Hazards Management for ASTs

Hazard Events that can Affect Your Facility

- Lighting and Fires
- Wind Damage & Hurricanes
- Floods
- Seismic events
- Releases to the Environment

Causes of Tank Fires and Discharges

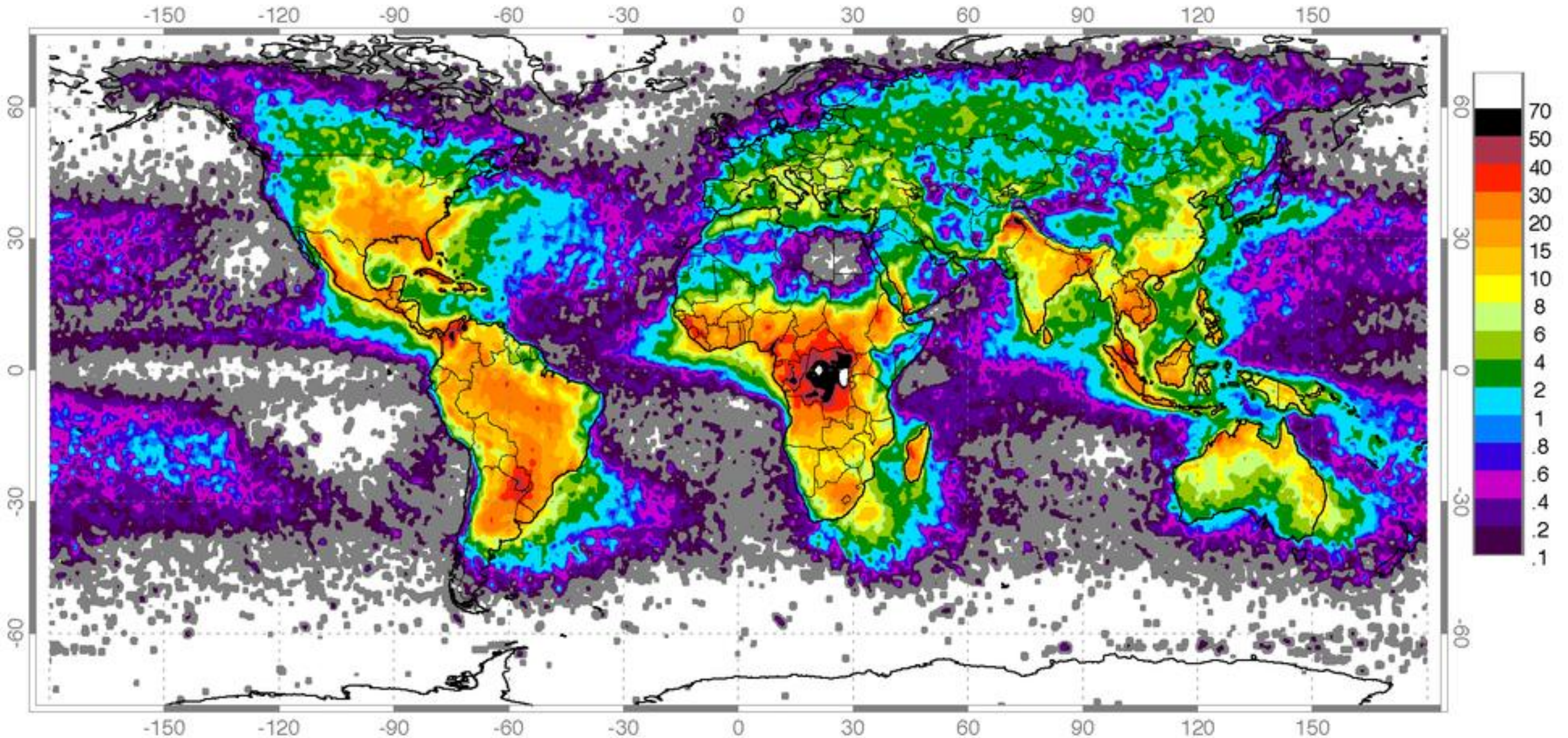
Year	60-69	70-79	80-89	90-99	00-03	Total
Lightning	4	10	19	37	10	80
Maintenance Work	1	5	9	12	5	32
Operational Error	1	5	6	8	9	29
Equipment Failure	3	1	5	7	3	19
Sabotage	2	5	2	6	3	18
Crack/Rupture	0	3	3	3	8	17
Leaks & Line Rupture	0	3	2	5	5	15
Static Electricity	2	1	2	2	5	12
Open Flame	1	0	4	2	1	8
Natural Disaster	1	2	1	1	2	7
Runaway Reaction	2	1	0	2	0	5
Total	17	36	53	85	51	242

Sources: The Loss Prevention Journal – Report - 26 May 2005

33%(80 accidents) from Lightning 25% (61 accidents) due to Human error (Welding:18 of 32 for Maintenance, and Overfills were 15 of 29 Op error)

Hazard Prevention - Lightning

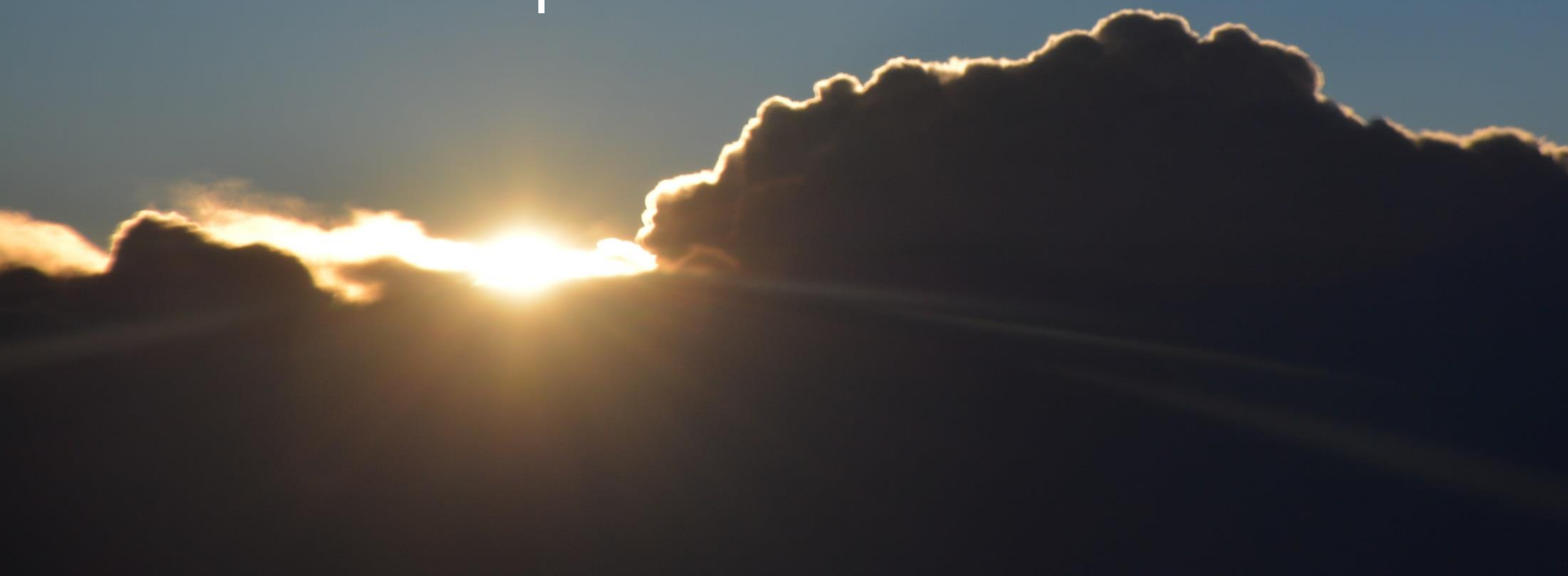
Lightning Protection – Annual Flash Rate



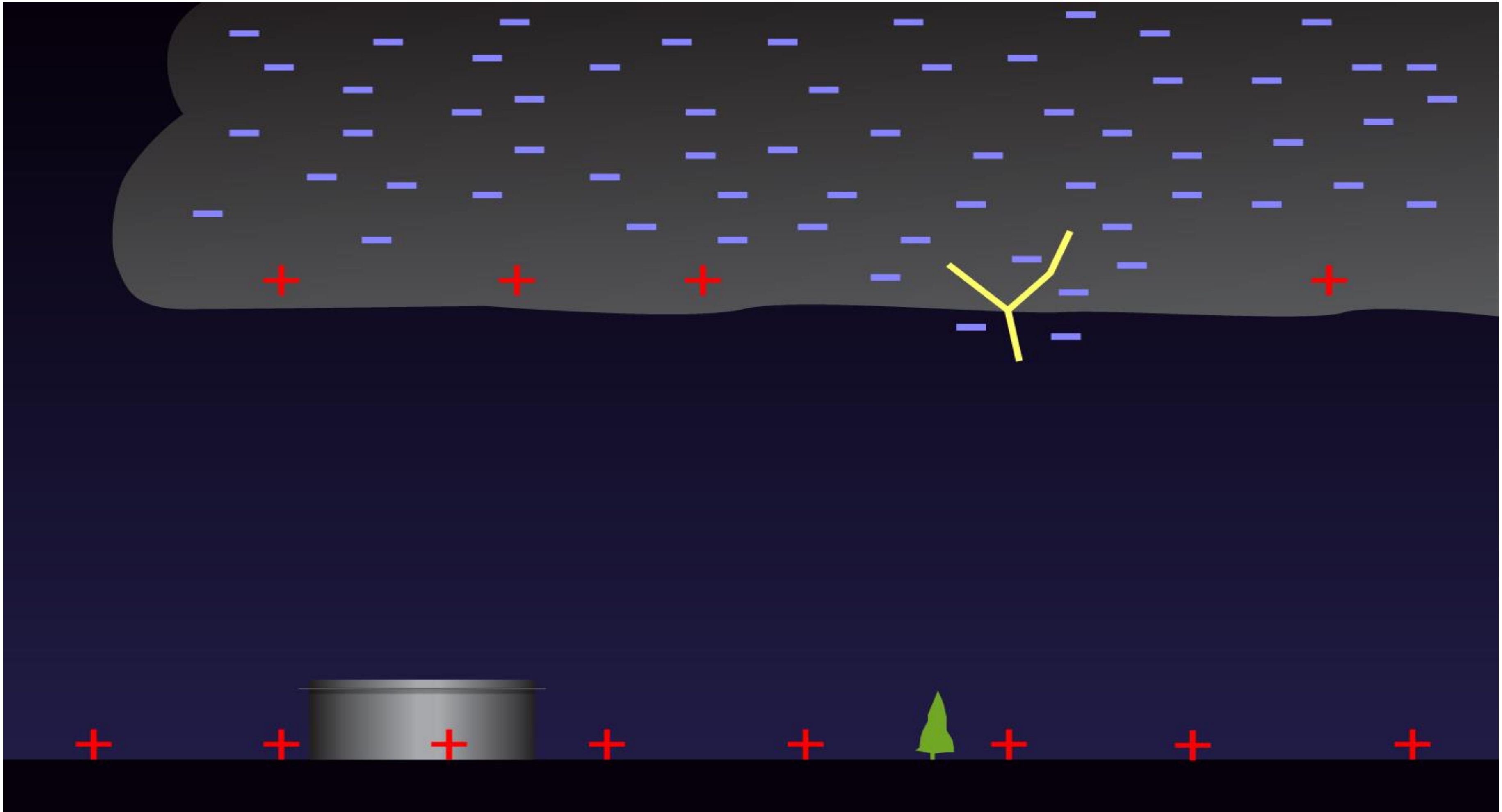
Units: Flashes/sq km/year – Global distribution of lightning over an 8 year study from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

Types of Damage from Lightning

1. Physical damage
2. Secondary effect damage
3. Electro-Magnetic Pulse (EMP) damage
4. Damage caused by changes in ground reference potential



Lightning Propagation



SOURCE: *All About Lightning*, Martin A. Uman, Dover Publications

Lightning Protection - Grounding

- API 650 – Tank Grounding
  - A minimum of 4 grounding lugs, equally spaced at a maximum 30 meters spacing is recommended

Background and Best Practices and Principles for Grounding

- Metallic structures can have buildup of electrical energy and can also attract electrical energy from storms
- Electrical energy always takes the path of least resistance
- Multiple low-impedance contiguous downward coursing paths to the grounding system transfer lightning energy off of the structure and into ground as quickly as possible

Additional Best Practices & Principles

- Since lightning is high frequency, low-impedance, they key to grounding is not just low-resistance, but the geometry of the grounding paths
- The higher the impedance the lightning energy "sees", the greater the voltage increases.
- The higher the voltage, the more likely the energy will arc, or take unwanted paths to ground.

Grounding and Bonding for Open Top Tanks with Floating Roofs

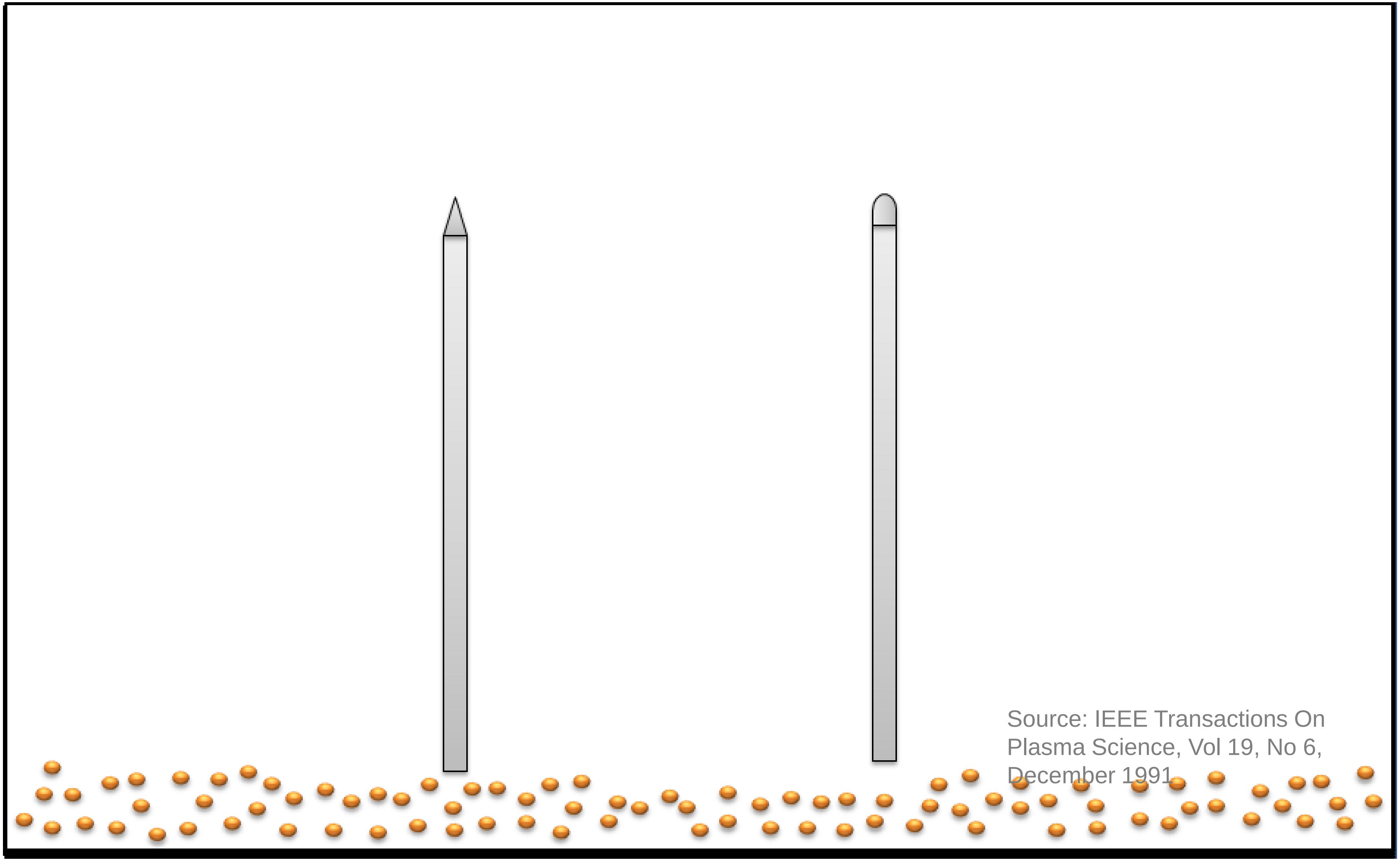
1. All conductive parts shall be grounded
2. All movable cover accessories (hatches, manholes, pressure relief devices, etc.) on the external floating roof shall be electrically bonded to the external floating roof to prevent static electricity sparking when they are opened
3. Ladders shall be grounded to both the roof and the gauger’s platform
4. Shunts should be provided on the uppermost seal and bond the shell and roof of the tank in 3m intervals

Lightning Protection – Shunts and Bonding

Codes Addressing Bonding and Lightning Protection for ASTs

- API 650 – Above Ground Storage Tanks
- NFPA 780 – Standard for Installation of Lightning Protection Systems
- API RP 2003 – Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
- NFPA 30
- International Fire Code

Discharge Phenomena – Traditional Lightning Rods Compared to Streamer-Delaying Air Terminals

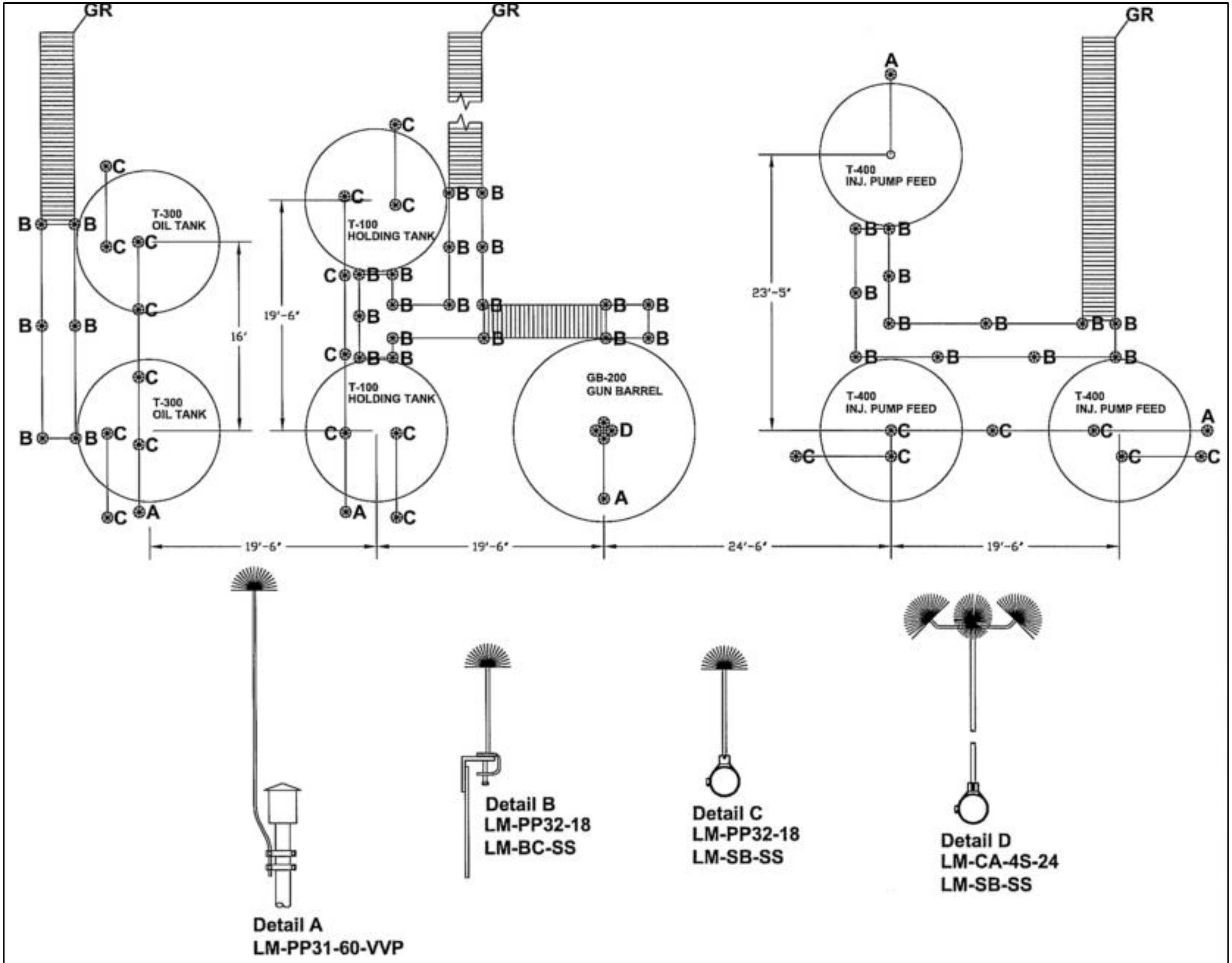


Source: IEEE Transactions On Plasma Science, Vol 19, No 6, December 1991

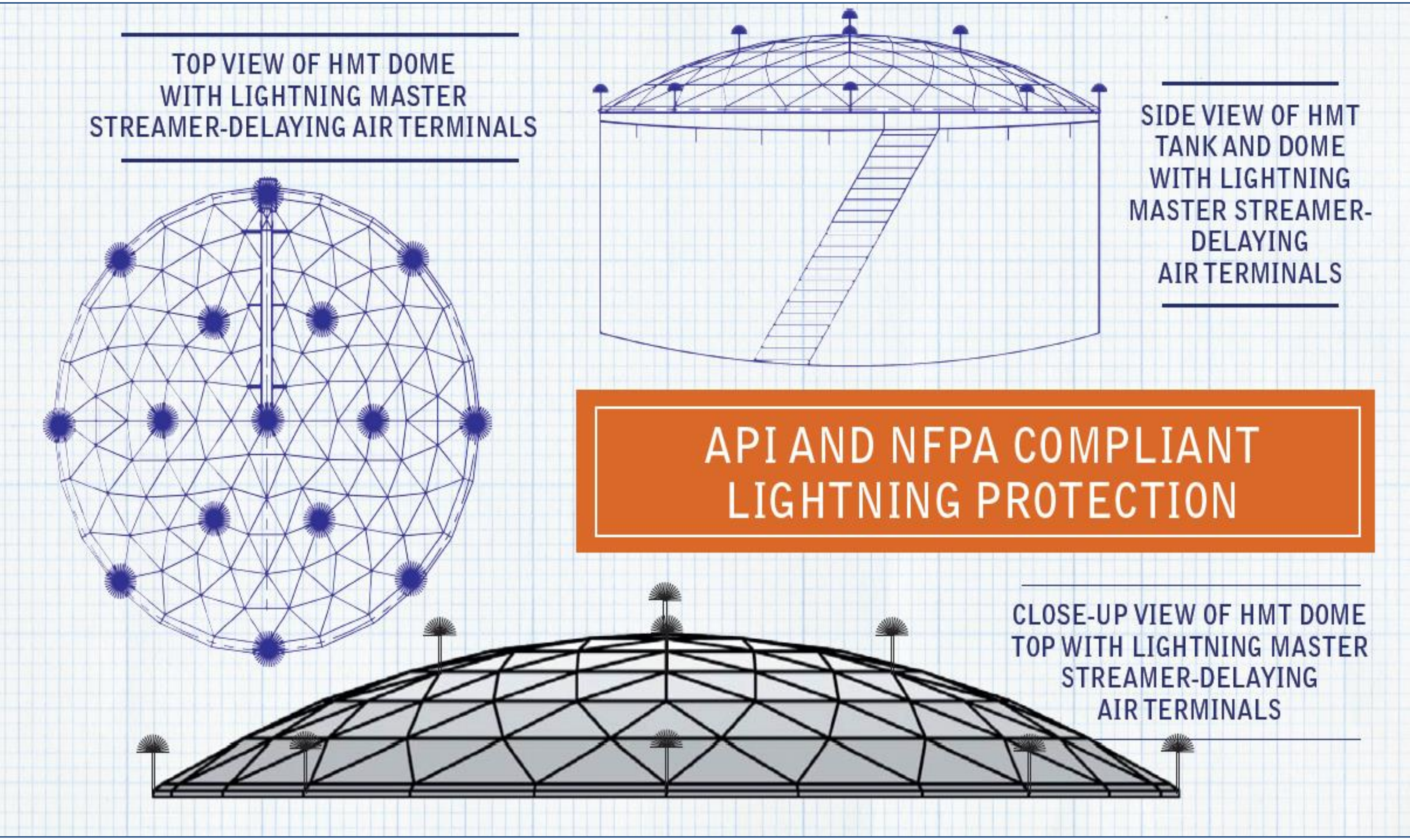
System Design

- Charge accumulates on (and streamers tend to form from) a structure predictably - according to the physical principle of point discharge
- A structure properly blanketed by air terminals designed to delay the formation of streamers is thus protected

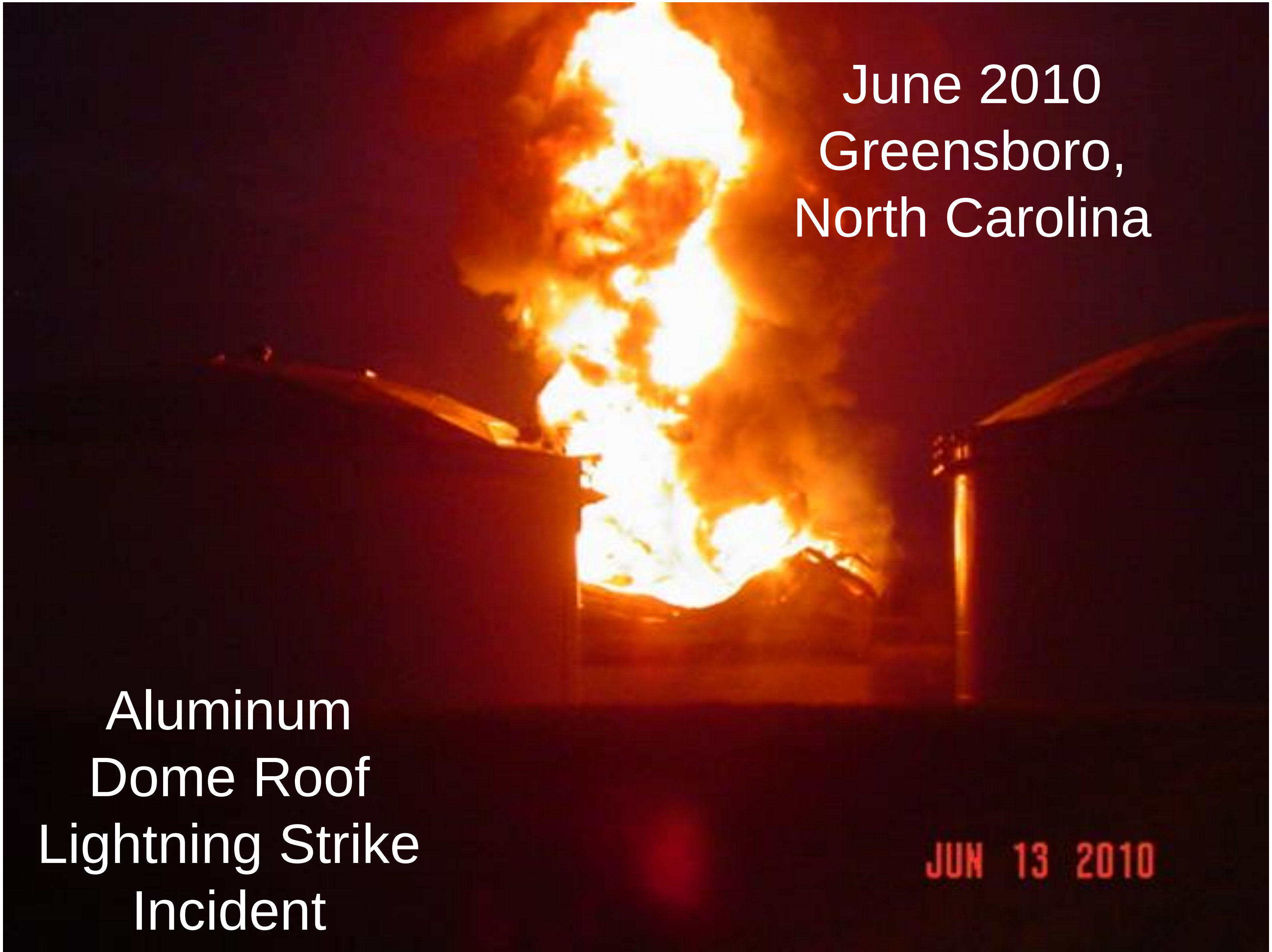
Example - Site Layout and System Design



Dome Roof Lightning Protection Design



Dome Roof Considerations




COUNT 0:00:31:06

The Aftermath…

Conventional Protection

Tank Fires

Fire Prevention

- Lightning Protection Systems
- Proper Operations and Maintenance Procedures
- Electrical Code Compliance

Buncefield, England, 11 Dec 05

Buncefield, England, Aftermath

August 18 -20 2008 –
Tanjung Langsat Oil Port Terminal

Caribbean Petroleum, Puerto Rico, United States, October 23-25, 2009

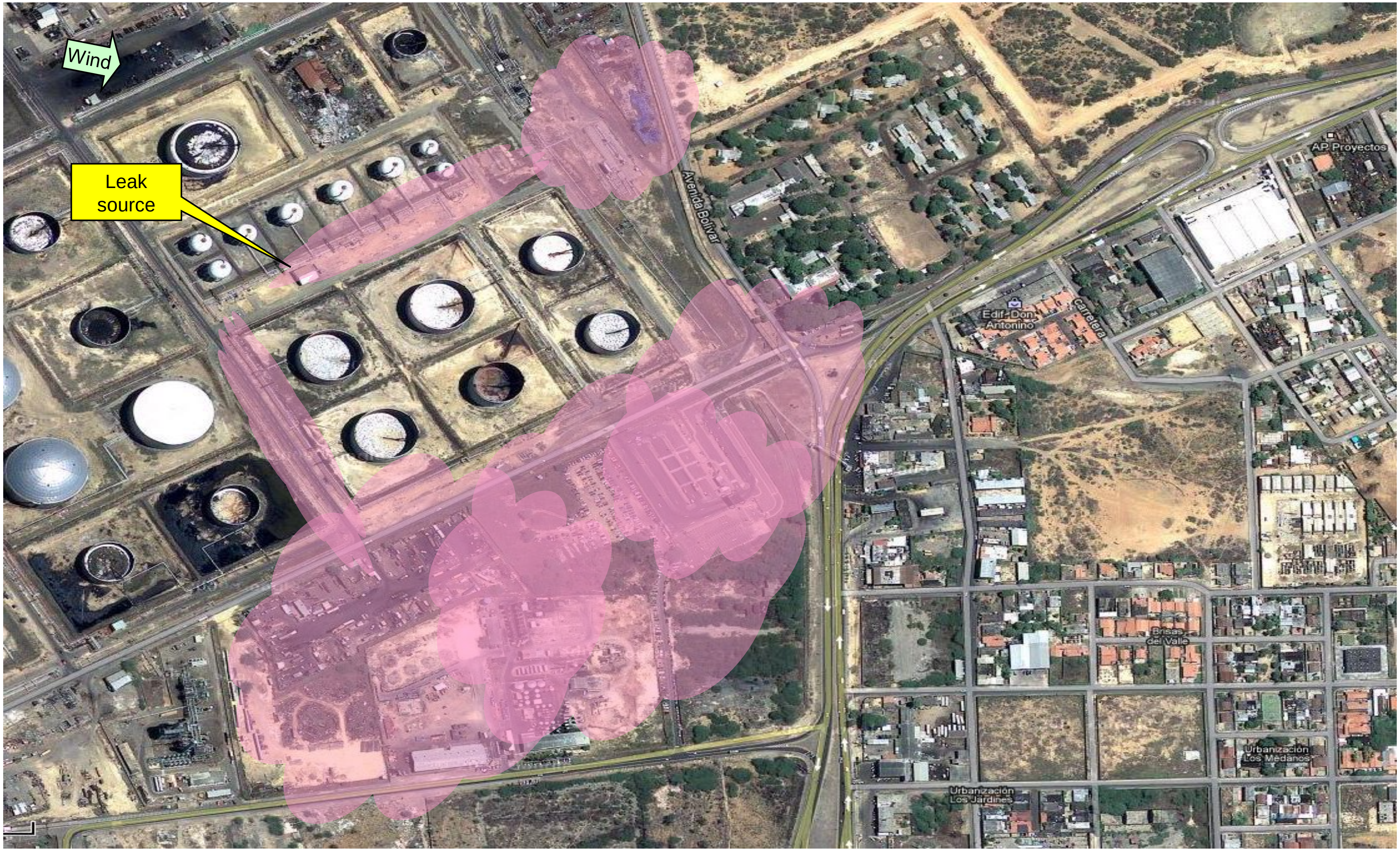
Jaipur, India, October 29-November 6, 2009, Indian Oil Corporation

Miami International Airport, Florida, March 27, 2011

Chevron Refinery in Richmond, California – August 11, 2012

Petroleos de Venezuela, Amauy, Venezuela – August 25, 2012

Petroleos de Venezuela, Amauy, Venezuela – August 25, 2012



Fire Protection Systems and Plans

- Fire Protection is driven by code and risk management
- What are the risks?
  - Design risks?
  - Operational risks?
  - Plan risks?
  - Human Element- coordination with fire authorities, employee training, and designated personnel?

Fire Protection Design Risks/Hazards

- Hazard/Consequence Analysis – What are the risks involved?
  - Heat Flux Calculations
  - Vapor Cloud Fires
  - Pool Fires
  - BLEVEs (Boiling Liquid Evaporating Vapor Explosions)
  - Vapor Cloud Explosions

Risk Mitigation

- Site/ Location
- Suppression/ Extinguishing Systems
- Blast/ Fire Walls
- Early Detection Systems

Fire Scenarios

- Ground Fires
- Vent Fires
- Rim Seal Fires
- Obstructed Fires
- Unobstructed Fires

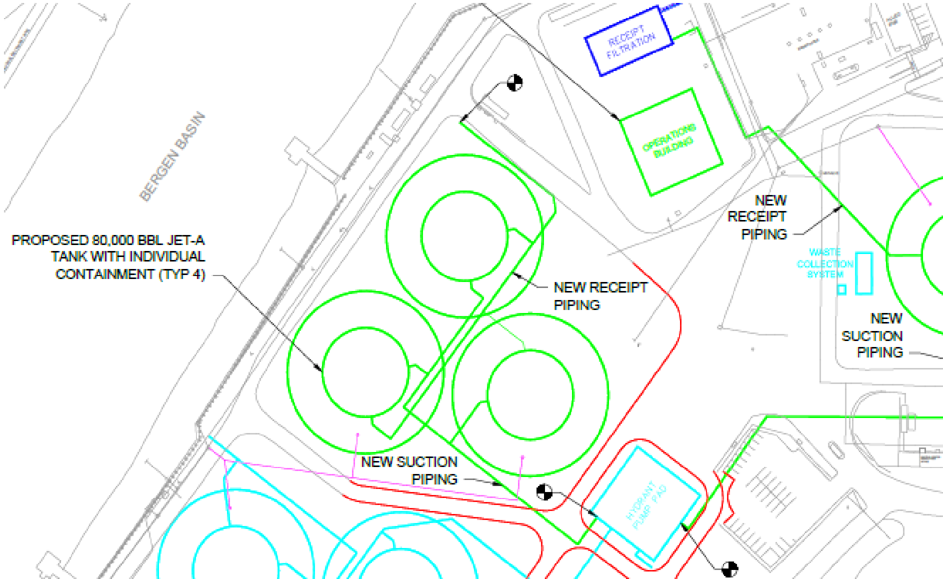
Fire Protection Systems and Plans

Extingushing Systems

Techniques & Equipment

Water Supply

Site Access



Fire Response

- Most response plans include effort to prevent the fire from spreading, not just extinguishing a tank fire.

API Standard 650 Provides Most of the Tools We Need-Foundations, Shell, & Roofs

- Wind loads
- Flooding
- Seismic

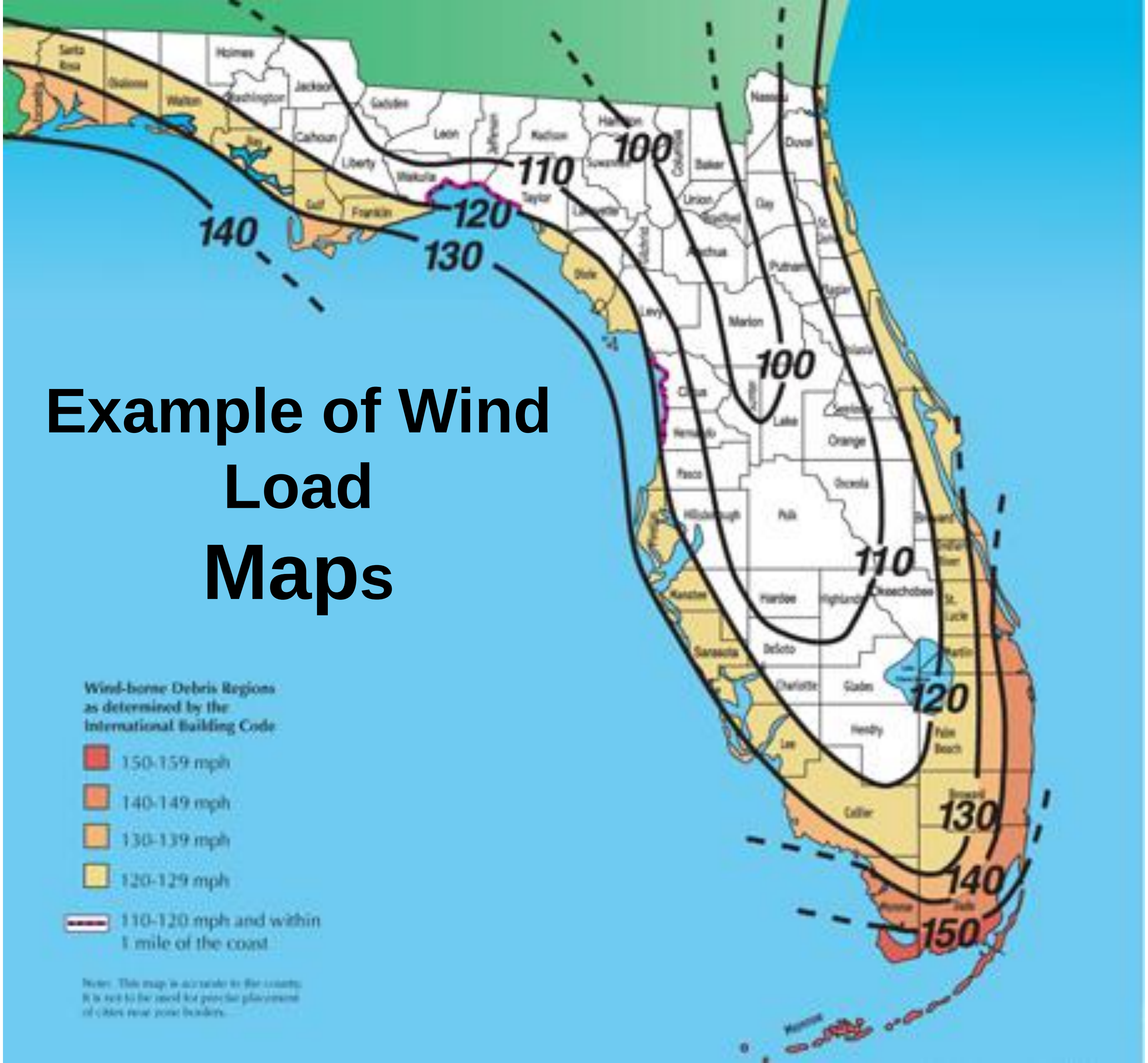
What are the Risks from Wind Damage?

Wind Issues…Shell Buckling, Tank Overturning, and Roof Damage

Wind Loads on Tanks

- API Standard 650 has specific requirements for shell buckling and tank overturning
- Provides a set of rules for evaluating the uplift or overturning stability of a tank
- If the design does not satisfy the uplift requirements:
  + Increase shell weight
  + Provide anchorage

Example of Wind Load Maps



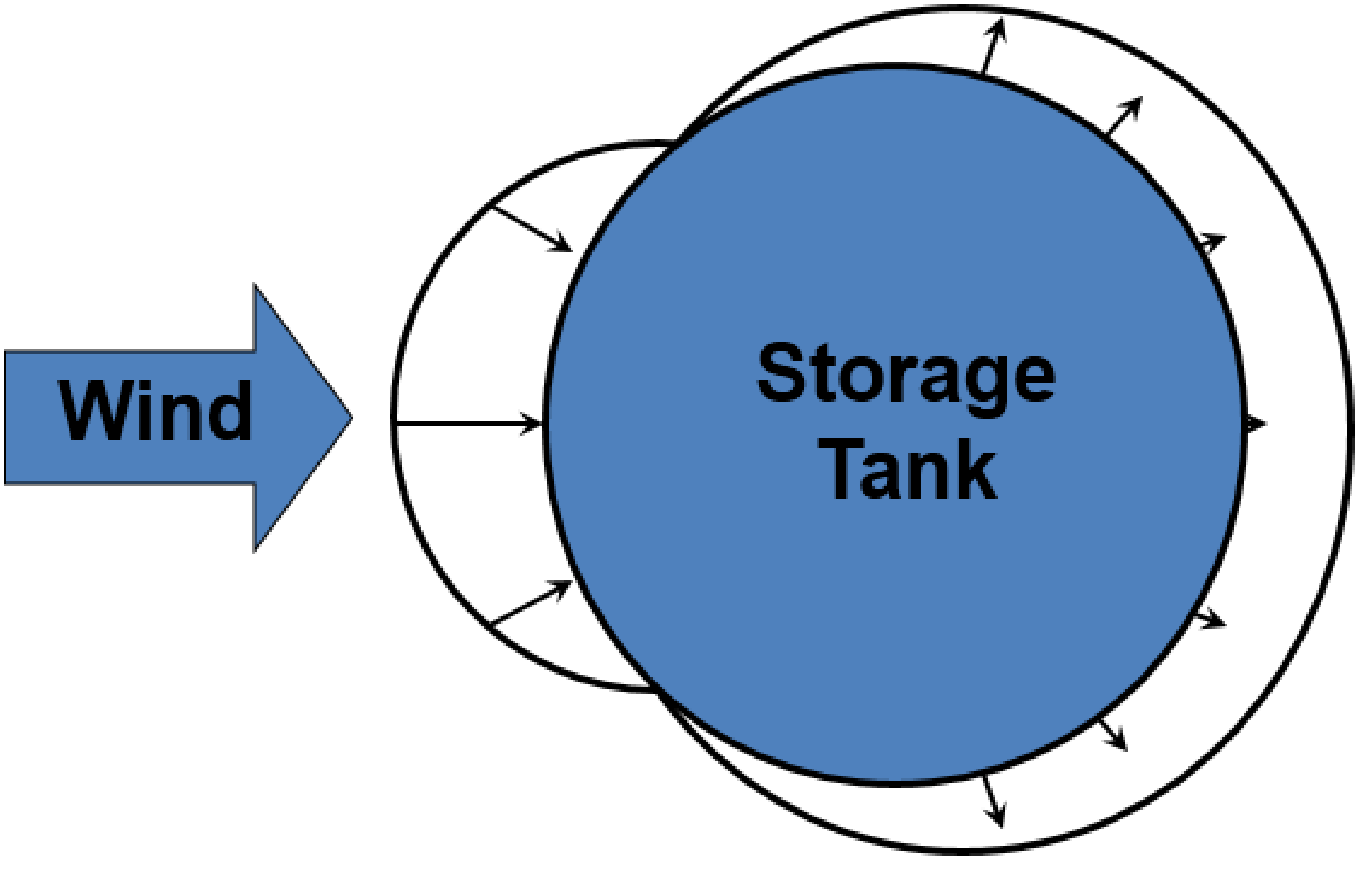
Wind Speed

- The current edition of API Standard 650 defines wind speed in terms of the "3-second gust" criteria
- New tanks are designed to resist wind speeds of 193 km/hr in the current API-650
- The 3-second gust criteria is 20% greater than the sustained wind velocity criteria

API-650 Shell Stability

- Tank is most vulnerable when empty
- API procedures originated in early 1960s
- Methods based on uniform vacuum analogy using the maximum wind pressures on shell

Buckling on Windward Side



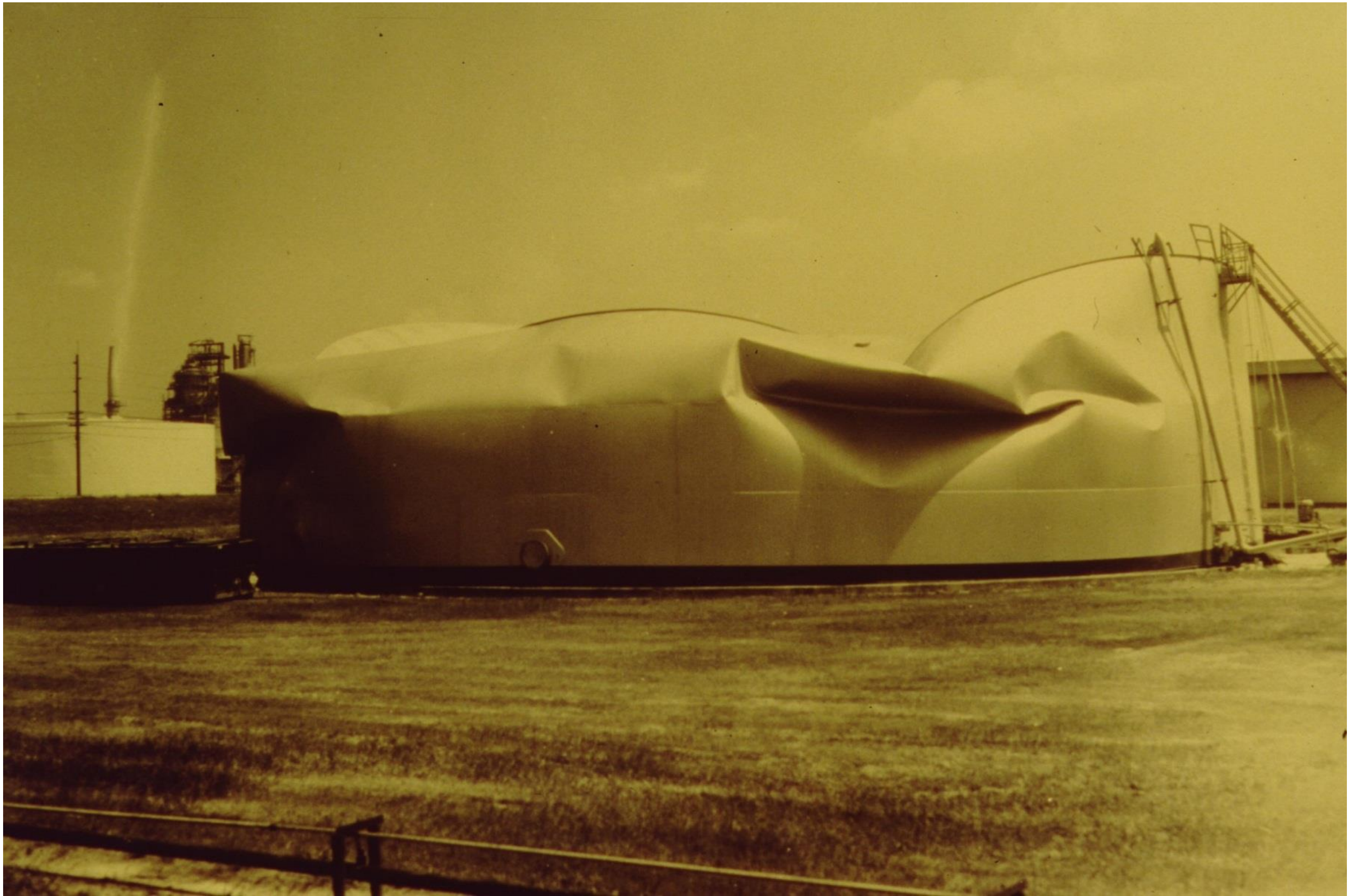
Shell Buckling During Construction - Vulnerable Without Wind Girder

Shell Buckling When Empty

Shell Buckling After Loss of Roof

Tornado Damage

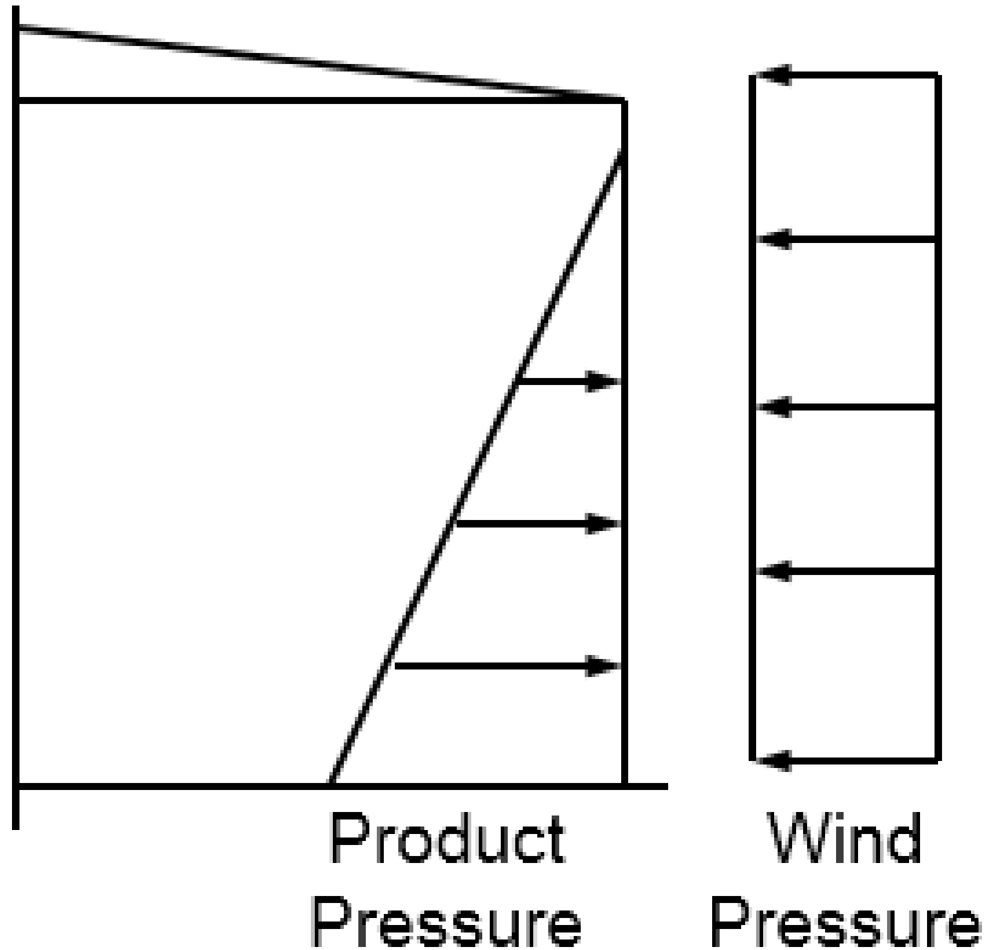
Roof Damage BEFORE the Storm…Then Water Ponded on the Roof



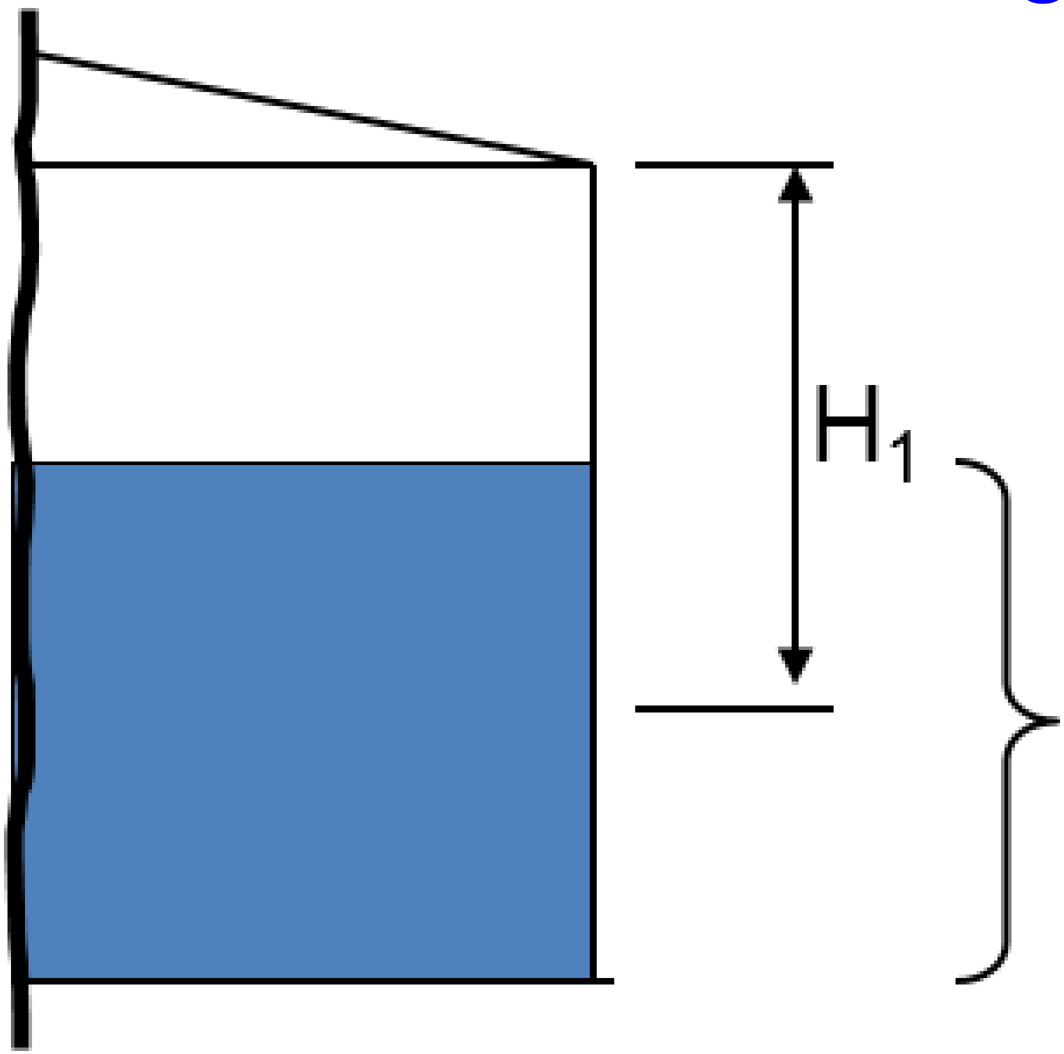
Shell Buckling BEFORE the Storm…Then Water Ponded on the Roof

What if the Shell is not Stable for the Expected Wind Speed?

- Fill tank with product
- Partially fill tank
- Do nothing and hope for the best



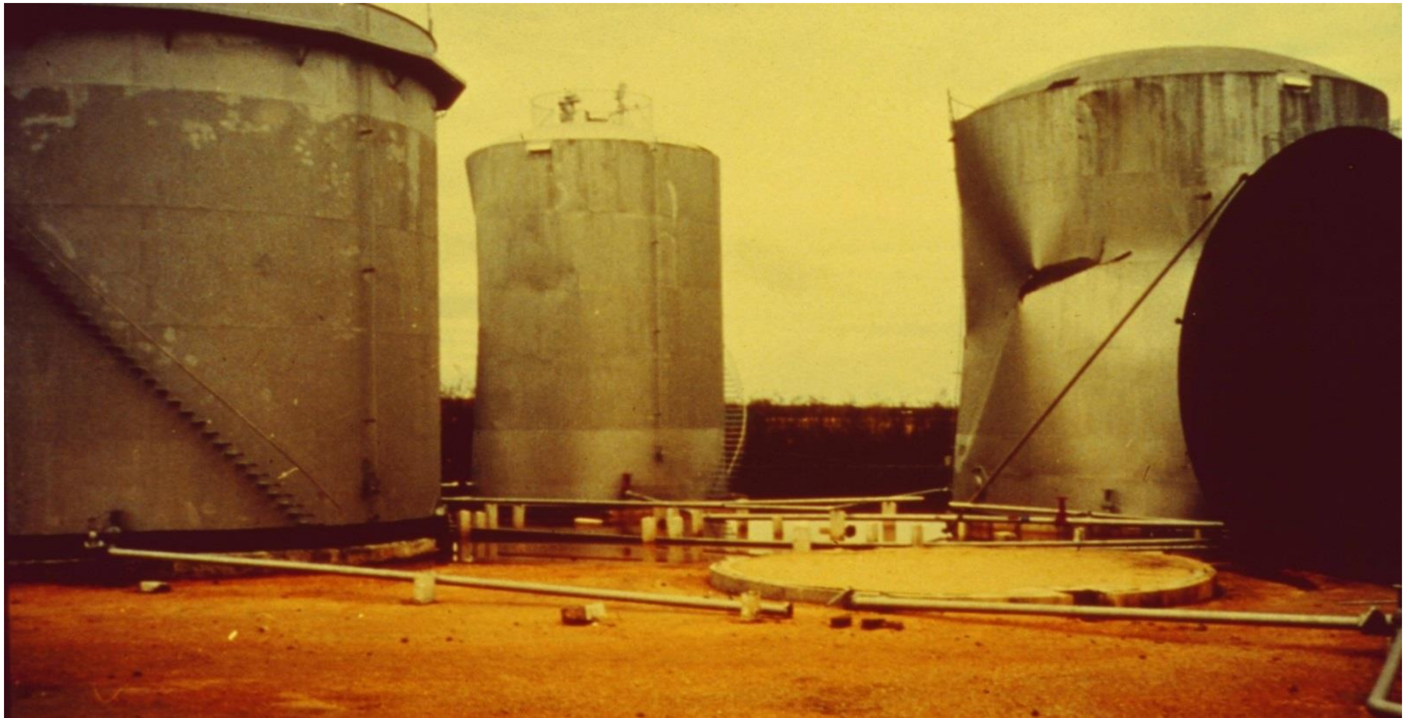
Add Product to Tank to Reduce Risk of Shell Buckling



- Determine a product depth that will increase shell stability

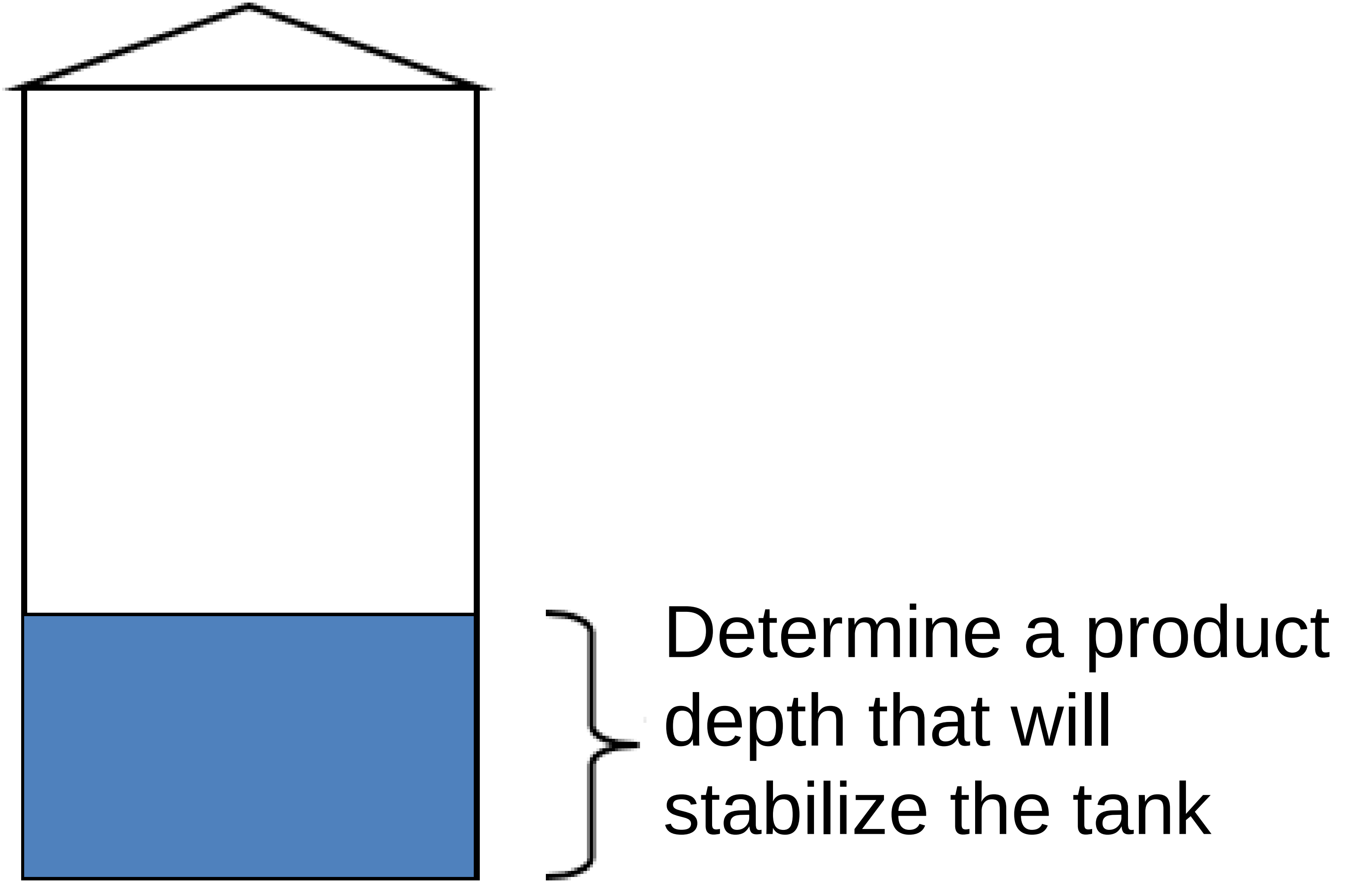
Wind Overturning

- Primarily a problem for small diameter tanks that are empty
- Doesn’t happen often, but should be considered
- API-650 has simplified procedures to verify

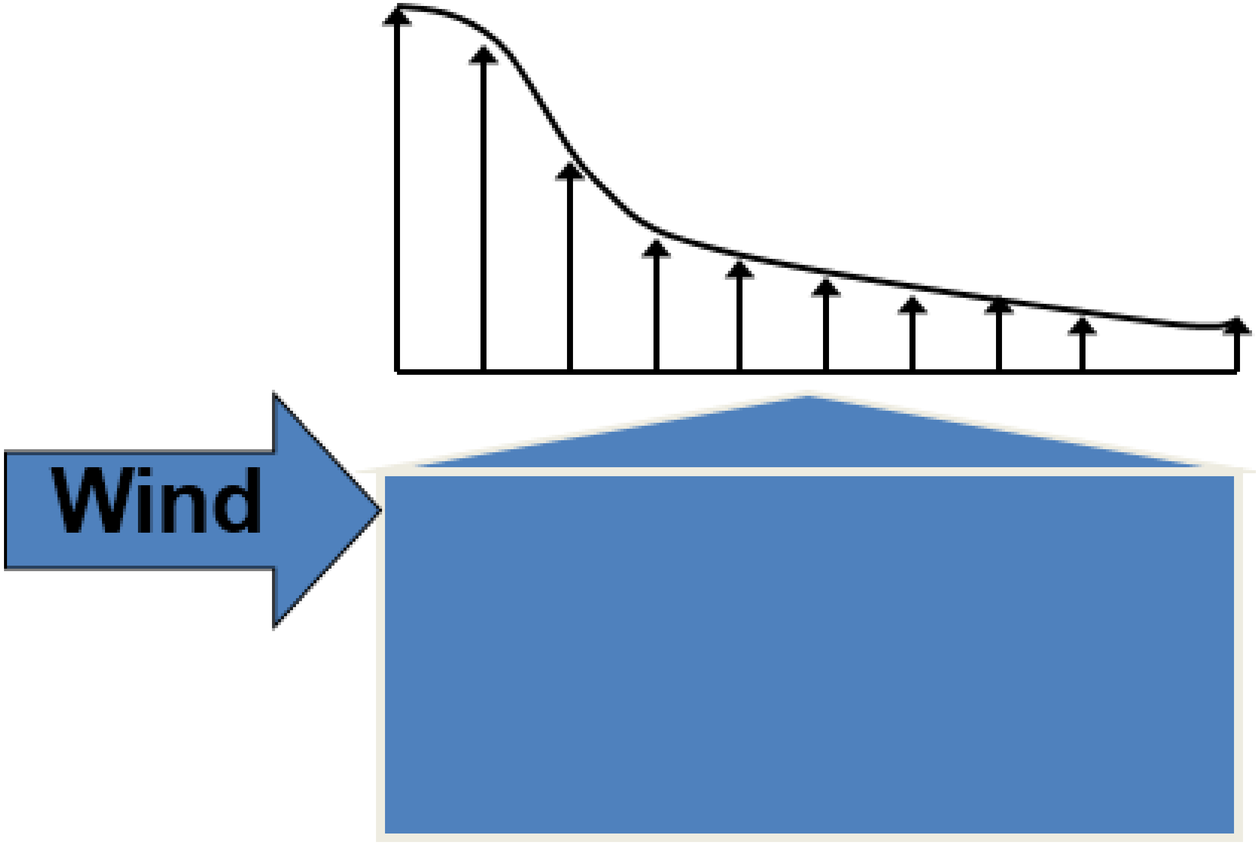


Wind Overturning

Add Product to Tank to Prevent Overturning of Unanchored Tanks



Fixed Roof Damage



- Roof uplift pressure will occasionally damage tanks
- Roof -to-shell joint may tear and “peel” away roof plate
- Roof structure may be dislodged by distortion of shell

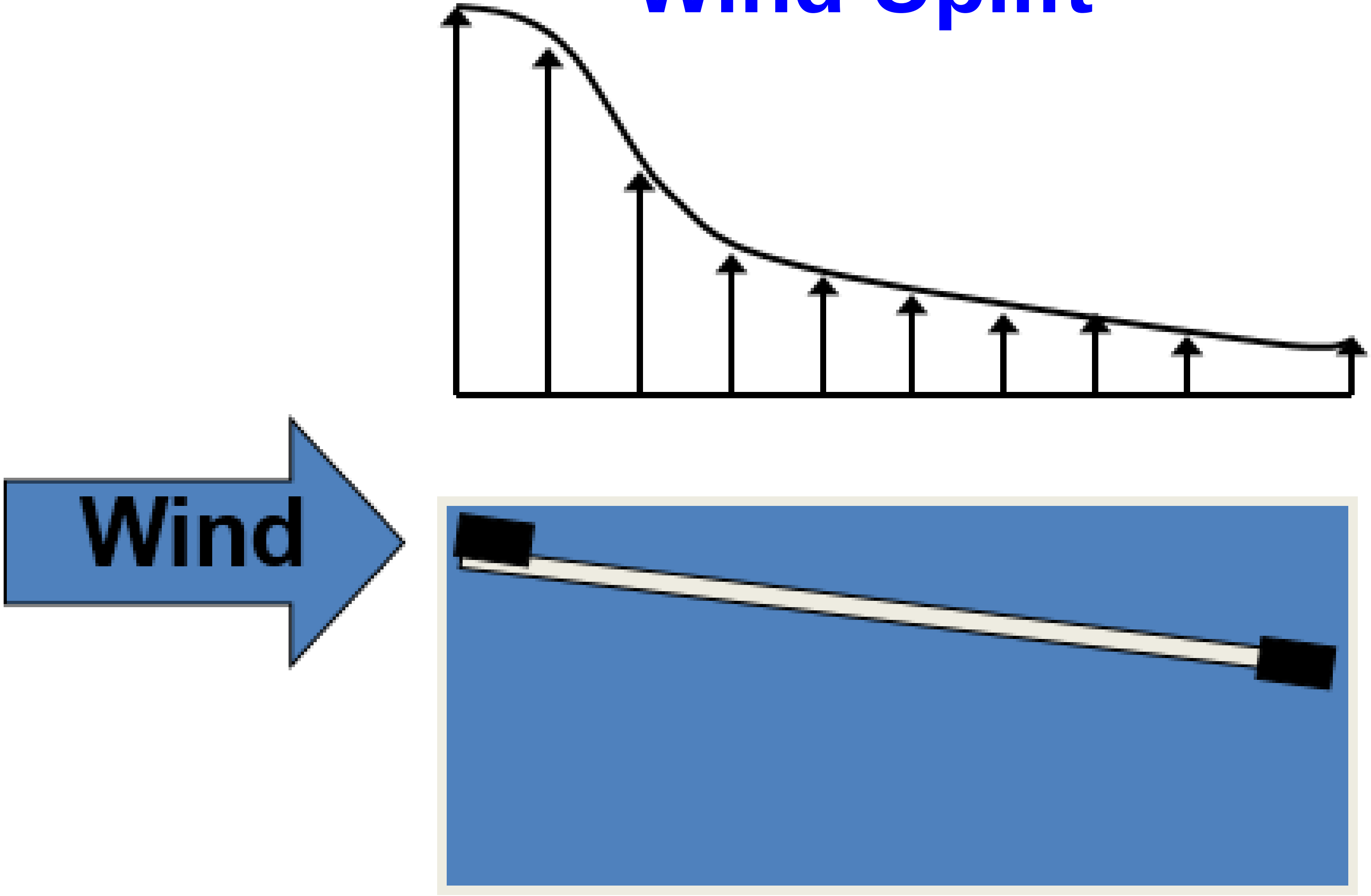
Peeling Off of Roof Insulation

Peeling Off of Roof Plate

Plate Pulled Off Tank Roof

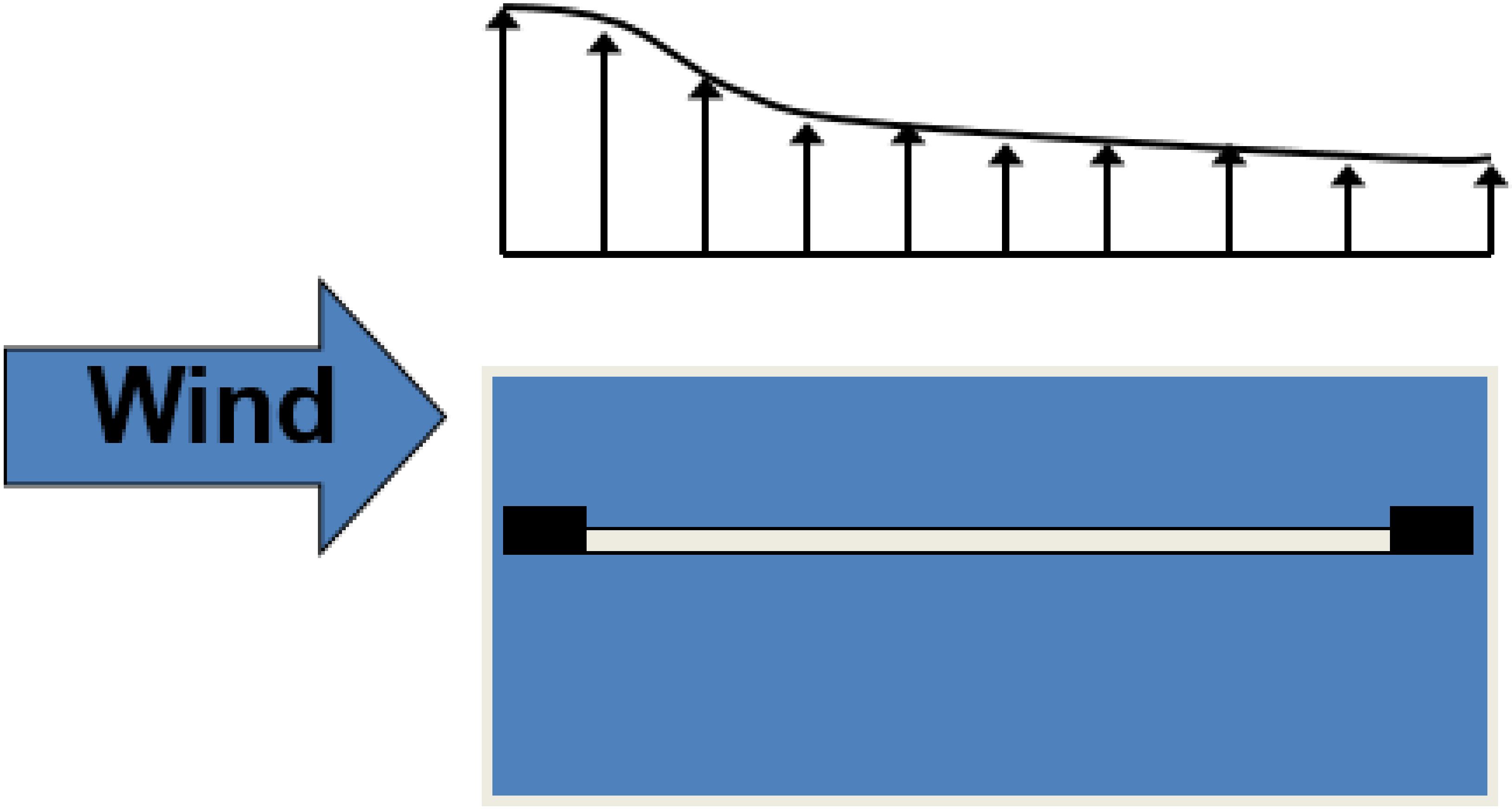
Floating Roof Damage

Wind Uplift



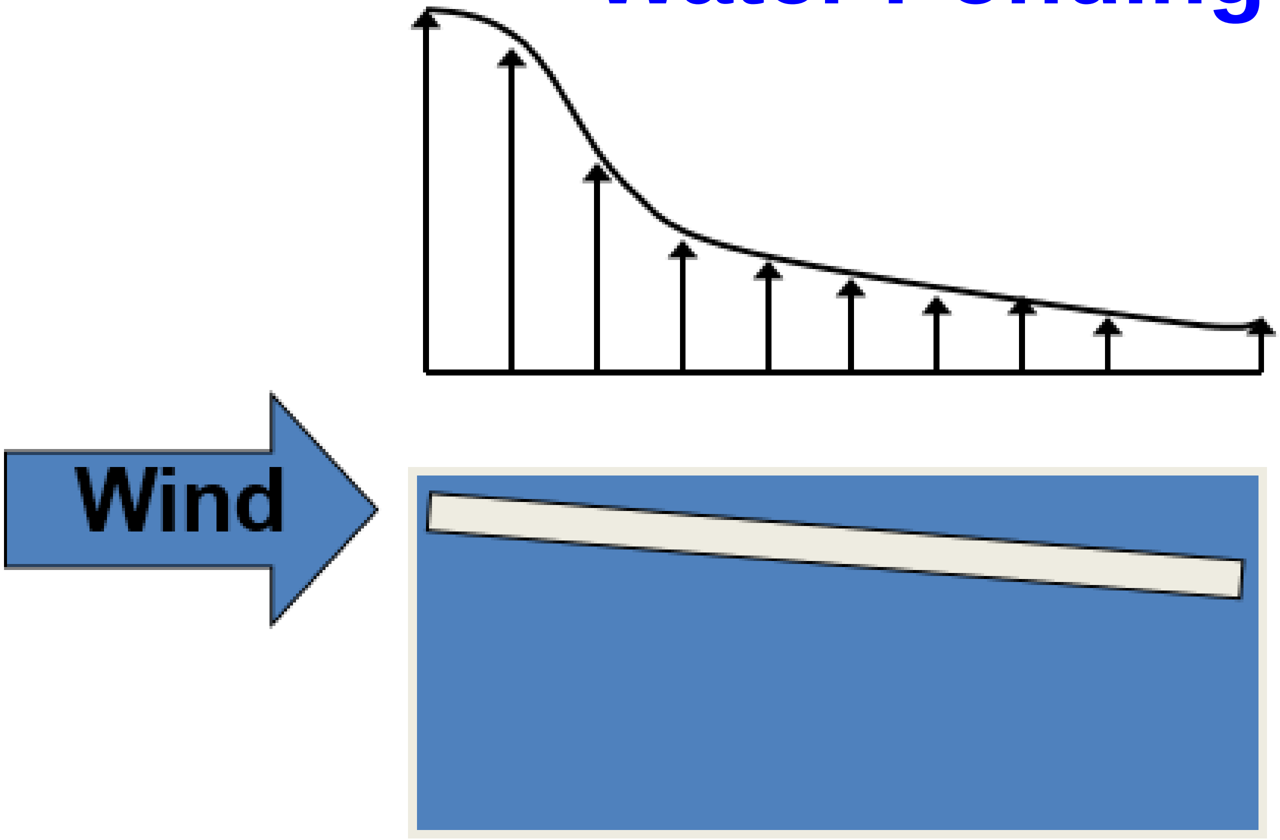
- Floating Roofs are more vulnerable when tank is full
- Worst case for differential wind uplift

Wind Uplift



- Floating Roofs are less vulnerable when tank is not full
- Differential wind uplift is minimized
- Uplift load is less

Water Ponding



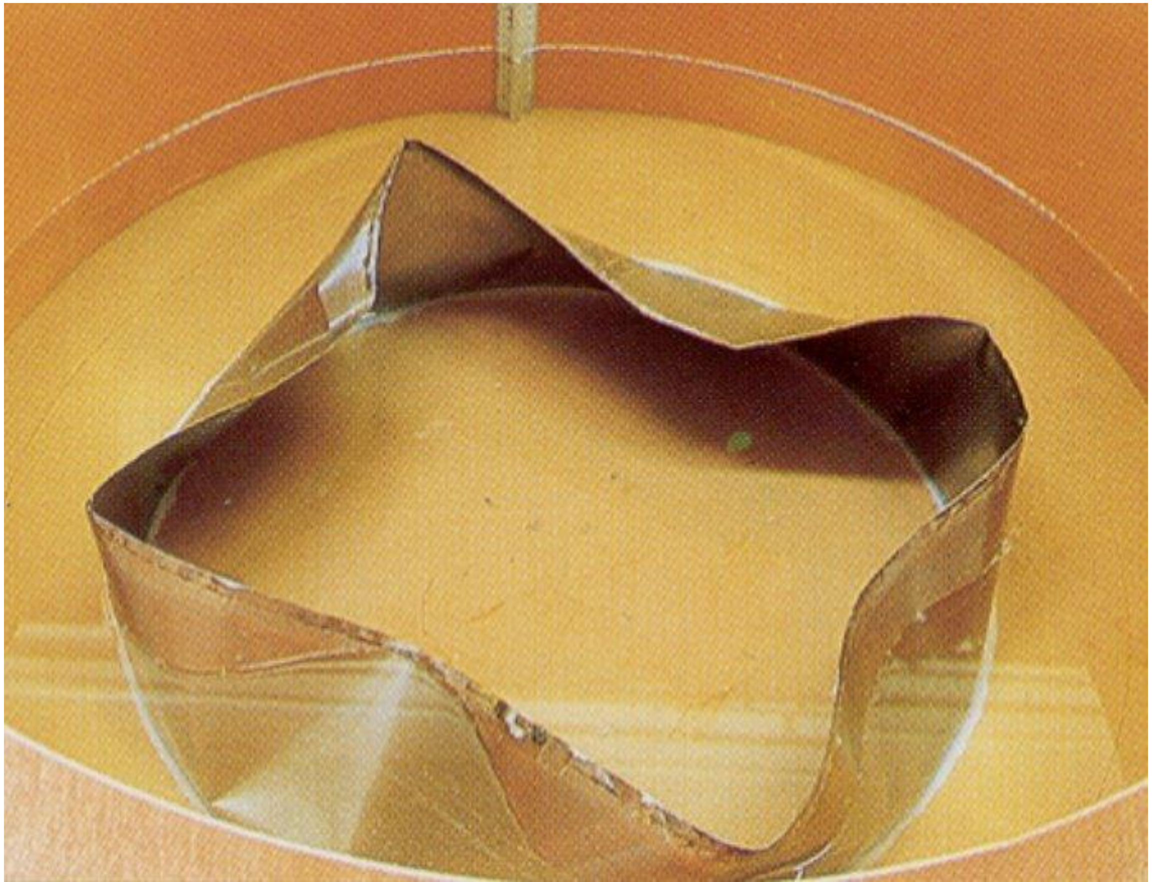
- Roof tilting will cause water ponding
- Water may shift away from location of roof drains… overloads with water may result
- Unsymmetrical load may lead to roof structural failure

Hazard Prevention - Floods

Hurricane Katrina, New Orleans

What Are the Risks for Tanks from Floods?

- Flooding Issues…
  - Floating Off of Foundation
  - Shell Buckling

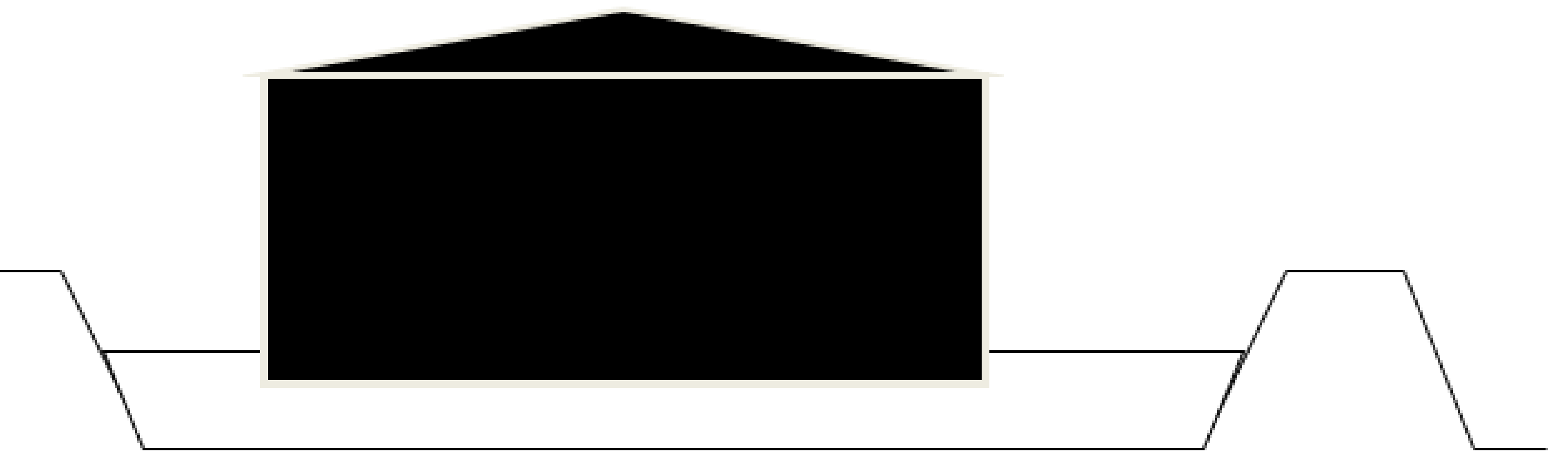


Tank Flotation

- Empty tanks are most vulnerable to flotation
- Minimal flood depth required to float a tank off of its foundation
- Wind may displace a floating tank laterally

Dike Flooding

Flood depths of a half a meter will float most large diameter storage tanks when they are empty



ASTs Displaced by Flooding

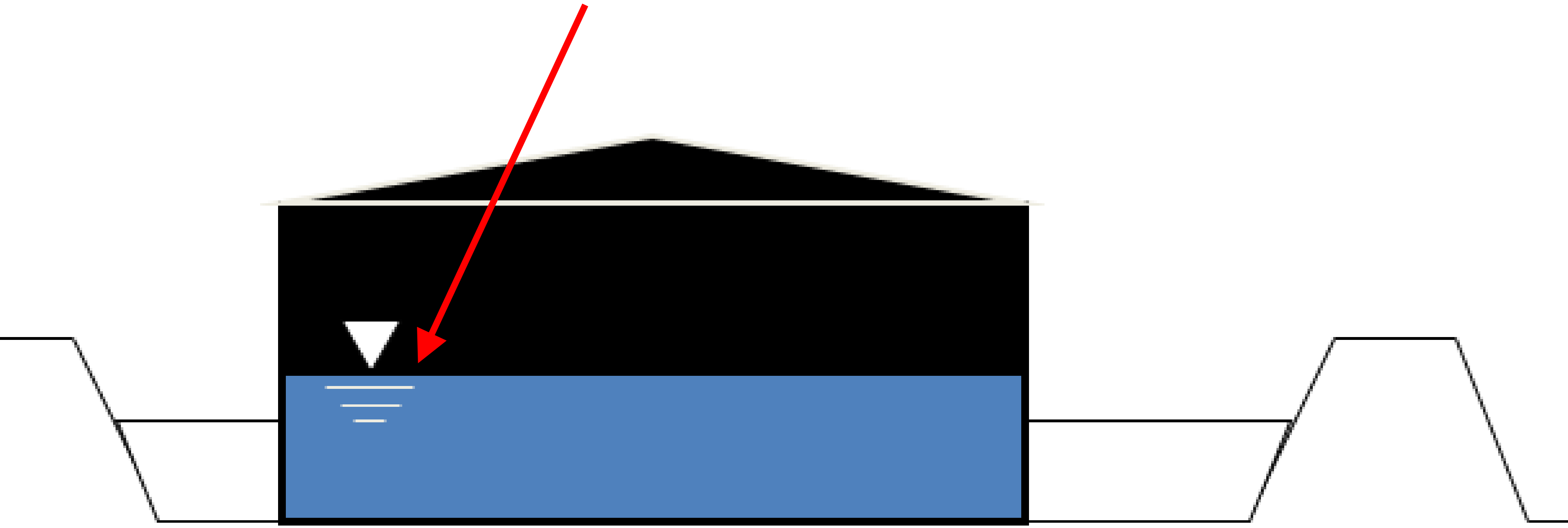
ASTs Displaced by Flooding

ASTs Displaced by Flooding

ASTs Displaced by Flooding

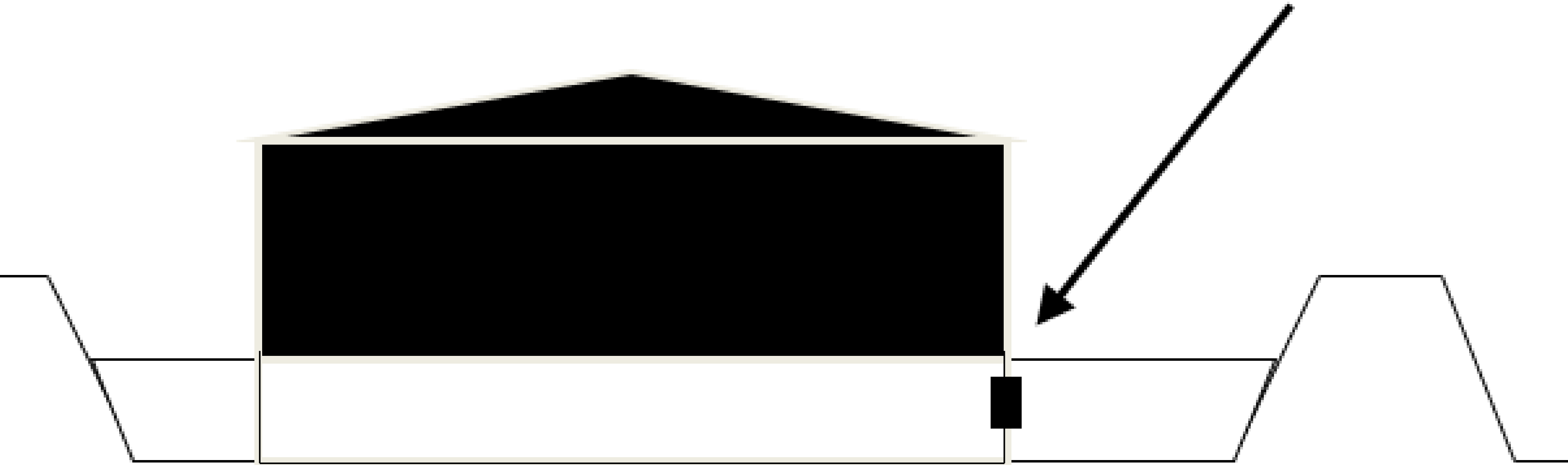
Avoid Tank Flotation

Your Tank Engineer can determine a recommended product depth



Avoid Tank Flotation

If tank is empty and clean, leave the shell manholes open



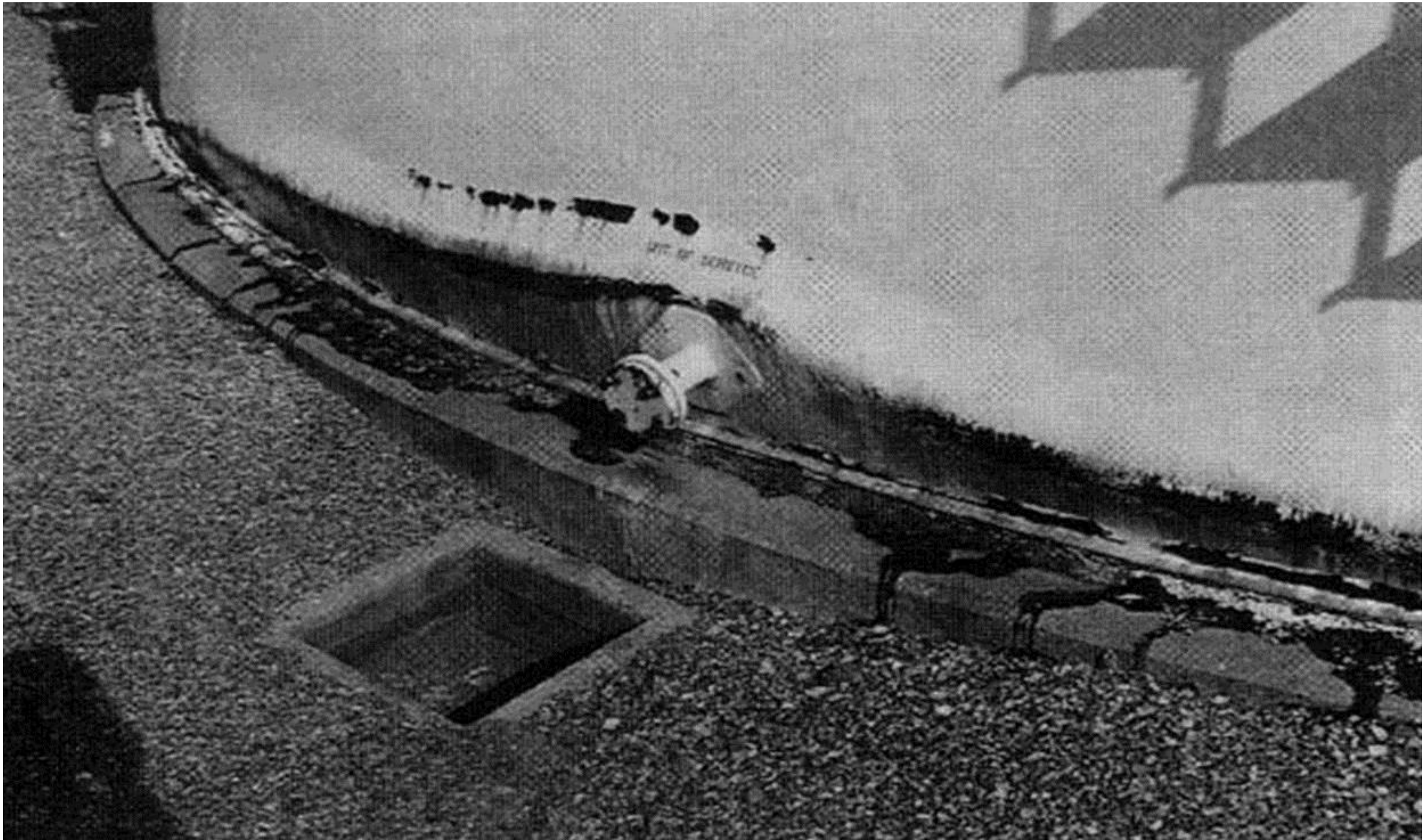
Hazard Prevention - Hurricanes

Hazard Prevention - Seismic

API 650 Requirements for Seismic Ground Motion -
Goal – Protect life and prevent catastrophic collapse

API 650 Appendix E-Seismic Design

Based on the allowable stress design (ASD) methods with specific load combinations

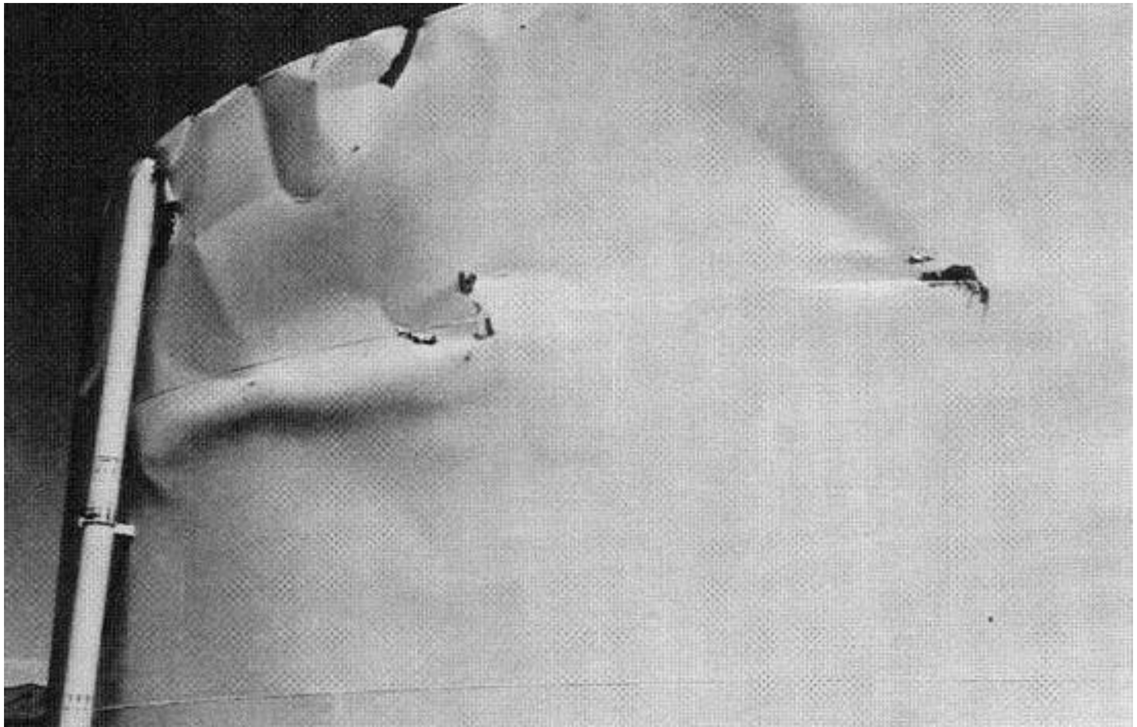


API 650 Appendix E Seismic Design

Control methods use an equivalent lateral force analysis that applies equivalent static lateral forces to a linear mathematical model of the tank based on a rigid wall, fixed based model.

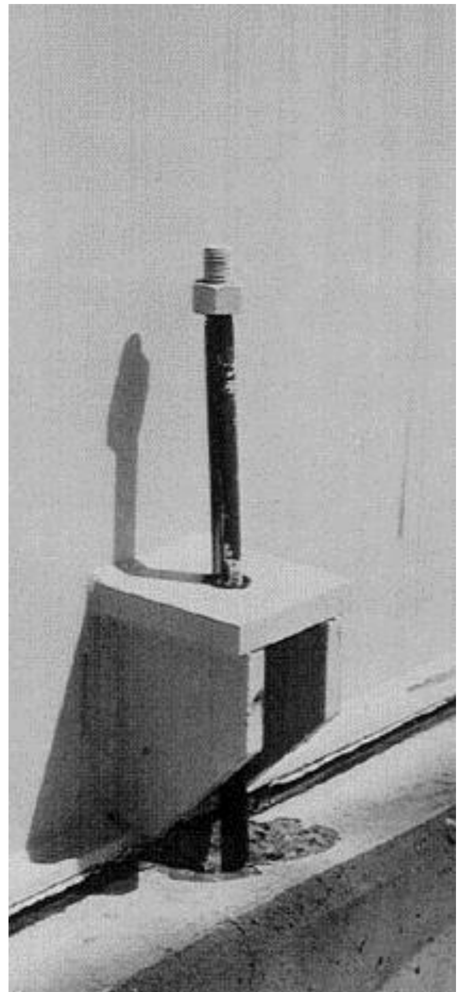
API 650 Appendix E Seismic Design

Ground motion requirements are based on a maximum considered earthquake ground motion - an event with a 2% probability of exceedance within a 50-year period (a recurrence interval of approximately 2,500 years).

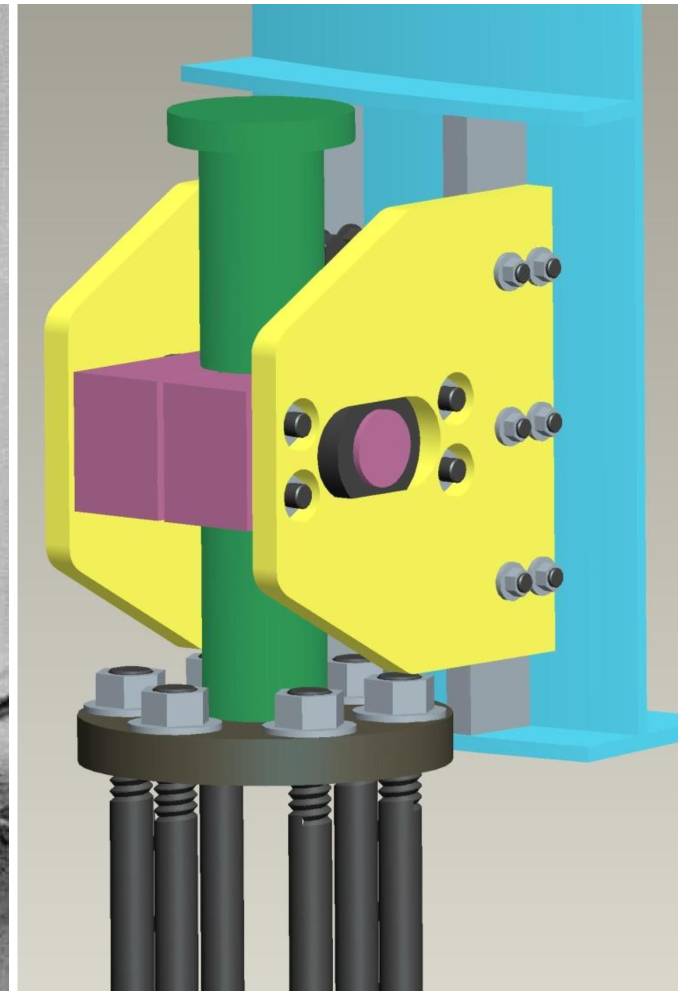


API 650 Appendix E Seismic Anchor Design

- Mechanically-anchored tanks have anchor bolts, straps or other mechanical devices to anchor the tank to the foundation.
- Self-anchored tanks use the inherent stability of the self-weight of the tank and the stored product to resist overturning forces.



Traditional Anchor



Energy-Dissipating Anchor

API 650 Appendix E Seismic Design

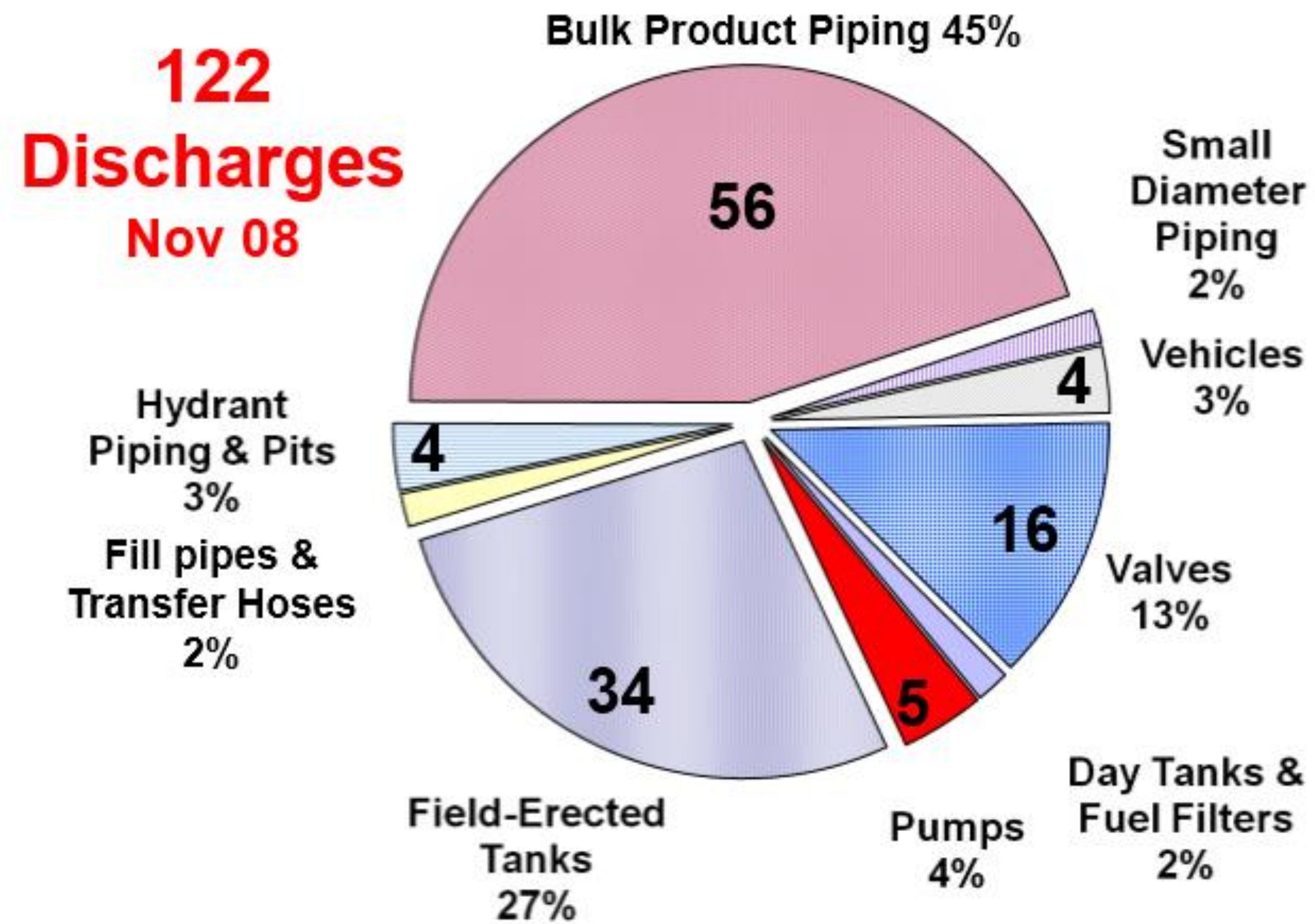
Site-specific design is needed when the tank is located within 10 km of a known active fault or when the structure is designed using base isolation or energy dissipation systems.

Earthquake and Tsunami Damage - Japan

Hazard Prevention – Environmental Releases

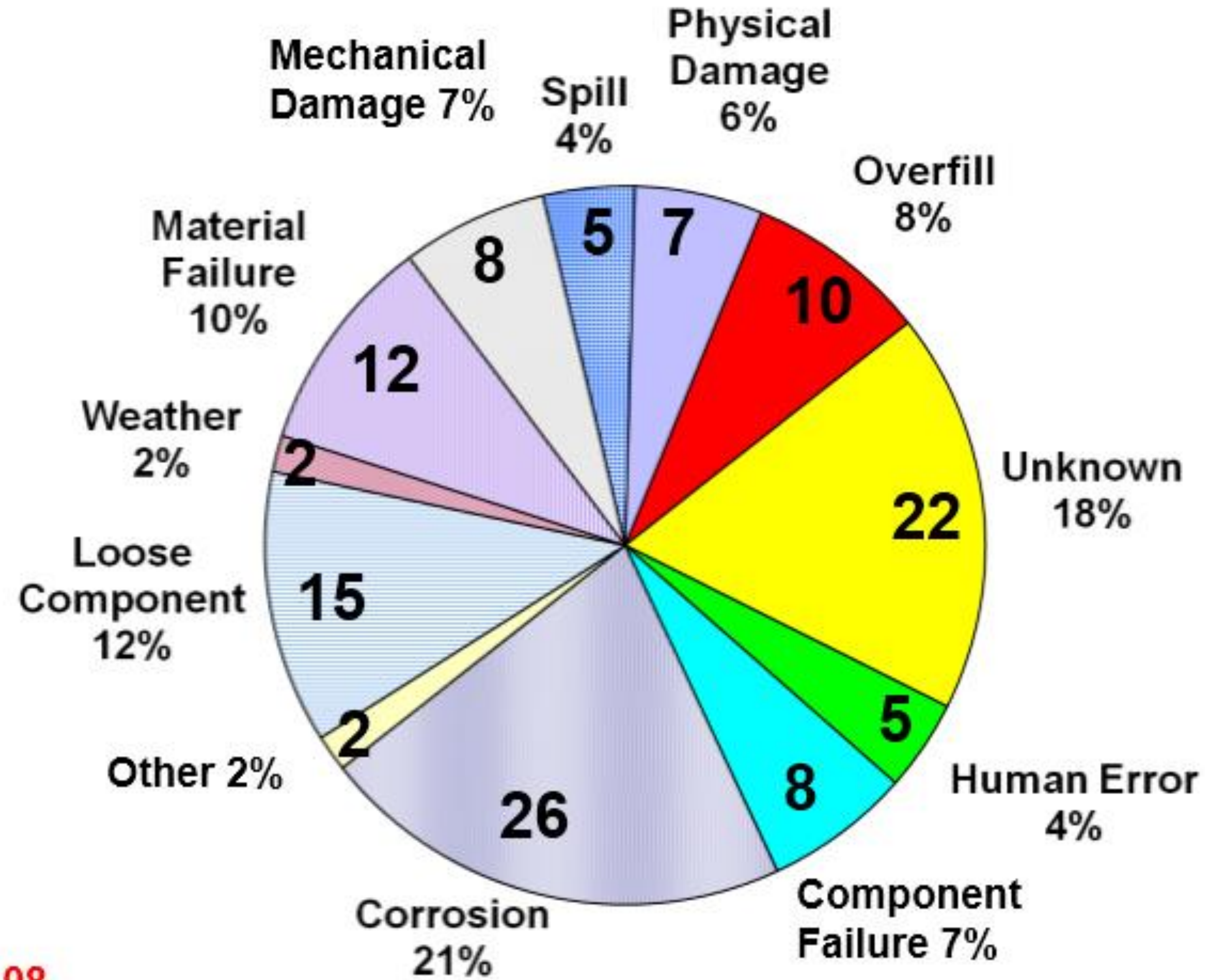
Leak Autopsy Report Data

Sources of Discharges - Field-Erected AST Systems



Tanks are only 17% if overfills and other external factors are excluded

Causes of Discharges from All Sources



Nov 08

Examples of some of the Major Problems

Port Everglades, Florida - Jet Fuel Overfill – Approximately 378,540 Liters

2400 Barrels (2004)

Rio de Janiero - May 2013

http://www.youtube.com/watch?v=wiDH_H1sEyQ

- One dead from inhalation of vapors, 7 injured
- 6 tanks at terminal, spread to administration buildings
- Site did not have environmental license to operate

Surat, India – Jan. 2013

http://www.bing.com/videos/search?q=Surat%2c+India+terminal+fire&FORM=HDRSC3#view=detail&mid=7AAC4DD29507831F37F57AAC4DD29507831F37F5

- 10,000 kL tank is one of 9 tanks at terminal
- Welding work ongoing
- Cause was faulty valve and no blind used
- 3 contractors killed
- 500 firefighters & 50 water tankers to extinguish
- Roof blown 30 meters

West Thurrock, Essex, UK, April, 2013

Fire in the rim seal of one of the empty tanks had automatically set off Terminal's foam fire extinguishers. Sixty fire fighters extinguished the fire, no injuries

Lyttleton, New Zealand, March, 2014.

A landslide during a major storm damaged 2 tanks and caused 1.2 million liters of jet fuel to spill from a tank at Mobil Oil New Zealand's tank farm at Naval Point. About 1500 liters of fuel went into Lyttelton Harbor through a drainage system before sandbags were put in place.

The End

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