

# USDOT PHMSA LNG Workshop

May 18, 2016

## LNG Technologies Incorporated Since NFPA 59A 2001 Edition for Concrete LNG Tanks



**BRAEMAR**  
ENGINEERING

**Presented by**  
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**VP – LNG Technical Services**  
**Braemar Engineering**  
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# What are Refrigerated Hydrocarbon Liquid Storage Tanks?



**Historically  
Constructed to  
API 620  
All Metal LNG  
Tanks**

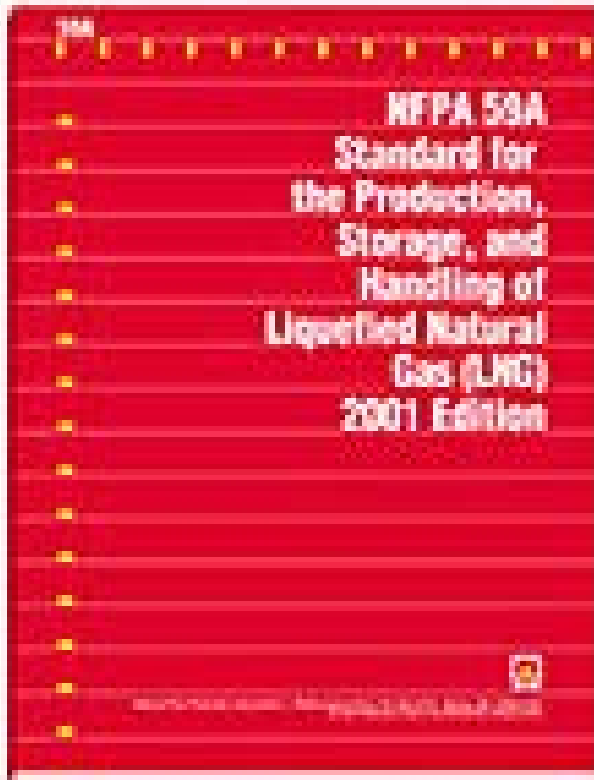
**Design and Construction of  
Large, Welded, Low-pressure  
Storage Tanks**

API STANDARD 620  
TWELFTH EDITION, OCTOBER 2013  
ADDENDUM 1, NOVEMBER 2014

**API**  
AMERICAN PETROLEUM INSTITUTE

**Answer: Large field erected tanks used for storage of liquid products at cryogenic temperature, low pressure generally designed to API 620 and < 15 psig maximum allowable operating pressure.**

# Concrete LNG Tanks are Acceptable in 49 CFR Part 193 and NFPA 59A 2001 Edition.



NFPA 59A 2001 edition contains provisions for the use of reinforced concrete and Prestressed concrete for primary and secondary containment with references to ACI 318, 372R, and 373R.

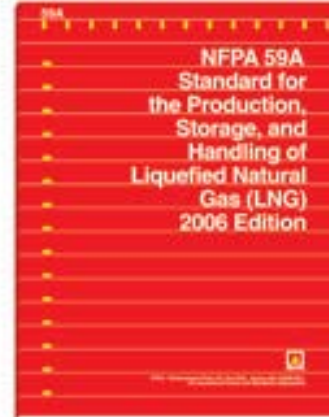
However, the usefulness of these references to NFPA 59A was limited by these references did not provide guidelines specifically tailored to the use of concrete at cryogenic temperatures and the impetus by NFPA 59A that ACI undertake the preparation of a standard to address this particular need.

# NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas

2001 Edition  
(PHMSA  
Current)



2006  
(Seismic Only)



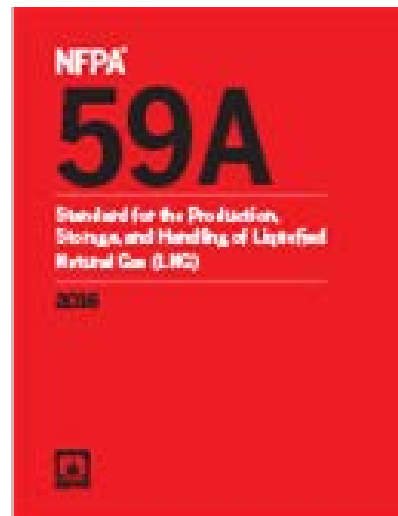
2009



2013



2016 – Latest Available



Reference  
to ACI 376 - 2010

First Reference  
to ACI 376 - 2010

**Not Currently  
Recognized  
by 49 CFR  
Part 193**

# Shop Fabricated LNG Storage Tank (Excluded from Presentation)

ASME Boiler and Pressure Vessel Code Section VIII  
> 15 psig Maximum Allowable Operating Pressure



Vertical



Horizontal

# LNG Tank Arrangements

## Tank Types

- Single Containment
- Double Containment
- Full Containment

## Foundation

- At Grade
- Elevated Above Grade
- Below Grade

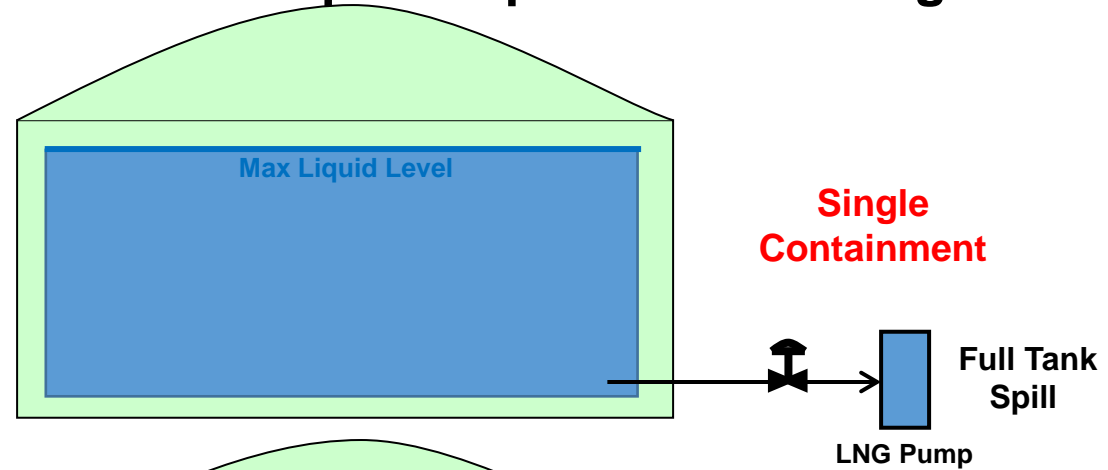
## Primary Containment

- Aluminum
- Stainless Steel
- 9% Nickel Steel
- Prestressed Concrete

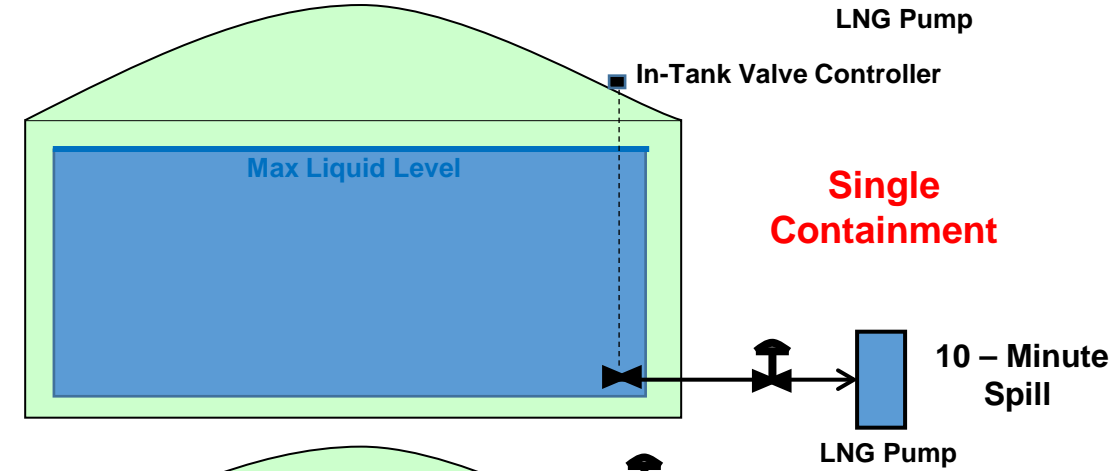


3 - Design Spill Cases for Vapor Dispersion Modeling

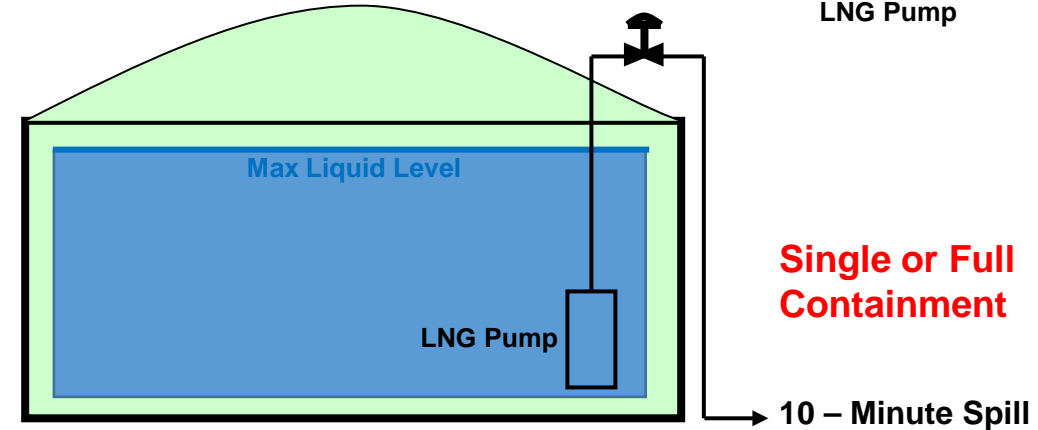
1. Bottom Withdrawal



2. Bottom Withdrawal with In-Tank Valve



3. Top Withdrawal - No Penetrations Below Liquid Level



# Single Containment LNG Tank



- **Aluminum, Stainless Steel, or 9% Nickel Inner Tank**
- **Carbon Steel Outer Tank**
- **Secondary Containment Berm**



# Full Containment Concrete LNG Storage Tanks



- **Stainless Steel, or 9% Nickel Primary Inner Tank**
- **Integral Concrete Secondary Containment Walls**
- **Carbon Steel Vapor Barrier**

# Current US Facilities with Full Containment LNG Tanks



**Full Containment Pre-  
Stressed Concrete  
Inner and Outer Wall  
LNG Tanks  
(Unlined - LNG in  
Direct Contact With  
Primary Concrete  
Walls)**

**2 – 94,000 m<sup>3</sup> Tanks  
Philadelphia Gas  
Works  
Port Richmond  
Built 1974**



# 59A 2001 Edition and 193 Siting Requirements

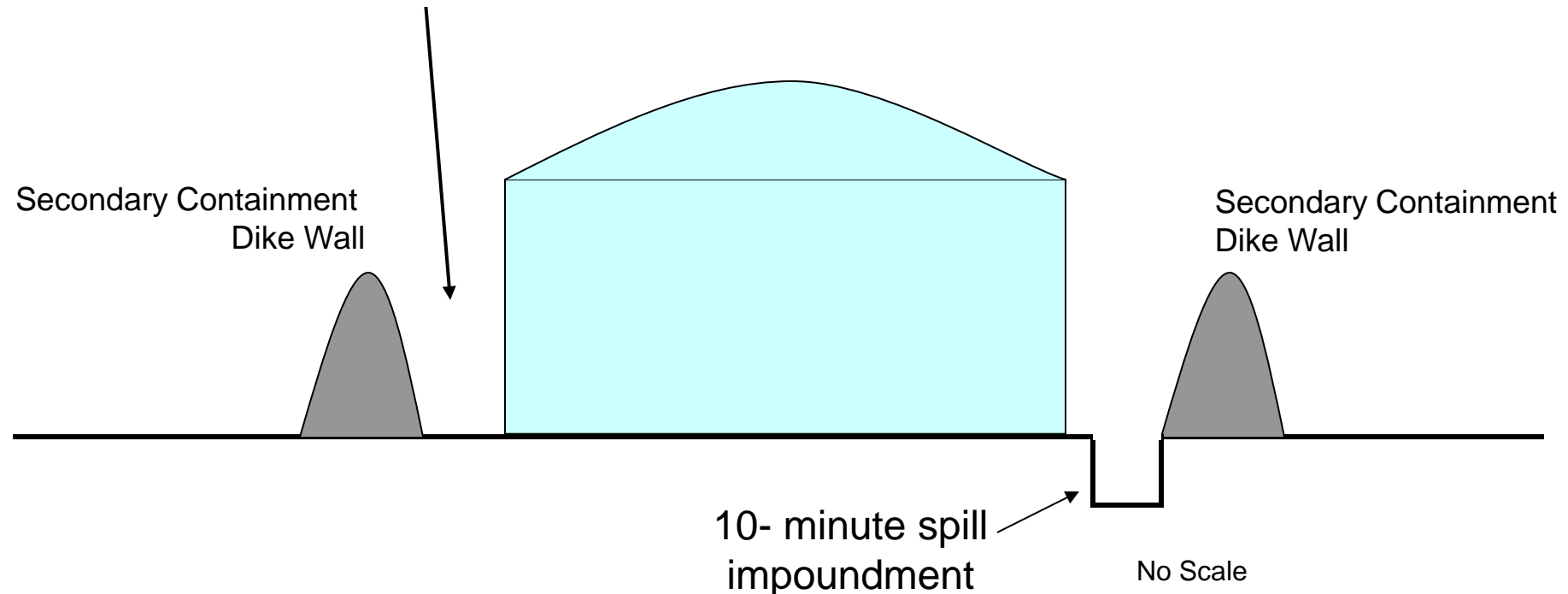


**Single Containment LNG Tank**

# Single Containment LNG Tank

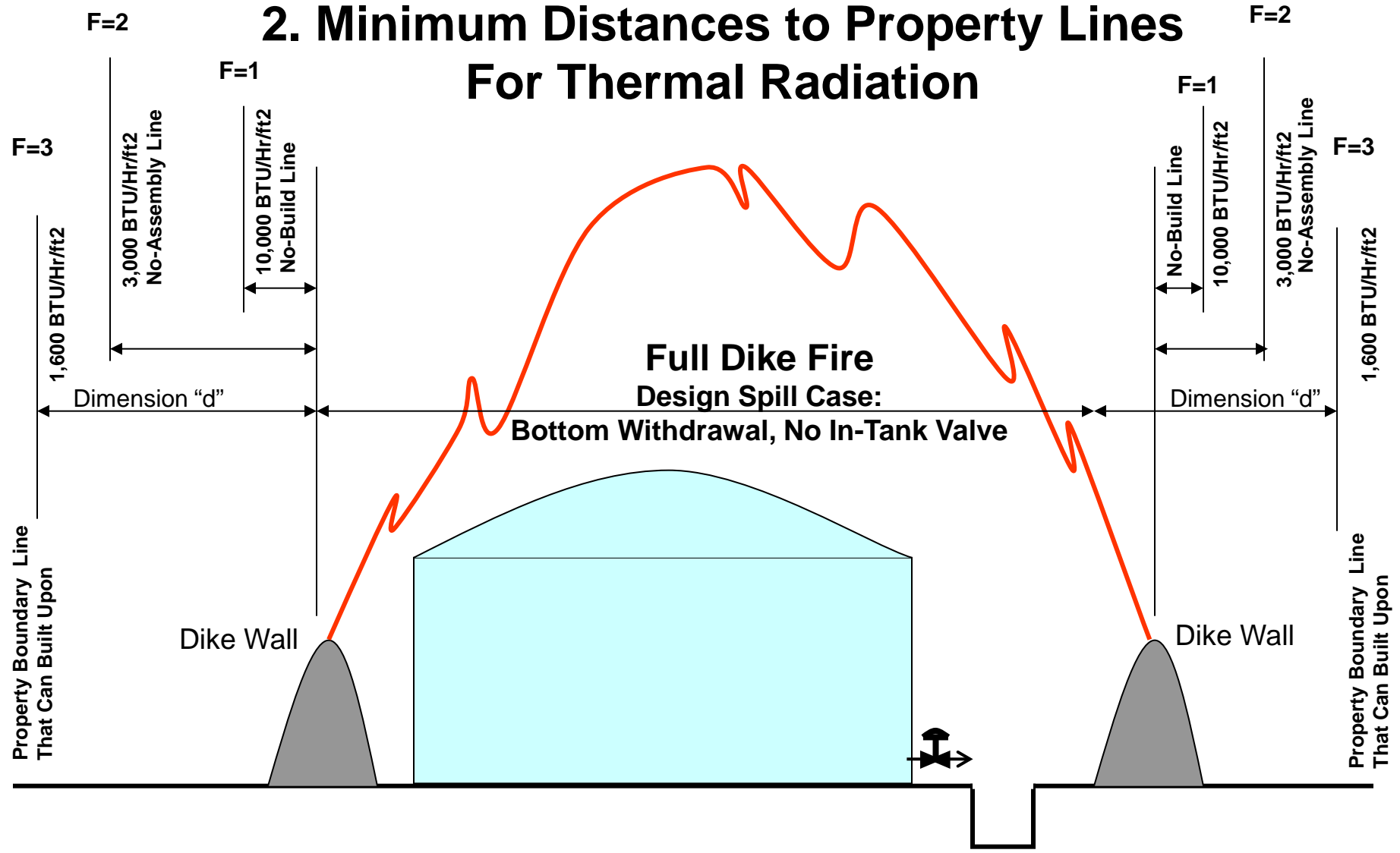
## 1. Secondary Containment Capacity

**Full Tank Failure**  
**Tank Impoundment has a Minimum**  
**of 110% Full Capacity of Largest LNG Tank**  
**(Includes Volume Displaced by Tank)**



# Single Containment LNG Tank

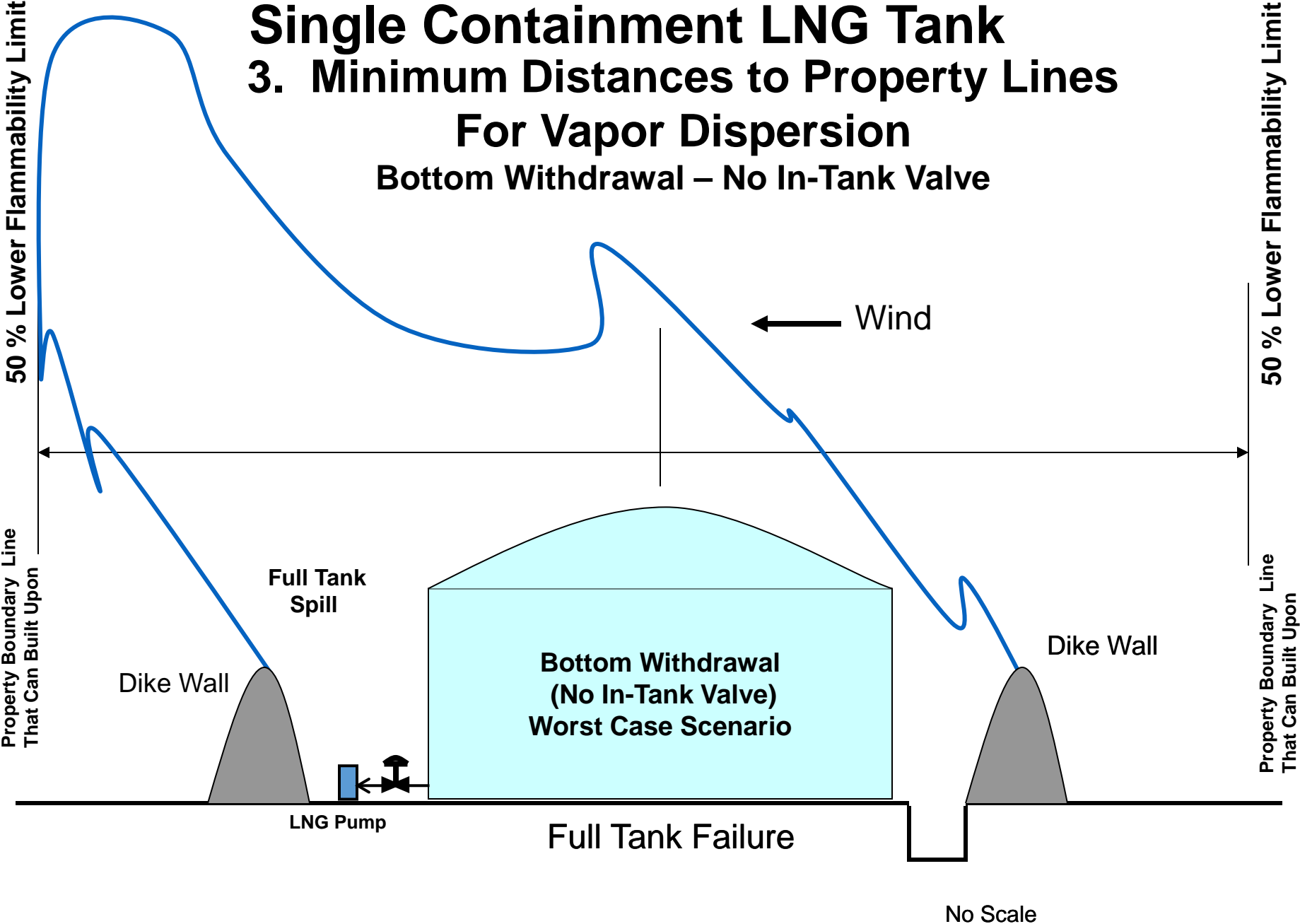
## 2. Minimum Distances to Property Lines For Thermal Radiation



# Single Containment LNG Tank

## 3. Minimum Distances to Property Lines For Vapor Dispersion

### Bottom Withdrawal – No In-Tank Valve

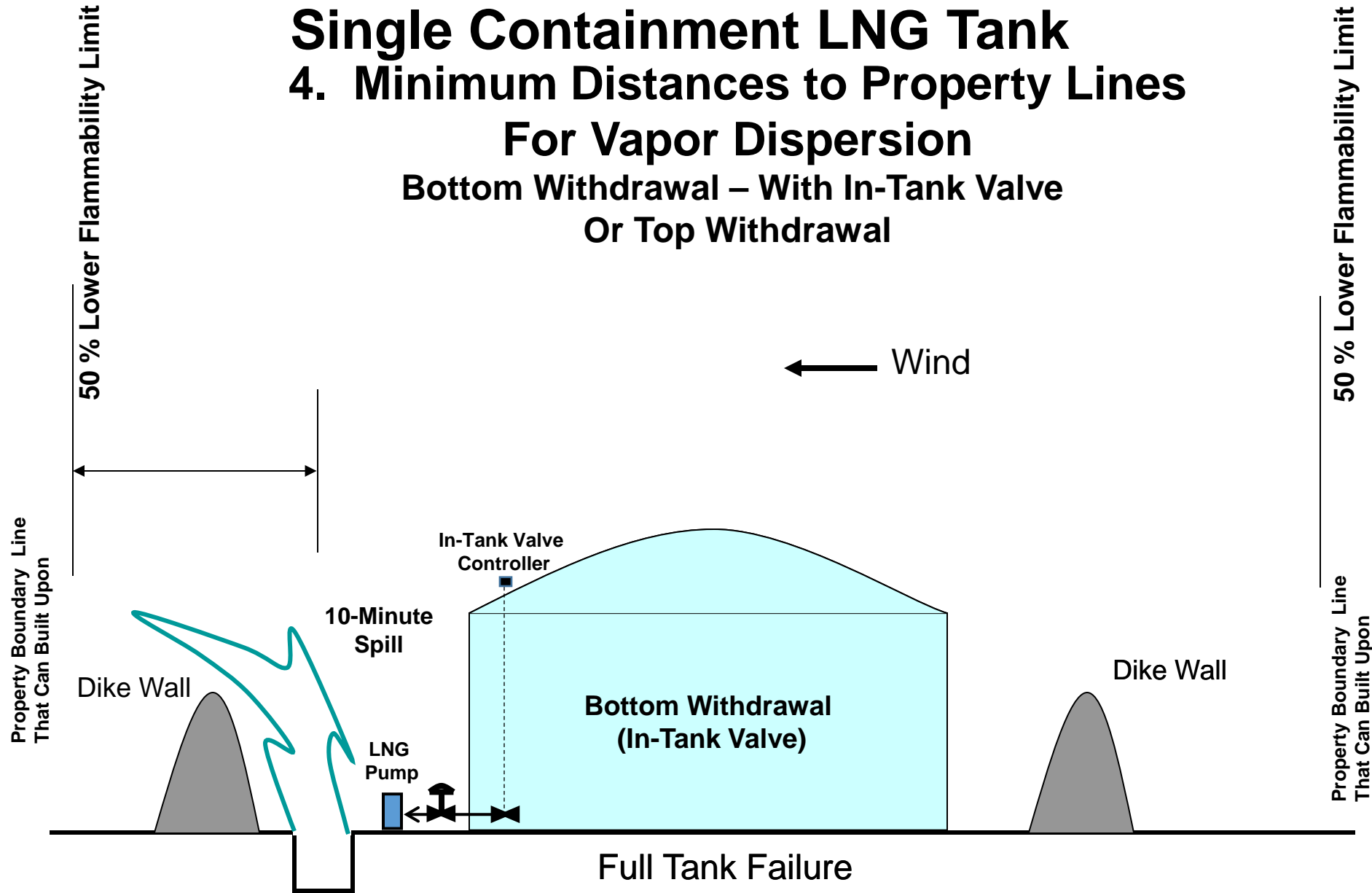


# Single Containment LNG Tank

## 4. Minimum Distances to Property Lines

### For Vapor Dispersion

Bottom Withdrawal – With In-Tank Valve  
Or Top Withdrawal



No Scale

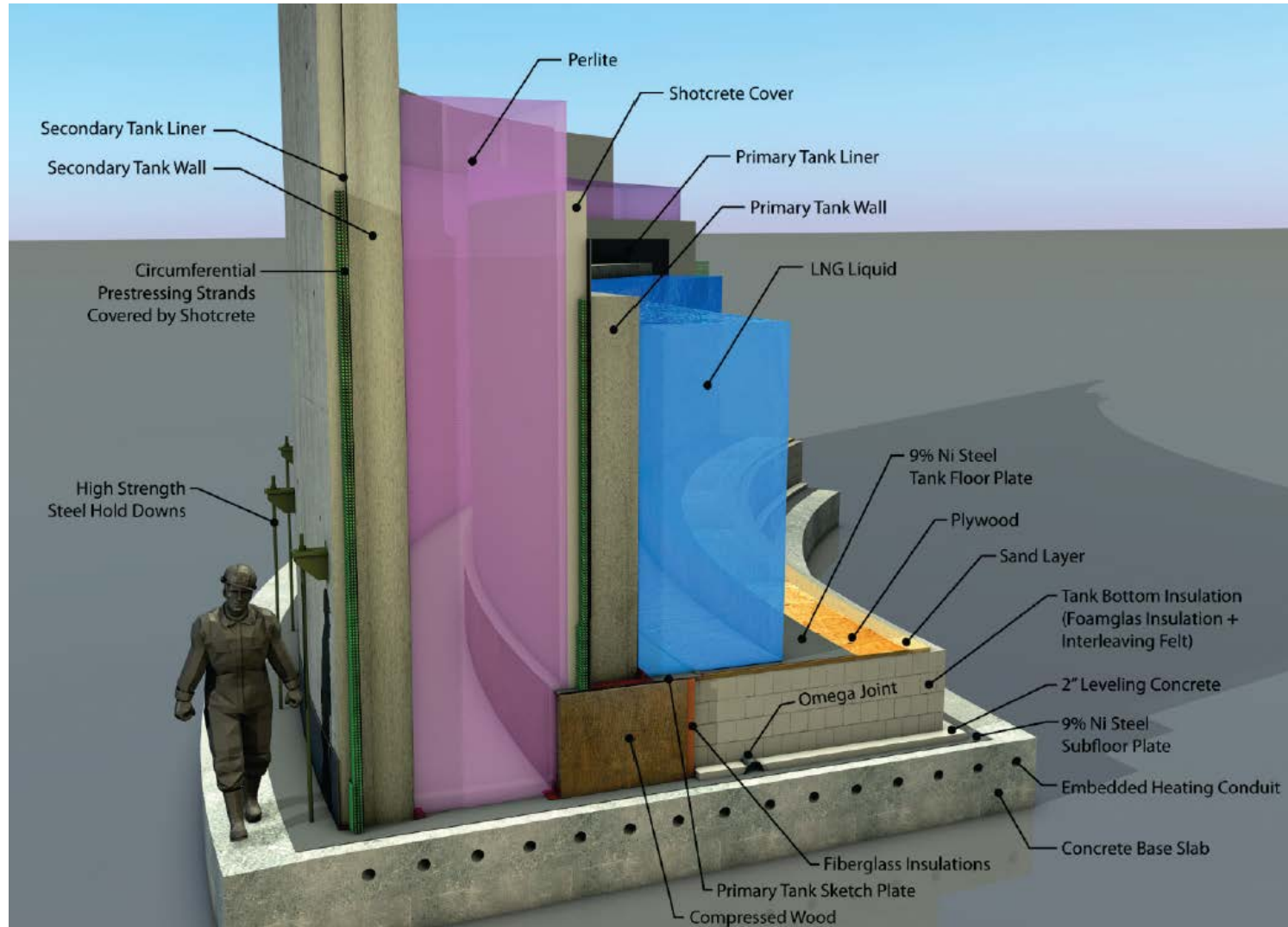


# Full Containment Concrete LNG Storage Tanks



## **3 - Siting Requirements**

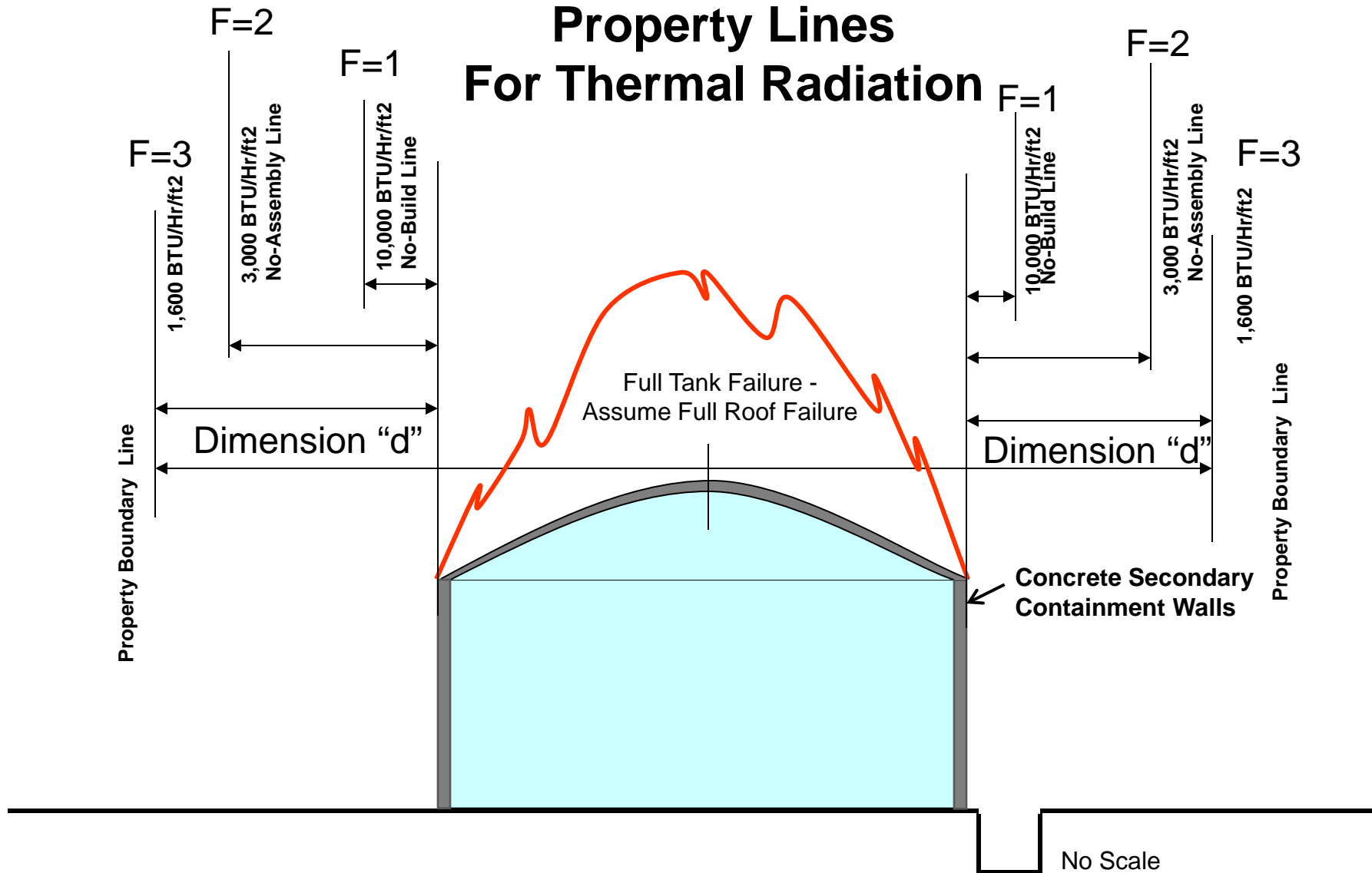
# Full Containment Concrete LNG Storage Tanks Integral Secondary Containment



**Note:** FERC also requires a tertiary berm for double and full containment tanks as an additional layer of protection.

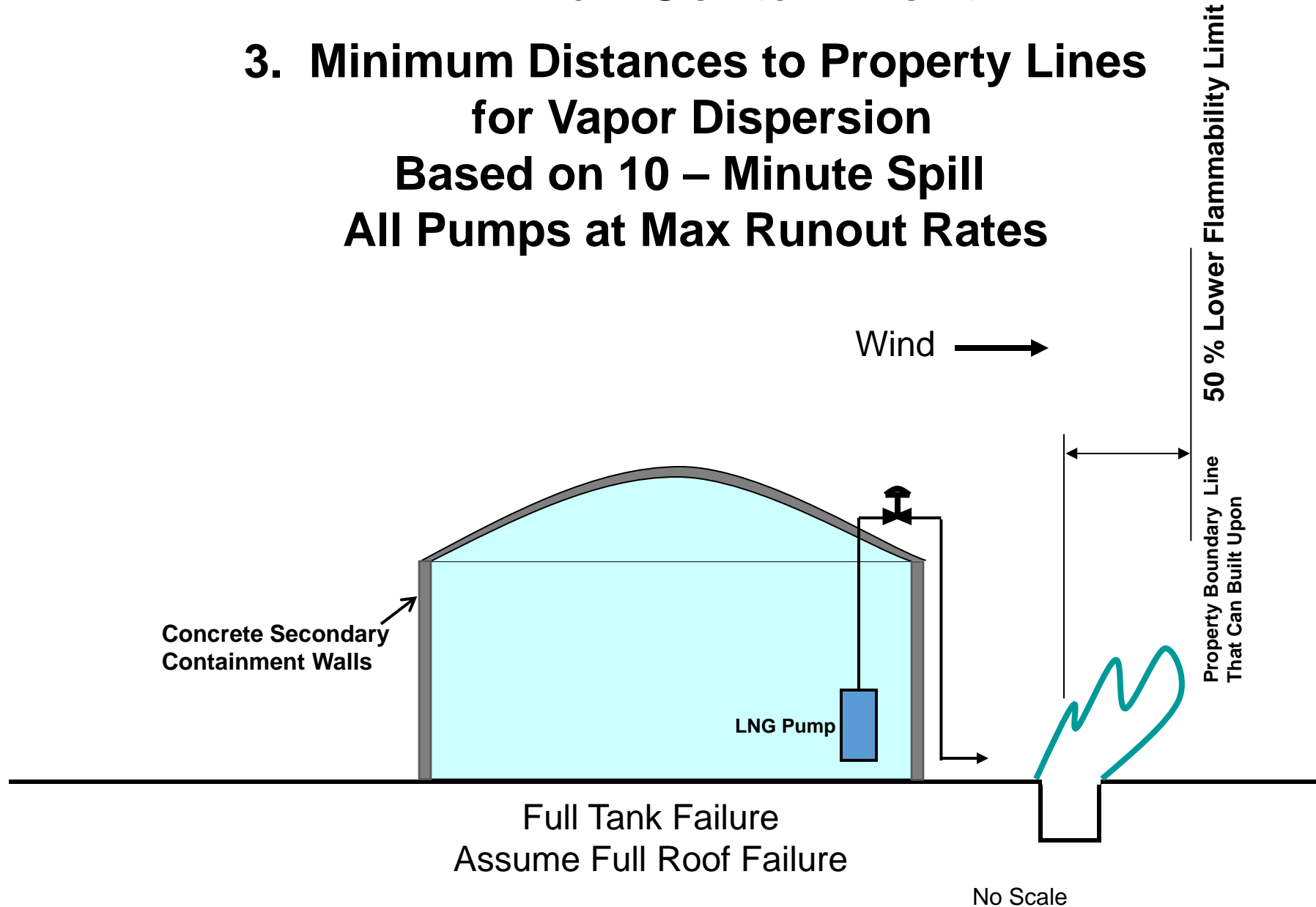
# Full Containment

## 2. Minimum Distances to Property Lines For Thermal Radiation



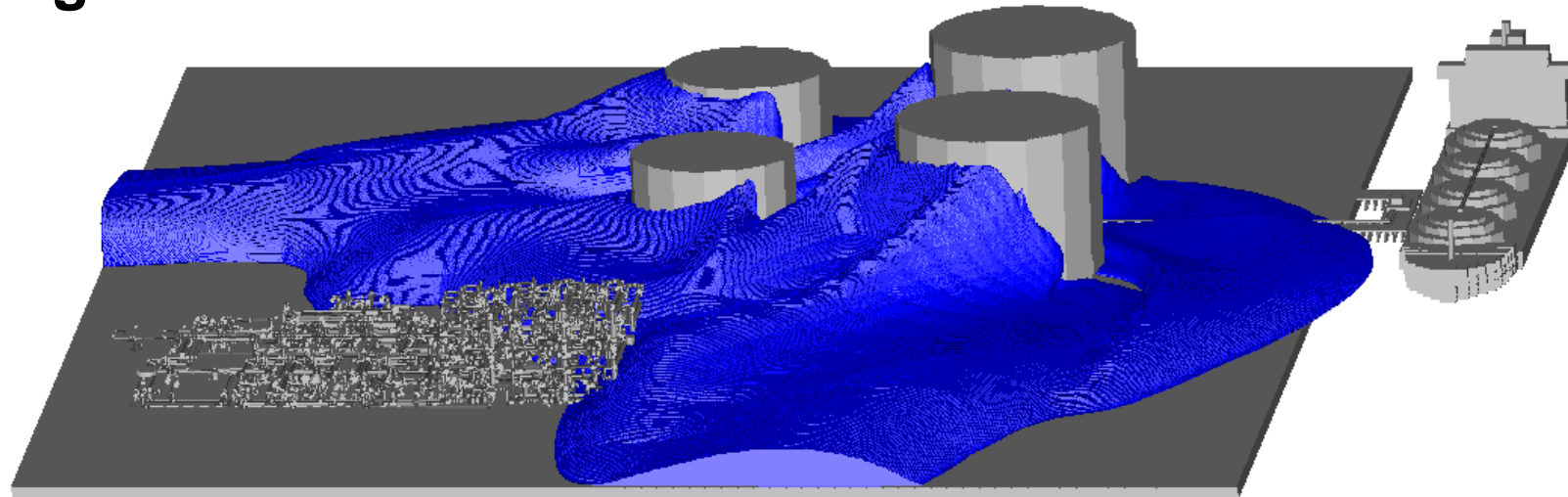
# Full Containment

## 3. Minimum Distances to Property Lines for Vapor Dispersion Based on 10 – Minute Spill All Pumps at Max Runout Rates



# Siting Studies & Modeling

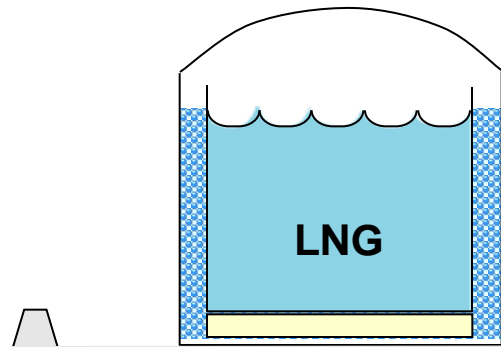
1. Tank Dimensions
2. Secondary Containment Area & Surfacing Material
3. Accidental Spill Size
4. Climate; Wind Speed & Direction, Temperature, Humidity
5. Local Terrain
6. Distance from Property Lines That Can Be Built Upon
7. Distance Between Multiple Tanks
8. VCE (Vapor Cloud Explosions) from Flammable Refrigerants



# What Type of Refrigerated Hydrocarbon Gas Storage Tanks Are Typically Used in Industry?

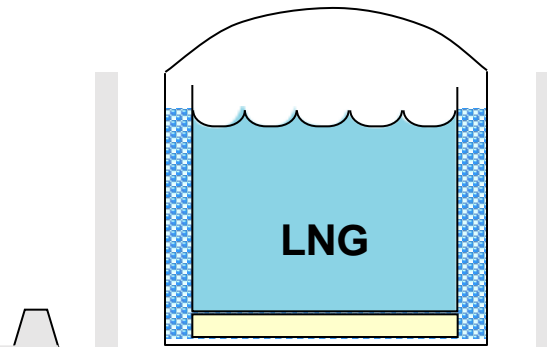
**3 Tank Types:** Current sizes up to 42 million gallons (1,000,000 barrels) of cryogenic liquid at -260 °F at low pressure, typically 1- 2 PSIG

## Single Containment



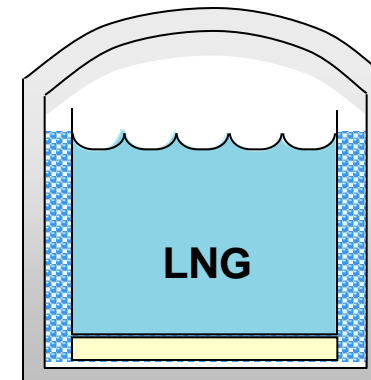
- Large amount of land available
- No public nearby
- Minimal security concerns
- API 620 Code

## Double Containment



- Less of land available
- Near public or close to other industry
- More security concerns
- API 620 & ACI 376 Codes

## Full Containment

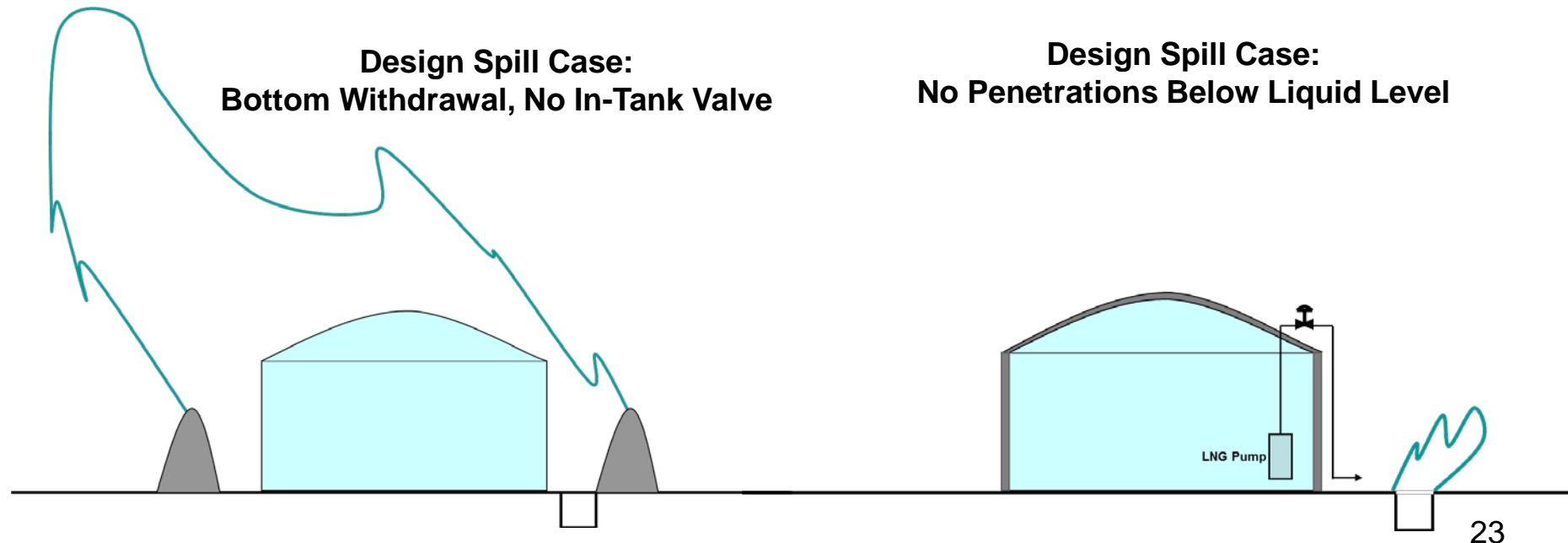


- Minimal land available
- Near people or public gatherings and close to other industry
- Maximum security concerns
- ACI 376 Code

## General Conclusions

### Compare Single Containment to Full Containment

1. **Smaller Exclusion Zones for Full Containment**
2. **Full Containment Requires Less Real Estate for Siting Compliance**
3. **Full Containment Considered More Robust to External Threats (Security, Weather, Fire, VCE Exposure)**
4. **Full Containment Cost More & Takes Longer To Construct Than Single Containment**



# Double Containment LNG Tank



**Ecoelectrica, Puerto Rico**



Initial Ecoelectrica  
Application to FERC was Full  
Containment, but Denied,  
Design Changed to Double  
Containment

**EcoEléctrica**  
A KINETIC ENERGY COMPANY  
FILED  
OFFICE OF THE SECRETARY  
94 OCT 25 PM 2:55  
FEDERAL ENERGY  
REGULATORY  
COMMISSION  
October 19, 1994

Honorable Lois D. Cabell  
Secretary  
Federal Energy Regulatory Commission  
825 North Capitol Street, NE  
Washington, DC 20426

CP95-  
CP95-35-000

RE: APPLICATION FOR APPROVAL OF A PLACE  
OF IMPORT FOR NATURAL GAS

Dear Ms. Cabell:

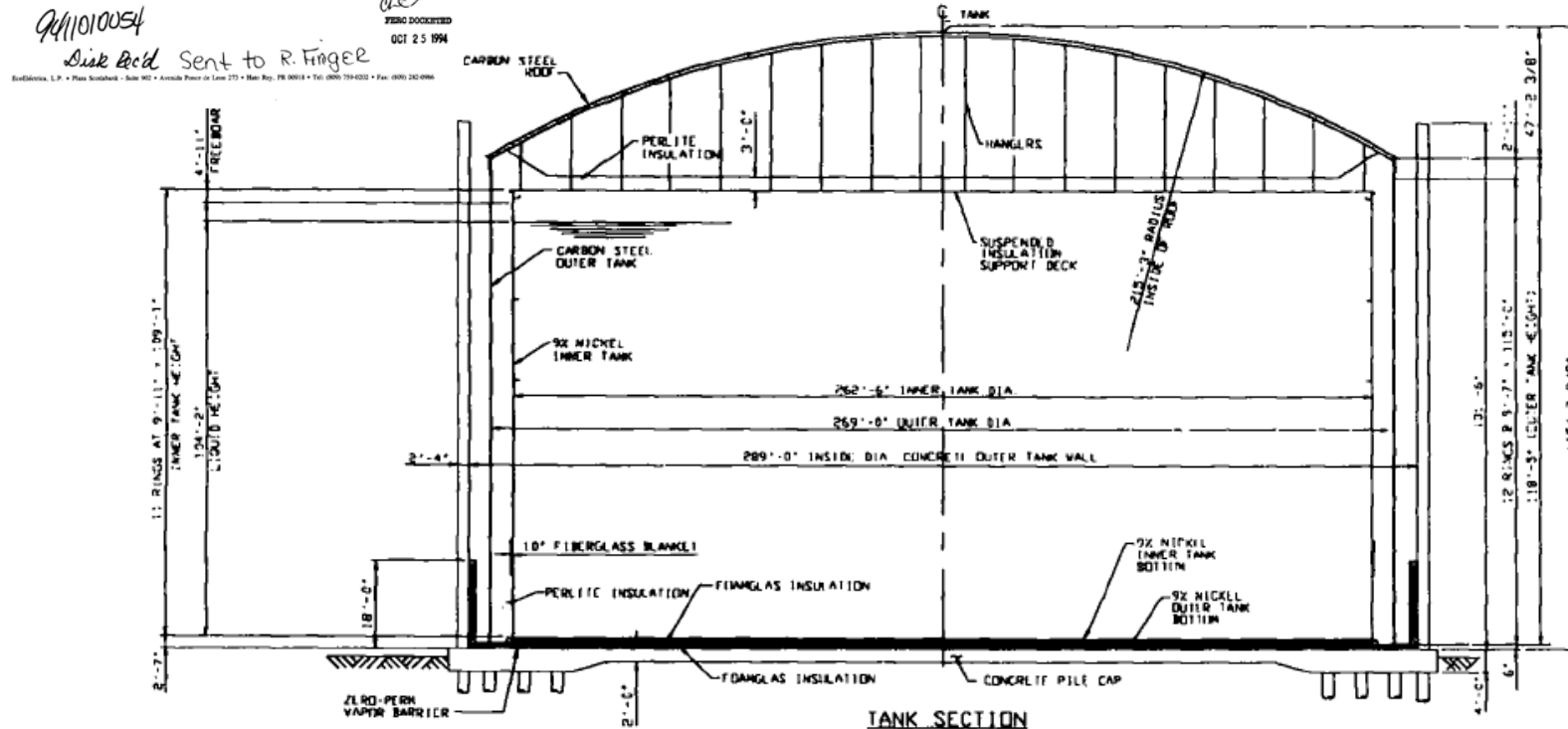
Pursuant to Section 3 of the Natural Gas Act, as amended, EcoEléctrica, L.P. submits herewith:

- 1) An original and seven (7) copies of its Application, for an order for approval of a place of import of Liquefied Natural Gas (LNG) for the EcoEléctrica Project;
- 2) A diskette which contains the same information as the original paper copy of the application, exclusive of maps, diagrams and externally generated documents; and
- 3) An Environmental Report which follows the preferred environmental report format identified in Commission Order 493 and updated in April 1993. In addition, detailed information for construction of new LNG facilities is presented as Resource Report 13 consistent with the information requirements specified in draft Order 555.
- 4) A completed Standard Form 277.
- 5) A copy of Project Description and Environmental Studies Overview Document.

The Environmental Report included herewith identifies additional environmental and engineering data that will be filed as Supplemental Environmental Report.

0411010054  
Disk Recd Sent to R. Finger  
OCT 25 1994

EIS April 1996 Part 2 of 11, Page 3-19

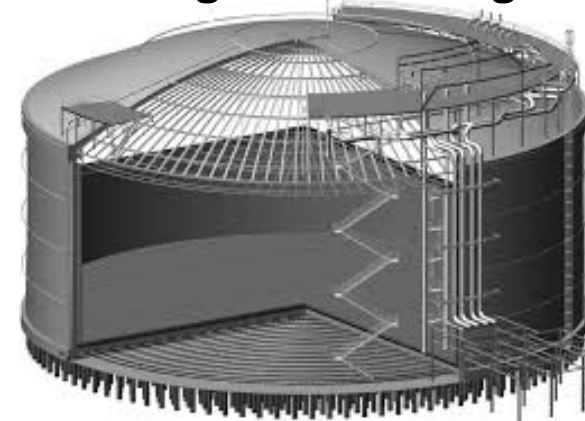


## Prior\* Regulatory Issues with Full Containment LNG Tanks

- Identifying Cold Spots in Tank Walls with Perlite Insulation
- If Cold Spots Exist, Repair Insulation in Tank Walls
- Prevention of Corrosion of Hidden Carbon Steel Plate in Contact with Concrete
- Inspection & Repair Corrosion of Carbon Steel Plate in Contact with Concrete
- “Cracking” of Concrete Containment When Exposed to LNG Temperature (How Big are the Cracks?)

Note: The word “cracking” is common industry term with various meanings. Cracking can be both stress relieving from curing and visible traits. Thermal cracking of cured concrete may not be visible (granular level) or may result in hairline cracks but specifically not continuous resulting in loss of tightness.

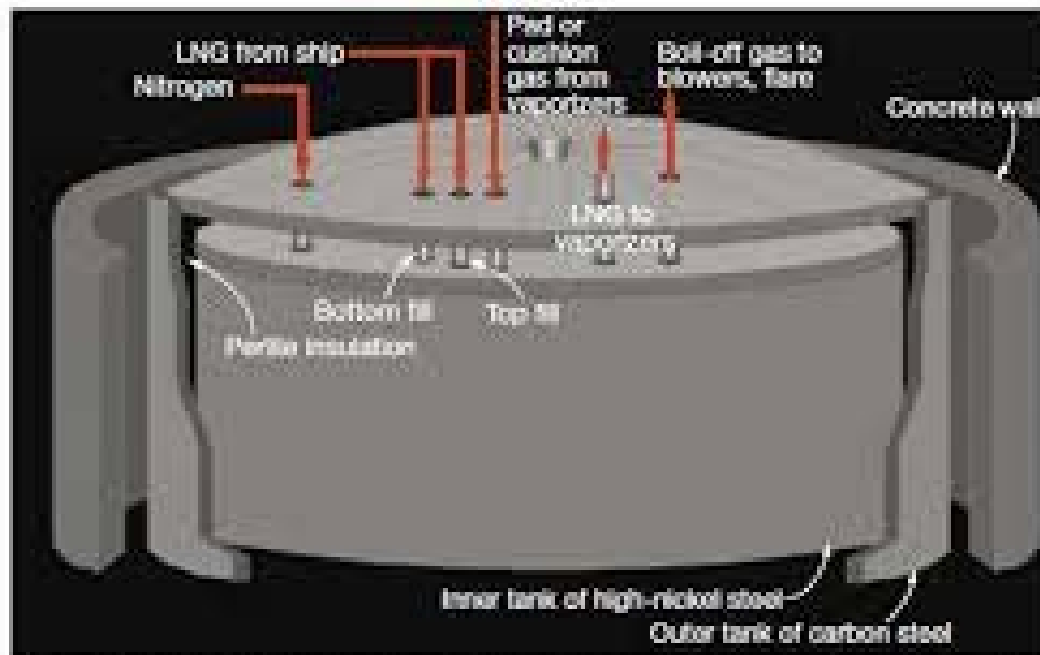
“Prior” refers to comments from Bob Arvedlund, FERC, in 1999+/- on his concerns of full containment LNG tanks.



# Ecoelectrica

## Double Containment LNG Tank Lessons Learned

- Collected Rainwater that Required Significant Pumping to Keep Dry
- OSHA Confined Space Entry Between Walls
- Potential Confined Space Explosion for Air-Gas Mixture
- Structurally More Complex – Tank & Secondary Containment Wall Needs to Be Self Supporting



**Full Containment LNG Tanks Have Been Subsequently Approved for a Number of Recent LNG Import/Export Projects**



# 49 CFR Part 193

## CODE OF FEDERAL REGULATIONS

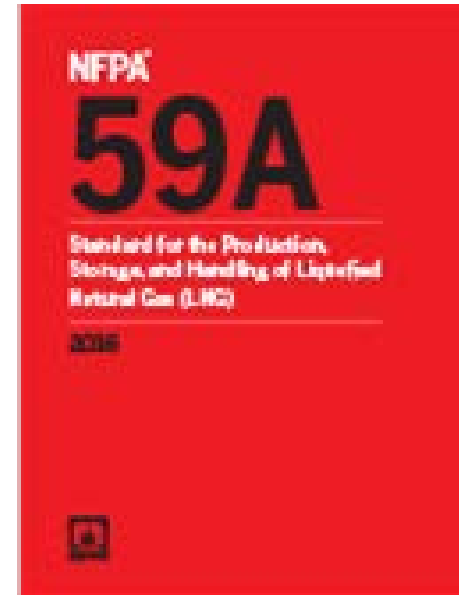
CILITIES: FEDERAL SAFETY STANDARDS

<b>Subpart A—General</b>	193.2301 Scope.
Sec.	193.2303 Construction acceptance.
193.2001 Scope of part.	193.2304 Corrosion control overview.
193.2005 Applicability.	193.2321 Nondestructive tests.
193.2007 Definitions.	
193.2009 Rules of regulatory construction.	<b>Subpart E—Equipment</b>
193.2011 Reporting.	193.2401 Scope.
193.2013 Incorporation by reference.	<b>Control Systems</b>
193.2017 Plans and procedures.	193.2441 Control center.
193.2019 Mobile and temporary LNG facilities.	193.2445 Sources of power.
<b>Subpart B—Siting Requirements</b>	<b>Subpart F—Operations</b>
193.2051 Scope.	193.2501 Scope.
193.2057 Thermal radiation protection.	193.2503 Operating procedures.
193.2059 Flammable vapors gas dispersion protection.	193.2505 Cool-down.
193.2067 Wind force.	193.2507 Monitoring operations.
	193.2509 Emergency procedures.
	193.2511 Personnel safety.
<b>Subpart C—Design</b>	193.2513 Transfer procedures.
193.2101 Scope.	193.2515 Investigations of failures.
193.2119 Records.	193.2517 Purging.
	193.2519 Communication systems.
<b>Impediment Design and Capacity</b>	193.2521 Operating records.
193.2155 Structural requirements.	
193.2161 Dikes, general.	<b>Subpart G—Maintenance</b>
193.2167 Covered systems.	193.2601 Scope.
193.2173 Water removal.	193.2603 General.
193.2181 Independent capacity; LNG storage tanks.	193.2605 Maintenance procedures.
	193.2607 Foreign material.
<b>LNG Storage Tanks</b>	193.2609 Support systems.
193.2187 Nonmetallic membrane liner.	193.2611 Fire protection.
	193.2613 Auxiliary power sources.
	193.2615 Isolating and purging.
	193.2617 Repairs.
	193.2619 Control systems.
<b>Subpart D—Construction</b>	193.2621 Testing transfer hose.

# Preferred Outcome



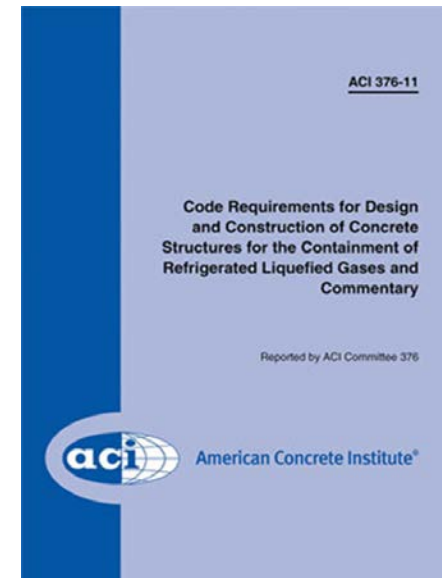
## 2016 Edition



## API 620 All Metal LNG Tanks



## ACI 376-2011 Concrete LNG Tanks

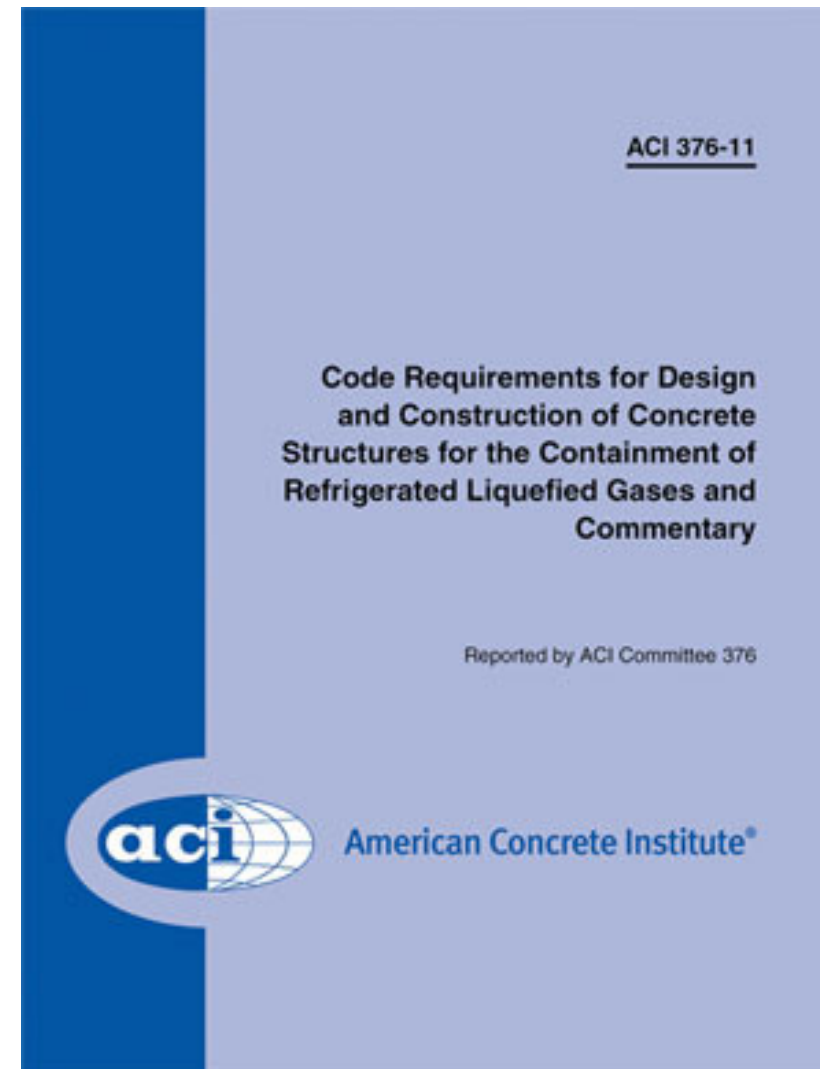


# Incorporated by Reference in NFPA 59A 2016 Edition

The formation of the ACI 376 Committee was based on a formal request in February 2003 by the NFPA 59A Committee that American Concrete Institute (ACI) undertake the preparation of a standard to address this particular need. ACI 376 Code was first published in 2013.

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Thank you!



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