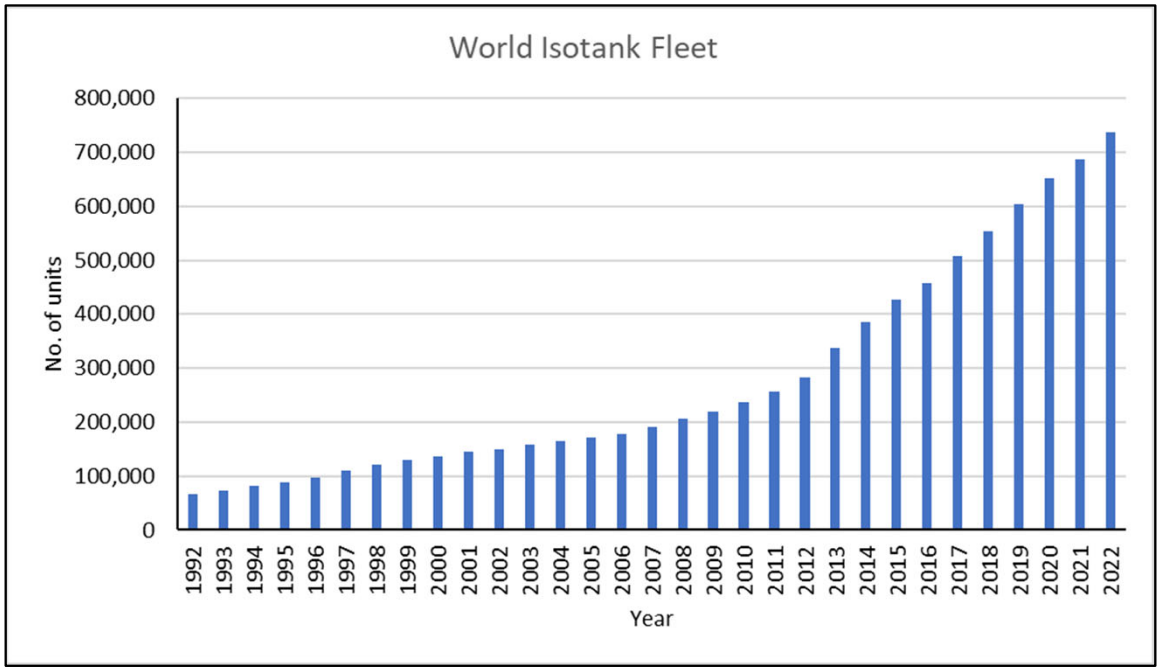
ISO Tank Containers – T Codes

T-Code	Minimum Test Pressure (bar)	Minimum Shell Thickness	Pressure-Relief Requirements	Bottom Opening Requirements
T10	4	6mm	normal + rupture disc	Not Allowed
T11	6	> or = 6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T12	6	> or = 6mm	normal + rupture disc	3 shut-off devices (Int + Ext + cap/blank)
T13	6	6mm	normal	Not Allowed
T14	6	6mm	normal + rupture disc	Not Allowed
T15	10	>or = 6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T16	10	> or = 6mm	normal + rupture disc	<3 shut-off devices (Int + Ext + cap/blank)
T17	10	6mm	normal	3 shut-off devices (Int + Ext + cap/blank)
T18	10	6mm	normal + rupture disc	3 shut-off devices

ISO Tank Containers – T Codes

T-Code	Minimum Test Pressure (bar)	Minimum Shell Thickness	Pressure-Relief Requirements	Bottom Opening Requirements
T19	10	6mm	normal + rupture disc	Not Allowed
T20	10	8mm	normal + rupture disc	Not Allowed
T21	10	10mm	normal	Not Allowed
T22	10	10mm	normal + rupture disc	Not Allowed
T50	Non-refrigerated liquefied gases and chemicals under pressure. Varies by material			
T75	Refrigerated liquefied gases and chemicals under pressure. Varies by material			

Logistics Role



2022 Global Tank Container Survey ITCO – International Tank Container Organisation

The global ISO container market is projected to grow from 801.5 thousand units in 2023 to 1,499 thousand units by 2030, at a CAGR of 9.4%

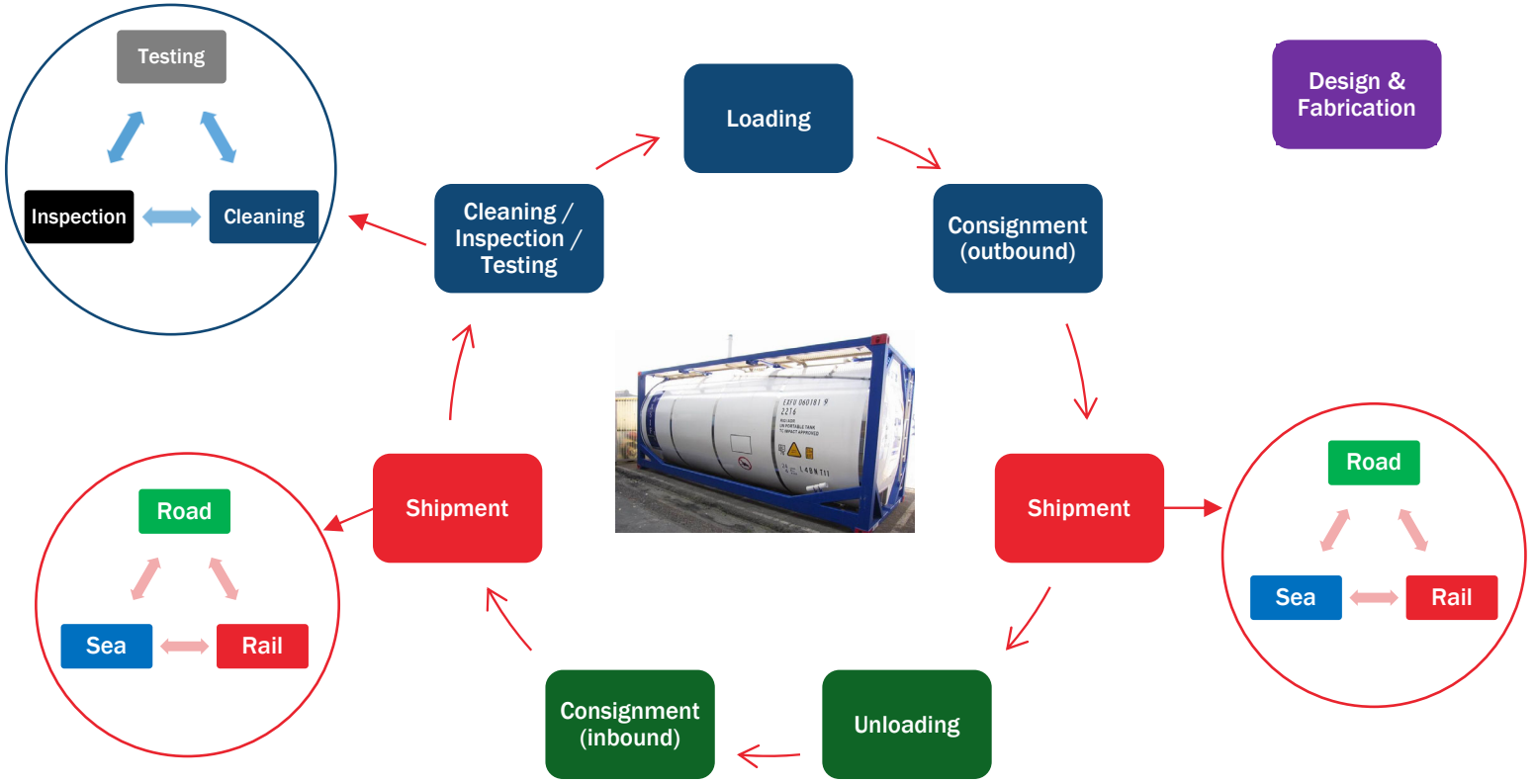
https://www.fortunebusinessinsights.com/industry-reports/iso-container-market-101387

- **Isotanks are significant vehicle for the transportation of hazardous materials worldwide – the current world fleet has been conservatively estimated as capable of carrying ca. 150 million tonnes of cargo per year**

Regulations

- Hazardous materials shipment is covered by:
  - IMDG - International Maritime shipment of Dangerous Goods (IMDG)
  - ADR - Accorde Dangerouse Routes - The European Agreement on the Transportation of Dangerous Goods by Road
  - RID - Regulation concerning the International Carriage of Dangerous Goods by Rail
  - UN Regulations
  - US DOT / EU / Other countries' regulations

Usage Cycle

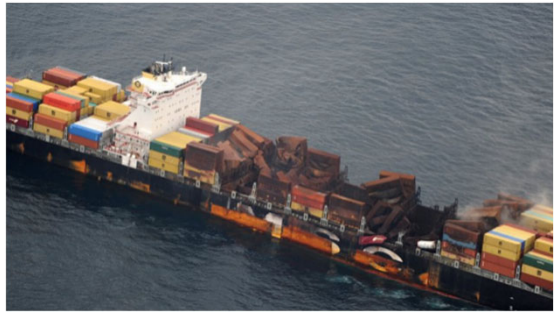

Testing
Inspection
Cleaning
Cleaning / Inspection / Testing
Loading
Consignment (outbound)
Design & Fabrication
Shipment
Road
Sea
Rail
Unloading
Consignment (inbound)
Shipment
Road
Sea
Rail

Loading - Risks

Event	Consequence	Prevention / Mitigation
Mis-loading of incompatible or inadequately stabilised material	Reaction during shipment (e.g. styrene – runaway)	Safety Audits of Management Systems Equipment reliability
Overfilling	Expansion results in loss of containment through relief system	Engineered Systems Human Factors / Safety Critical Task Analysis SCTA
Partial loading of unbaffled container (no hydraulic surge plates)	Hydraulic surge can overturn vehicle during braking	Human Factors / Safety Critical Task Analysis SCTA

Consignment - Risks

Event	Consequence	Prevention / Mitigation
Mis-declaration of cargo (container hazard status)	Flammable / reactive materials may be mis-loaded e.g. onboard ship (MSC Flaminia incident)	Safety Audits of Management Systems



https://shippingwatch.com/carriers/Container/article10867813.ece

Lifting and Moving

https://www.flickr.com/photos/hotshotimage/16475417601
https://www.abbeychemicals.co.uk/post/new-iso-tanks-12t-forklift
https://www.isoloader.com/content/el/index.html
https://www.eurotainer.com/video/spilltainer

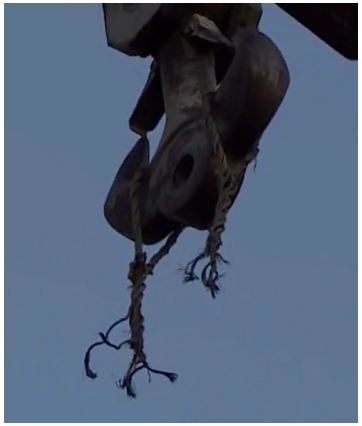
Lifting Incident

* Hudson Reporter

Dropped Container (Chlorine)

Jordan, 2022

Dropped Objects – Loss of Containment



Lifting and Moving - Risks

Event	Consequence	Prevention / Mitigation
Dropped objects	Equipment damage Loss of containment Fire / Toxic	Equipment design FMEA / FEA Lifting studies Training & Competency Assessments Human Factors

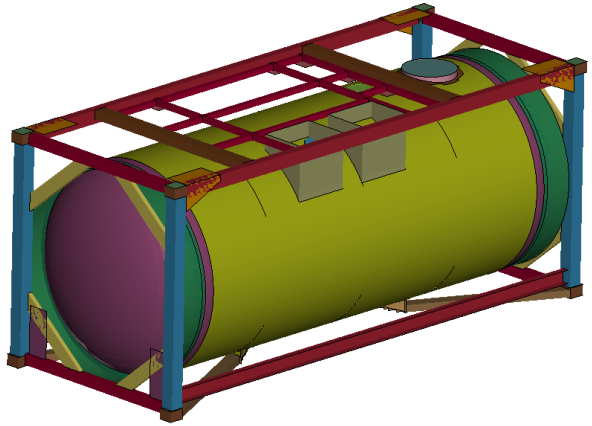
Storage Incident

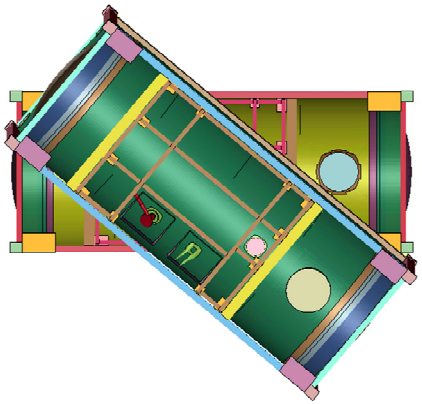
Insulation damaged; minor damage to outer cooling coils. No loss of containment.

Container scrapped

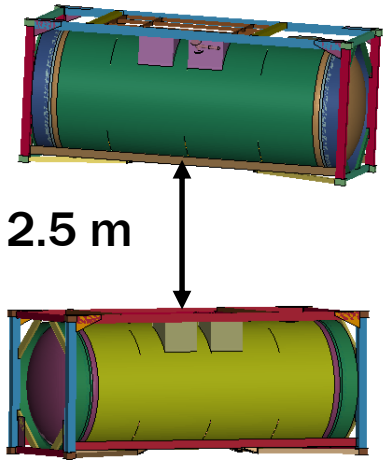
Finite Element Analysis (FEA) Model

- LS-DYNA model of ISO tank
  - Half million elements for ISO tank and fluid fill



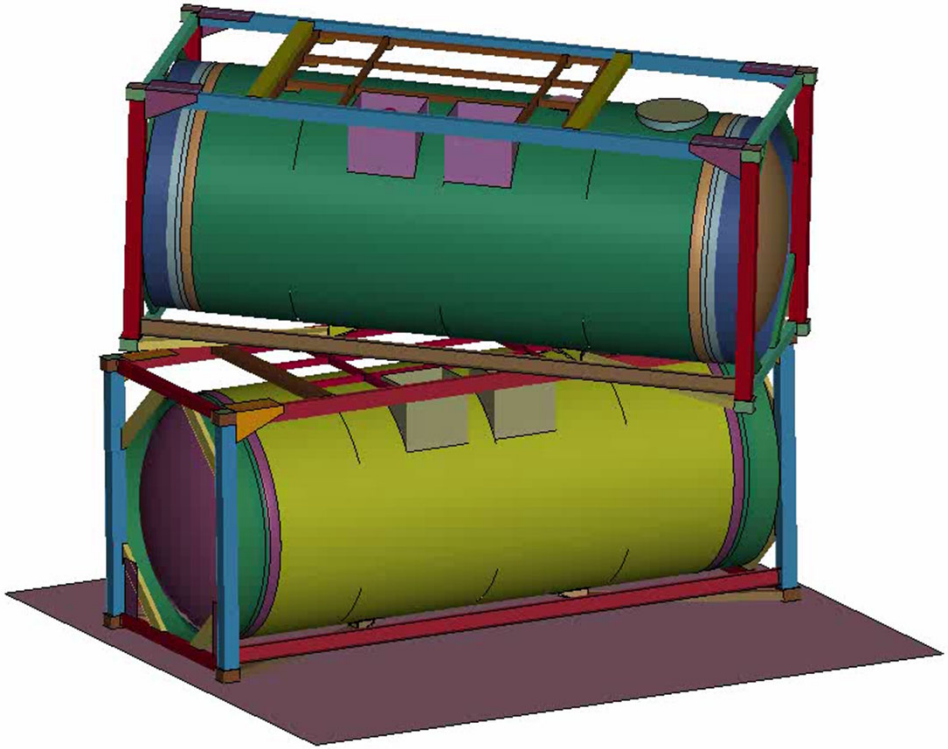


- Problem setup: drop during stacking

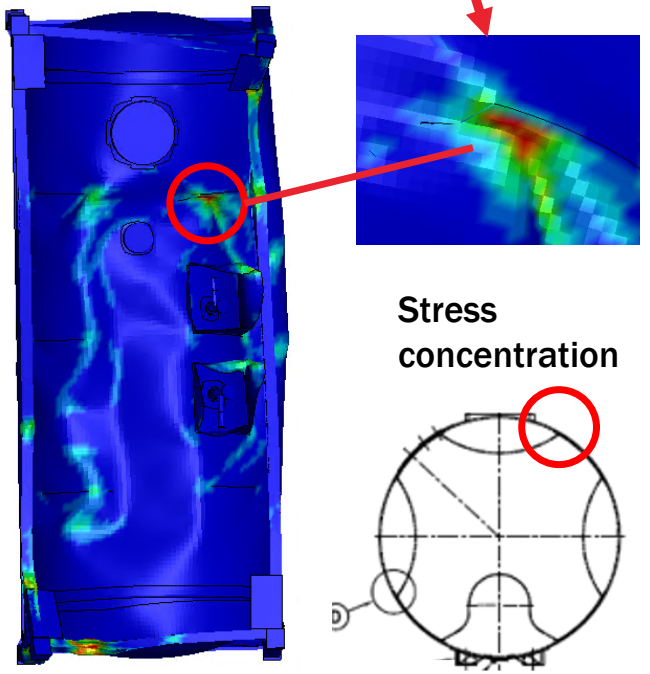


Not aligned during impact

FEA Results



Plastic strain exceeds limits, **LOC predicted**



Stress concentration

Lower isotank

FEA Results Summary for Isotank Drops

Drop Height (m)	Drop Orientation	Drop onto	Example FEA Results
4	Flat	Ground	No LOC
25	Flat	Ground	>12-inch LOC
1	Angled	Ground	No LOC
4	Angled	Ground	< 1.5-inch LOC
1	Flat	Isotainer	Top isotainer: No LOC Bottom isotainer: No LOC
2.5	Flat	Isotainer	Top isotainer: No LOC Bottom isotainer: < 1.5-inch LOC
6	Flat	Isotainer	Top isotainer: 12-inch LOC Bottom isotainer: < 1.5-inch LOC

Road Incident – Minor

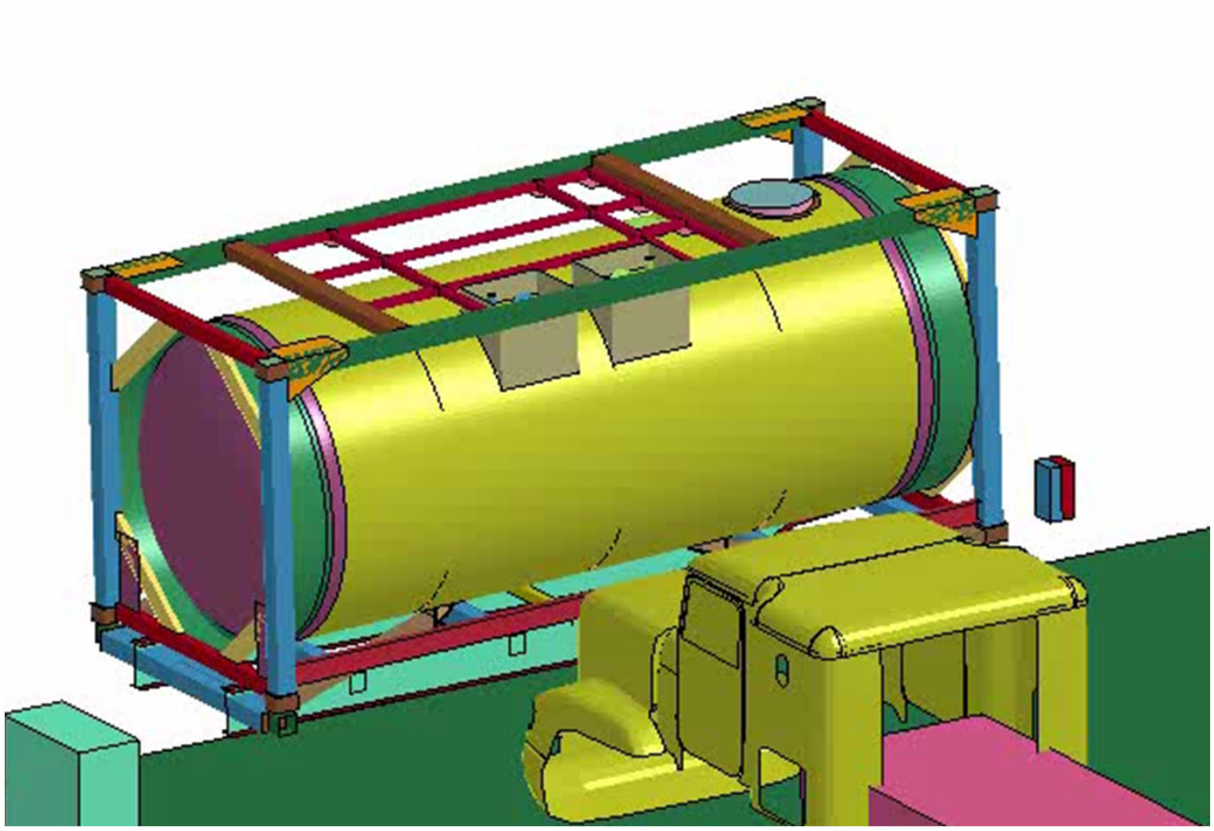
- Driver was asked to take an unfamiliar route (without guidance) through a customer's large site due to construction work in progress.
- It would have been better to ask for guidance…

Road Incident - Major

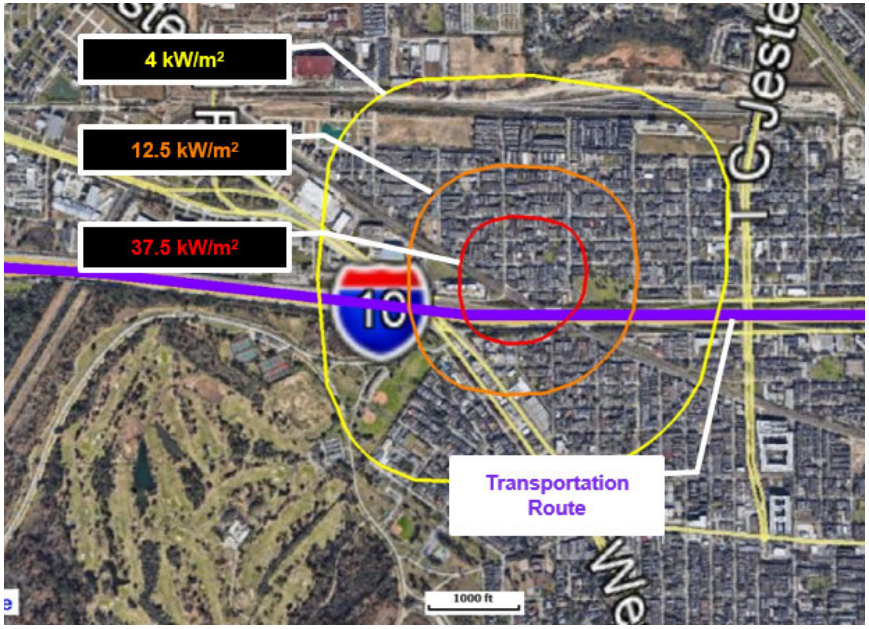
International Tank Container Organisation – ITCO
ICHCA International Ltd

No loss of containment

Vehicle Impact



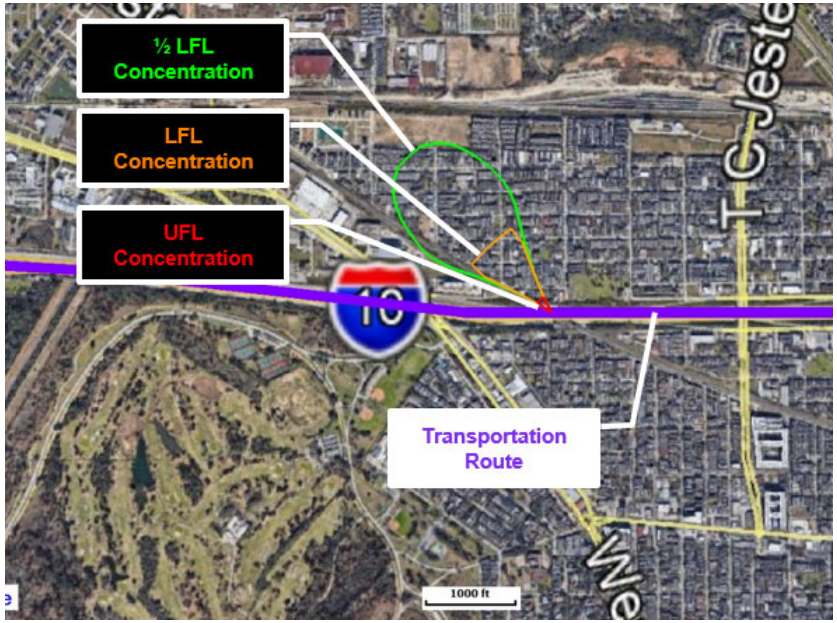
Route / Consequence Analysis



Fire scenario – thermal radiation contours

Change the route

- Avoid high population densities



Flammable release – Flammability contours

Those in Peril on the Sea

- The legal authority of a ship's captain is extensive and carries significant responsibility for:
  - the safe and efficient operation of the ship, its seaworthiness, safety and security, cargo operations, navigation, crew management,
  - legal compliance,
  - and for the persons and cargo on board.

Fatalities at Sea…

- Worldwide, during 1998–2008, accidents involving packaged dangerous goods on container ships were estimated to account for 15% of all fatalities.
- Self-ignition or ignition of incorrectly declared dangerous goods was identified as a contributing factor for the fatal accidents.
- Ensuring that dangerous goods are correctly prepared and documented for marine transport is thus very important for preventing releases and improving on board safety.

Ellis, J., 2011. Analysis of accidents and incidents occurring during transport of packaged dangerous goods by sea. *Safety science*, *49*(8-9), pp.1231-1237.

Fires at Sea

- You're 2000 km from land, from the nearest emergency services.
- A container is developing into a raging inferno.
- How do you protect your ship and crew ?

At Sea - Risks

Event	Consequence	Prevention / Mitigation
Mis-loading of incompatible or inadequately stabilised material	Reaction during shipment (e.g. styrene – runaway)	Safety Audits of Management Systems Equipment reliability
Overfilling	Expansion results in loss of containment through relief system	Human Factors / Safety Critical Task Analysis SCTA
Mis-declaration of cargo (hazard status e.g. flammable vs. non-flammable	Flammable / reactive materials may be mis-loaded onboard ship (e.g. MV Flaminia incident)	Human Factors / Safety Critical Task Analysis SCTA

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On a lighter note…

https://www.planetcruise.com/en/cruise-guides-and-features/exploring-the-northern-lights]#

Refrigerated Shipment ?

- Hazardous cargoes are stored on the upper (outer) deck and can be exposed to sea water
- 48 hours gentle work with a warm water supply…

Whose Risk Is It Anyway ? - Conclusions

- Hazardous chemicals are, by definition, hazardous.
- From pharmaceuticals to phones, our society requires materials which are made using these chemicals.
- The movement of these chemicals around the world creates risk for all who are involved – and those who are bystanders to the process.
- While containers can be designed for foreseeable scenarios, many of the protections rely upon people and the operation of process safety management systems (Human Factors).

- Whose risk is it ? – Everyone's
  - By risk assessing every step of the journey, we can all play our part.

Thank You for Listening

Questions?

www.BakerRisk.com

Contact Us – Stand 5 (next to the coffee !)

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