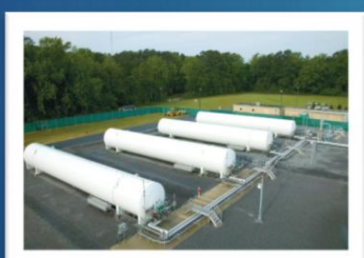
ASGMT 2018
LNG CUSTODY TRANSFER MEASUREMENT

May 11, 2018



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AGENDA

1. US NATURAL GAS AND LNG: HISTORY AND INFRASTRUCTURE
2. LNG SUPPLY CHAIN & MEASUREMENT
3. APPENDIX

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SOME GAS HISTORY 1850-Present

- 500 BTU/CF Manufactured Coal Gas was being Utilized in Europe and especially UK in the early to mid-1800's
- Manufactured Coal Gas was being Utilized in Major US Cities by the Civil War as Numerous Municipal Gas Lighting and then Heavy Industrial Applications.
- Natural Gas Transmission arrived in NE in the early 1950's.
- Complete Appliance Conversion was Required because of the new 1000 BTU/CF Fuel.
- Propane Air was quickly identified as a peak shaving Fuel.
- LNG and NY/PA Midstream Gas Storage was Developed in Parallel.

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SOME REGULATORY MILESTONES

- Natural Gas Act 1938: First Federal Regulation in Gas Industry. Rates, Section 7 Permits Public Convenience, and Section 3 Permits for Import and Export.
- 49 CFR 192: Minimum Safety Standards for Gas Distribution and Transmission established as Federal law in 1970.
- 49CFR 193: Minimum Federal Safety Standards for LNG Established as Federal Law in 1978.
- FERC Order 636 Unbundling and Open Access in 1992.
- Energy Policy Act 2005 Established Pre-Filing Process.

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US GAS SUPPLY SUMMARY

1. US LARGEST NG PRODUCER IN WORLD: 25 TCF/Y Non-linear Use
2. Approximately 100 LNG Facilities in US.
3. Approximately 100 BCF of LNG Storage in US.
4. 37 LNG Plants located in Northeast.
5. Approximately 4 TCF of Underground Storage in US.
6. Approximately 400 gas storage fields in US.
7. Gas costs per MMBTU: approximately $2.75

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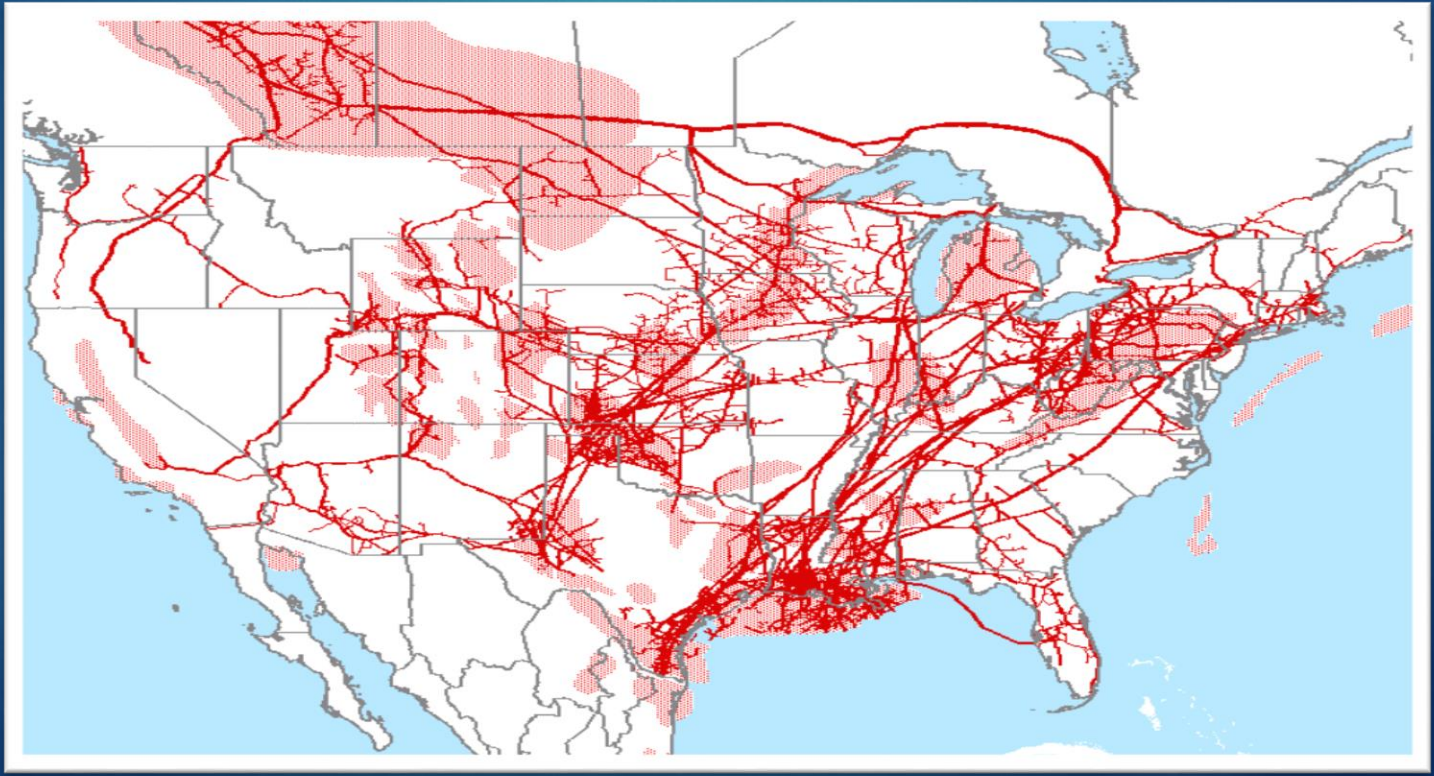
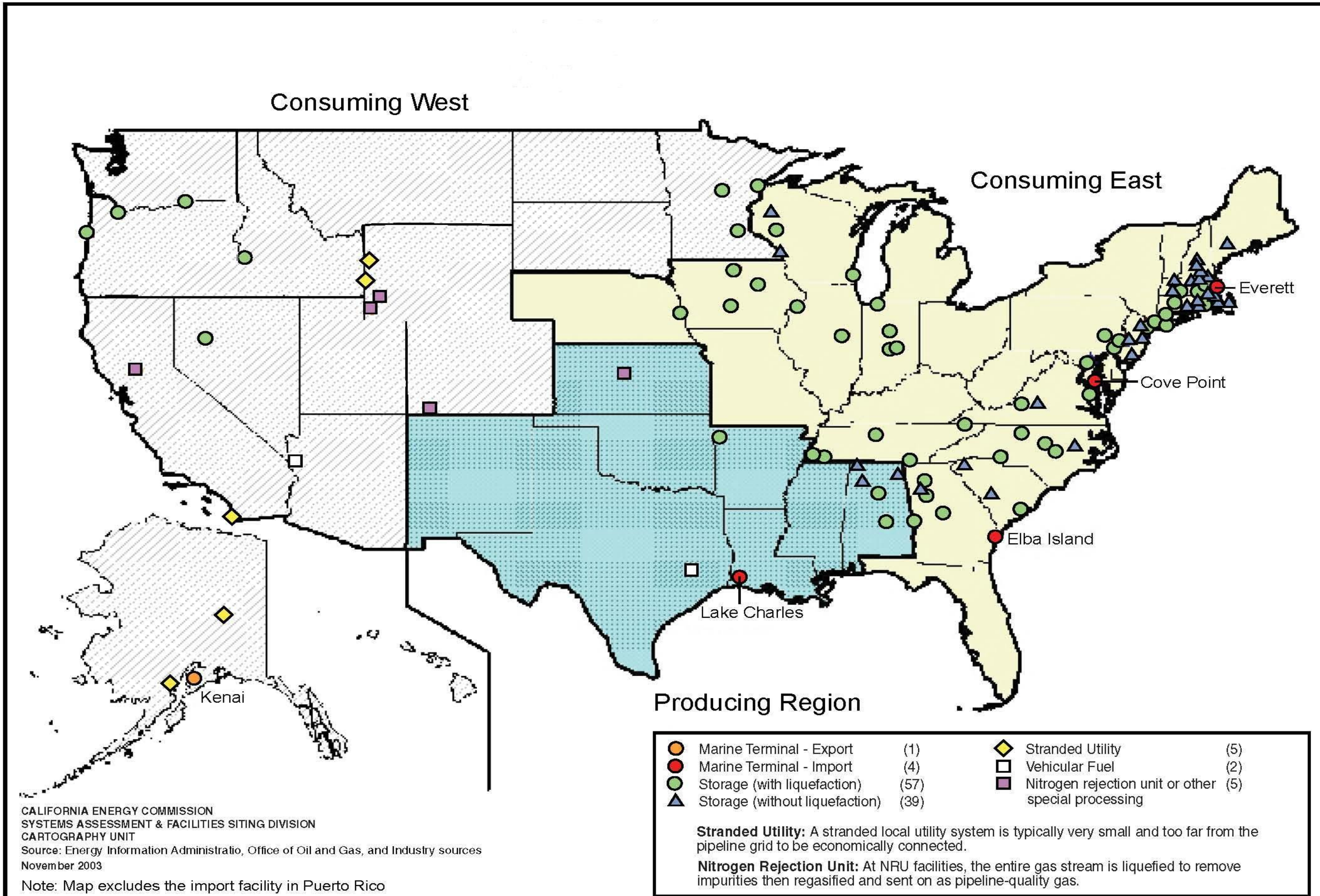
MAJOR US AND CANADIAN PIPELINES AND GAS PRODUCTION AREAS

UNITED STATES NATURAL GAS INFRASTRUCTURE

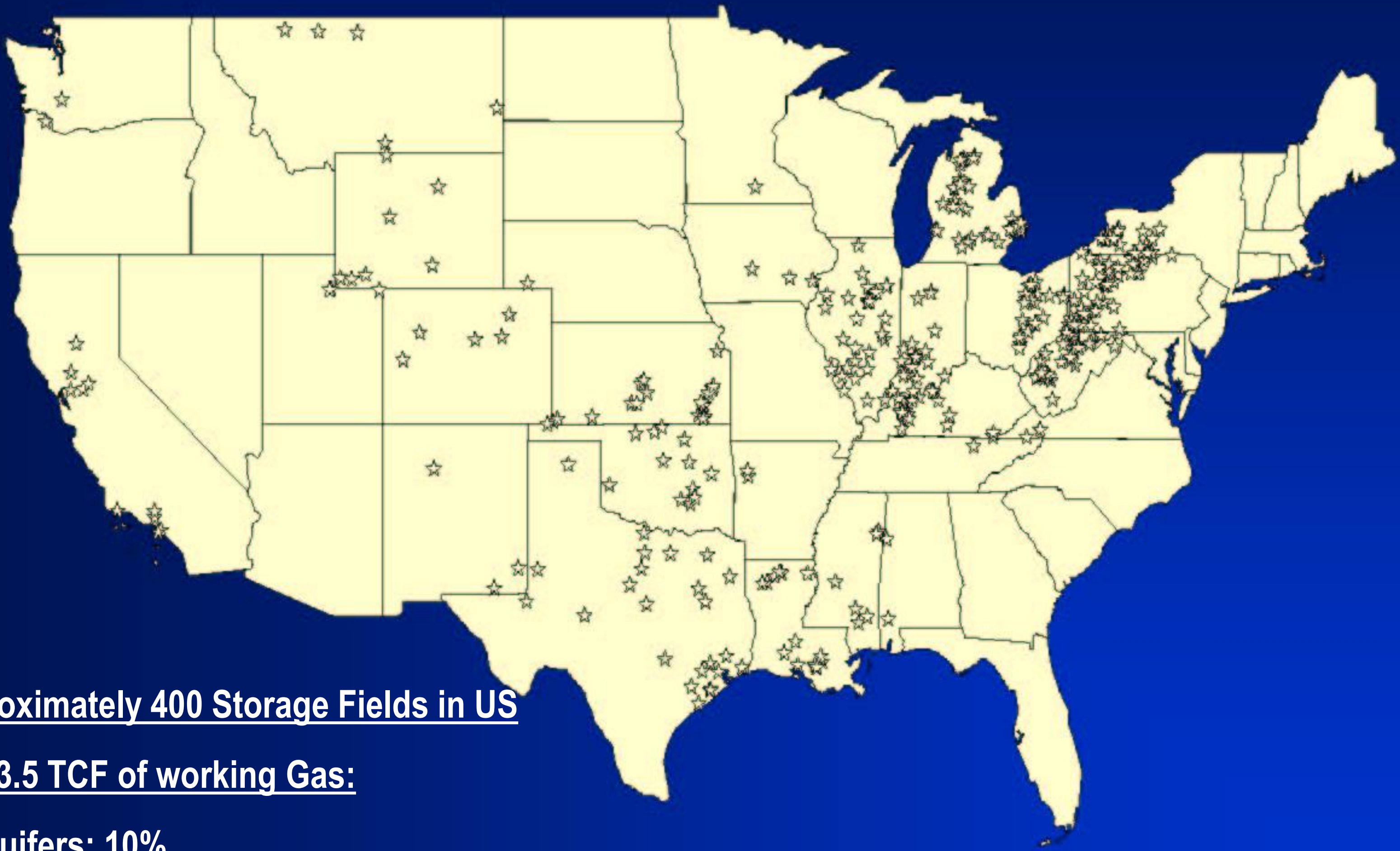
- LARGEST PRODUCER OF NATURAL GAS IN WORLD AT 25 TCF/YER (25 QUADS)
- 250K MILES OF NATURAL GAS TRANSMISSION PIPELINE
- 2.5 MM MILES OF GAS DISTRIBUTION
- 400 UG STORAGE FACILITES AT 4 TCF WORKING GAS
- 100 LNG PLANTS AT 100 BCF OF LNG STORAGE



US LNG FACILITIES



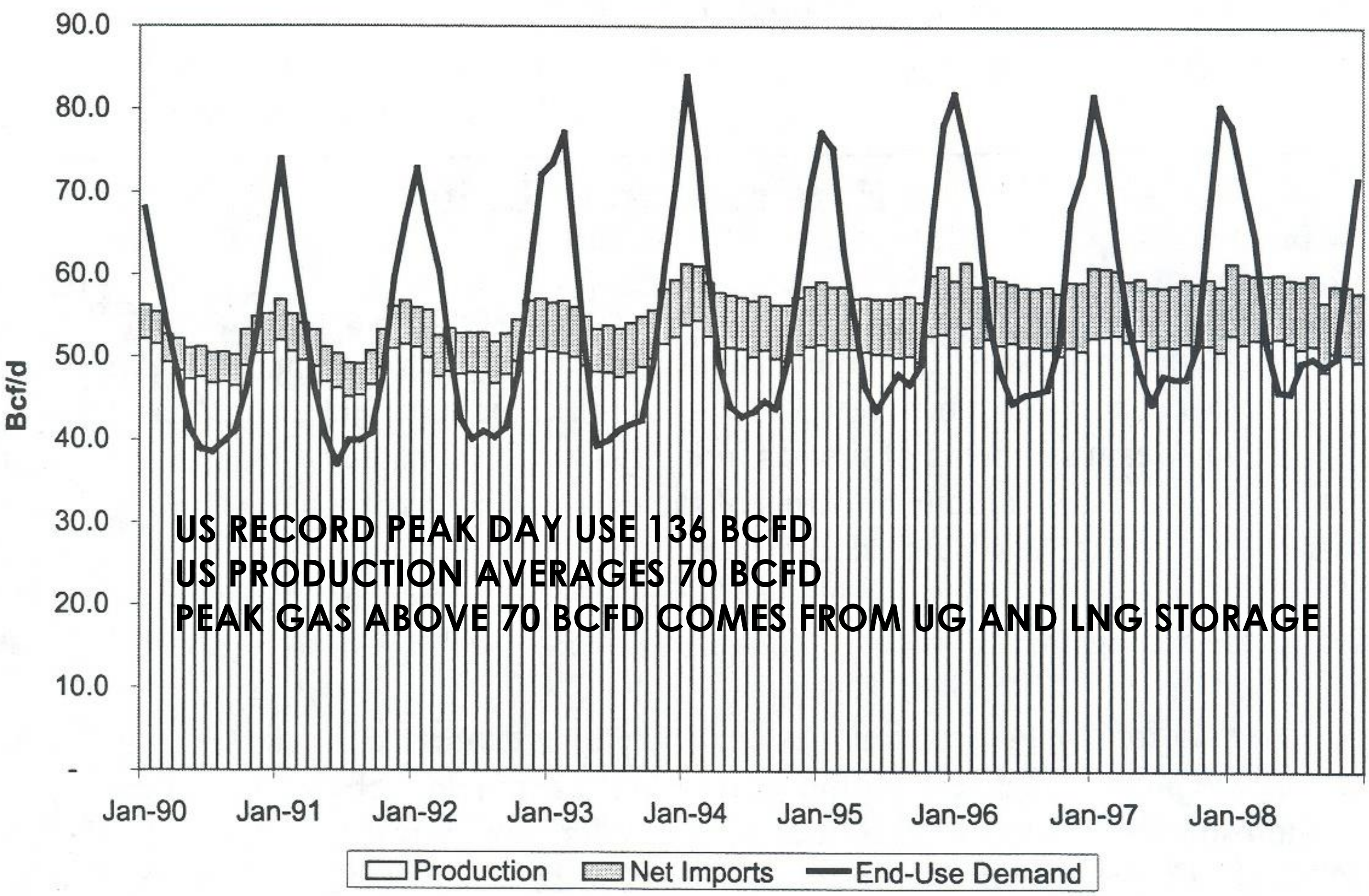
US GAS STORAGE FIELDS



1 Approximately 400 Storage Fields in US with 3.5 TCF of working Gas:

1. Aquifers: 10%
2. Depleted Gas/Oil Reservoir 86%
3. Cavern within Salt Dome 4%

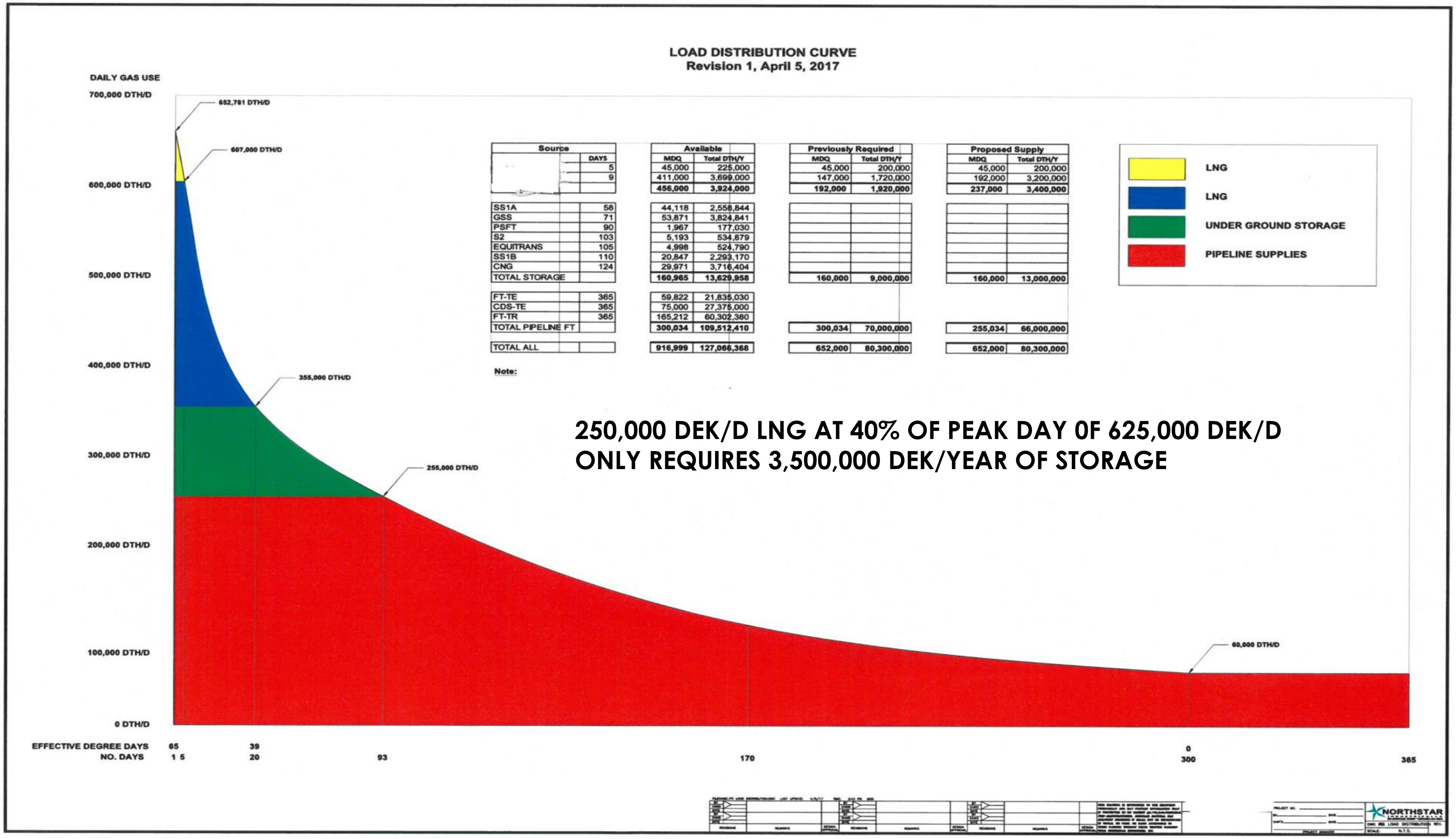
US GAS SUPPLY AND DEMAND CURVES



ANNUAL LOAD DURATION CURVE FOR CAPACITY PLANNING

100,000 MCF PER DAY CAPACITY COSTS $36-72MM PER YEAR.

30% OF PEAK DAY AS LNG IS TYPICAL AND 10 X PEAK DAY FOR ANNUAL



Source	DAYS	Available MDQ	Available Total DTH/Y	Previously Required MDQ	Previously Required Total DTH/Y	Proposed Supply MDQ	Proposed Supply Total DTH/Y
	5	45,000	225,000	45,000	200,000	45,000	200,000
	9	411,000	3,699,000	147,000	1,720,000	192,000	3,200,000
		456,000	**3,924,000**	**192,000**	**1,920,000**	**237,000**	**3,400,000**
SS1A	58	44,118	2,558,844				
GSS	71	53,871	3,824,841				
PSFT	90	1,967	177,030				
S2	103	5,193	534,879				
EQUITRANS	105	4,998	524,790				
SS1B	110	20,847	2,293,170				
CNG	124	29,971	3,716,404				
TOTAL STORAGE		**160,965**	**13,629,958**	**160,000**	**9,000,000**	**160,000**	**13,000,000**
FT-TE	365	59,822	21,835,030				
CDS-TE	365	75,000	27,375,000				
FT-TR	365	165,212	60,302,380				
TOTAL PIPELINE FT		**300,034**	**109,512,410**	**300,034**	**70,000,000**	**255,034**	**66,000,000**
TOTAL ALL		**916,999**	**127,066,368**	**652,000**	**80,300,000**	**652,000**	**80,300,000**

Note:

250,000 DEK/D LNG AT 40% OF PEAK DAY 0F 625,000 DEK/D ONLY REQUIRES 3,500,000 DEK/YEAR OF STORAGE

ECONOMICS OF LNG PEAK SHAVING ARE ABOUT AVOIDED PIPELINE CAPACITY CHARGES

LET US USE NEW ENGLAND AS AN EXAMPLE.

- COMMODITY AND ENERGY MEASUREMENT WAS LOW PRIORITY REG ENV.
- 20 BCF OF LNG CAPACITY IN 38 PLANTS WITH 2BCFD OF VAPORIZATION
- PEAK DAY IS 6,000,000 DEKATHERMS PER DAY(6BCFD)
- ONLY 4,000,000 DEKATHERMS PER DAY (4BCFD) PURCHASED PIPELINE CAPACITY
- 2,000,000 DEKATHERMS PER DAY (2 BCFD) IS LNG
- 100,000 DEKATHERMS PER DAY OF CAPACITY COSTS $50MM/Year
- 1BCFD OF CAPACITY IS WORTH $500MM / YEAR
- THE LNG PLANTS IN NEW ENGLAND SAVE CONSUMERS ABOUT $1B / YEAR.

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10 HELPFUL LNG RULES OF THUMB

1. Detection:	Odorless, Colorless & Nontoxic
2. Boiling Point at Atm Press.:	-260^{o}F
3. Expansion Ratio from Liquid to Vapor:	618 to 1
4. Volume of LNG per MSCF:	12.1 Gallons
5. Volume of Gas in 10,000 Gallon LNG Trailer:	833 MSCF
6. Flow of LNG to Vaporize 500 MSCFH:	100 GPM
7. Specific Gravity of Liquid (Water = 1.0):	0.46
8. Specific Gravity of Vapor at –260^{o}F (Air = 1.0):	1.43
9. Latent Heat of Vaporization at Atm Press.:	219 BTU's / lbs.
10. Specific Heat of Vapor at Atm Press.:	0.52 BTU's / lbs.-^{o}F

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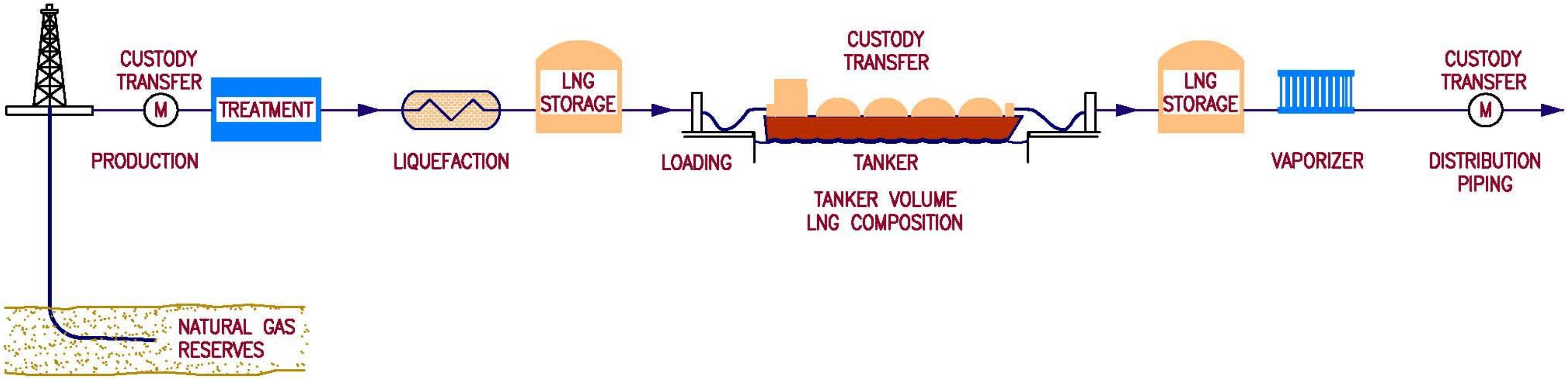
USA INTERNATIONAL LNG SUPPLY CHAIN

PREDOMINANTLY EXPORT BUT SOME IMPORT OF LNG FROM PRODUCING AREAS



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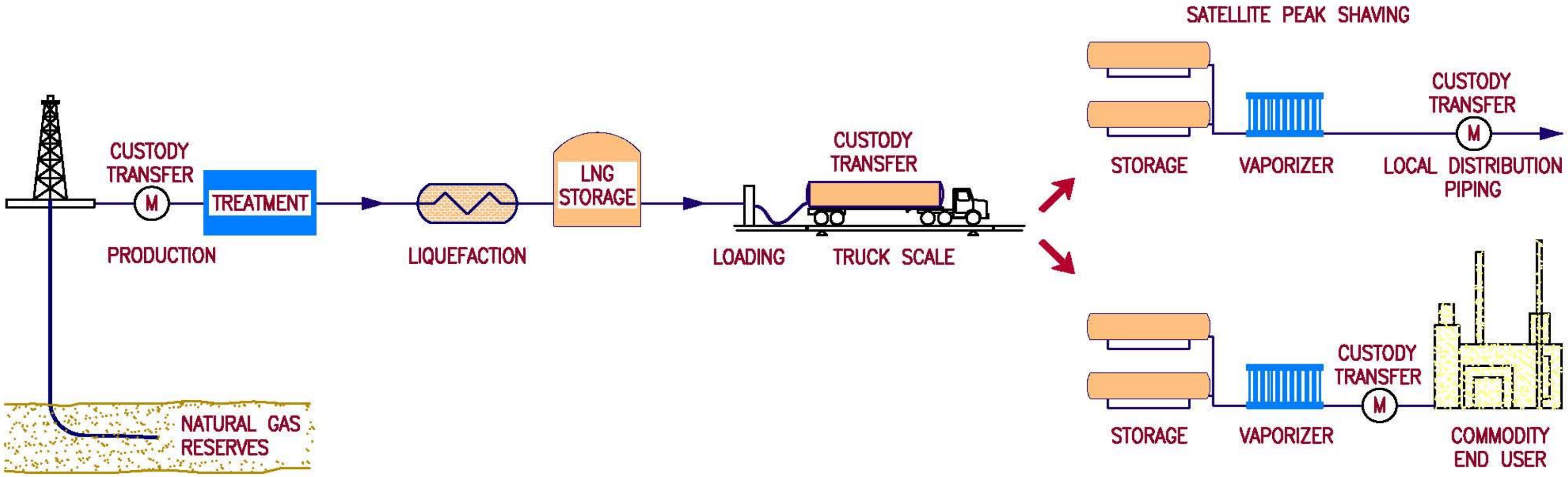
USA DOMESTIC LNG SUPPLY CHAIN

LNG SOURCE SITES: PRETRETMENT, LIQUEFACTION, STORAGE, TRANSPORT
LNG END USER SITES: STORAGE, LIQUID TRANSFER OR LNG VAPORIZATION



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TWO MEANS OF CUSTODY TRANSFER OF LNG LIQUID

1. LNG VOLUME: COMBINE WITH LNG BTU PER UNIT.

For example: $/US Gallon based upon BTU/Gallon: DEK purchased Chromatograph Sample for Energy Content then either:

-Agree on the volume of the delivery vessel.

-Use LIQUID custody meter (Coriolis, USM)

2. LNG DENSITY: COMBINE WITH BTU PER UNIT DENSITY

For example: $/pound based upon BTU/Pound: DEKS purchased. Chromatograph Sample for Energy Content then weigh the truck empty and weigh the truck full.

The Key is to contractually Design all these ingredients ahead to the mutual satisfaction of all…. Includes energy displaced during the transfer of LNG.

DEFINE STANDARD CONDITIONS OF CONTRACT
FIRST DEFINE STANDARD CONDITIONS: ATM P AND DEG F
TYPICALLY 60 DEG F AT 14.7 PSIA THEN

NATURAL GAS HEATING VALUE: HHV, LLV, GHV MUST BE DEFINED IN CONTRACT

The custody transfer heating value of gas defines the amount of energy available for the combustion process.
Combustion is a chemical reaction with the gas reacting with oxygen to form carbon dioxide, water, and heat. It is measured
in units of BTU/SCF. For billing, the heating Value is expressed in three different ways HHV, LHV, or GHV: (The scale to be used, should be defined in IA. RTU load consistent.)

HHV:
The quantity known as higher heating value does not take into account that water vapor is formed in combustion and that the heat of vaporization of water consumes some of the heat .

LHV:
lower heating value (or *net calorific value*) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. The energy required to vaporize the water therefore is not realized as heat.

GHV:
Gross heating value accounts for water in the exhaust leaving as vapor, and includes liquid water in the fuel prior to combustion.

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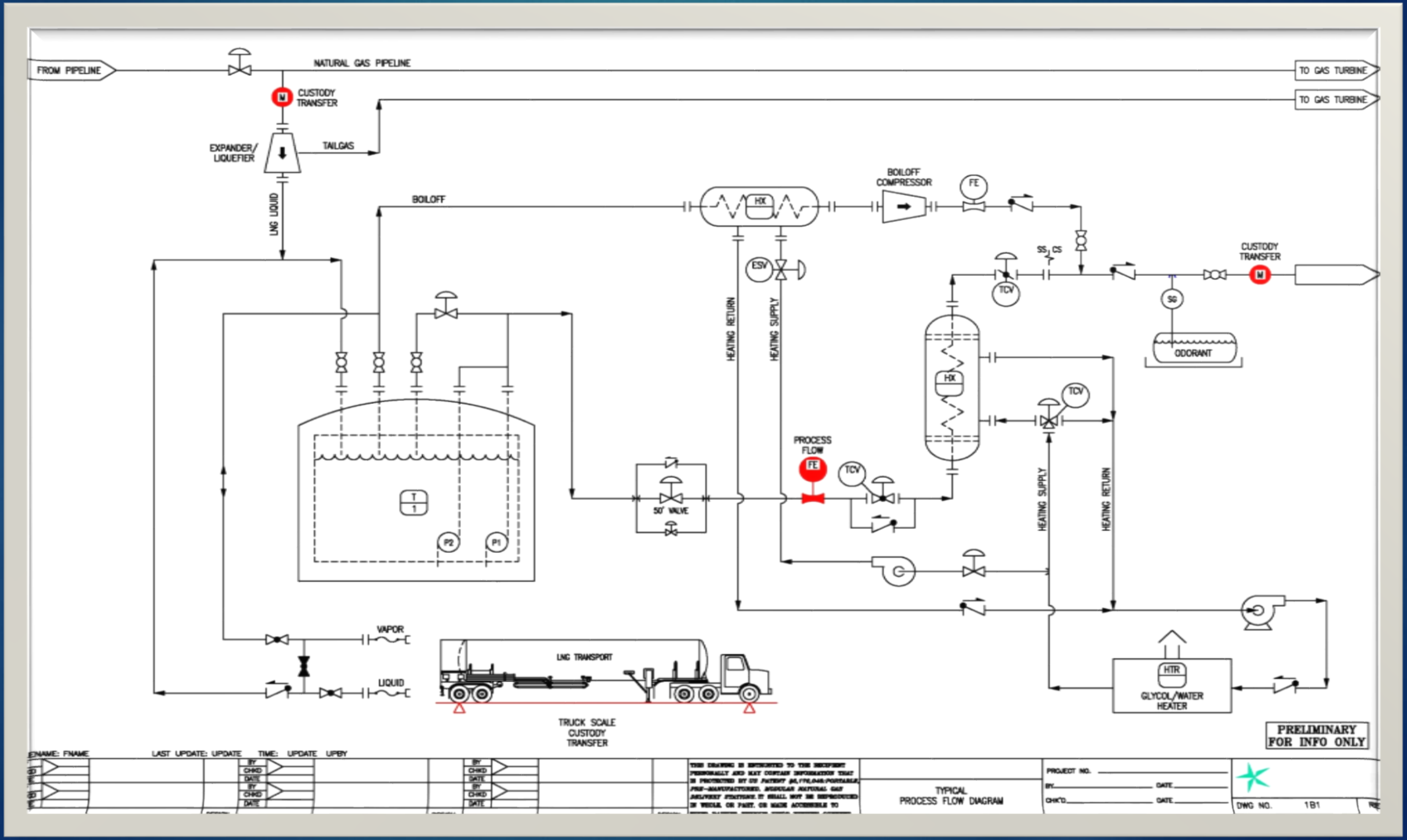
TYPES OF NG OR NG/LNG MEASUREMENT REQUIRED AT LNG FACILITIES

- CUSTODY TRANSFER NATURAL GAS IN: FROM LDC OR PIPELINE
- CUSTODY TRANSFER NATURAL OUT: BOIL-OFF/VAPORIZATION LDC OR PIPELINE
- CUSTODY TRANAFER LNG LIQUID IN OR OUT VIA CARRIER: VOLUME/WEIGHT OR METERING
- PROCESS FLOW: LNG PRETREATMENT, TAIL GAS, LIQ, BOIL OFF, LNG VAP,



LNG TANKER TRUCK ON WEIGH SCALE

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AGA NG MEASUREMENT INLETT AND AFTER REGASIFICATION

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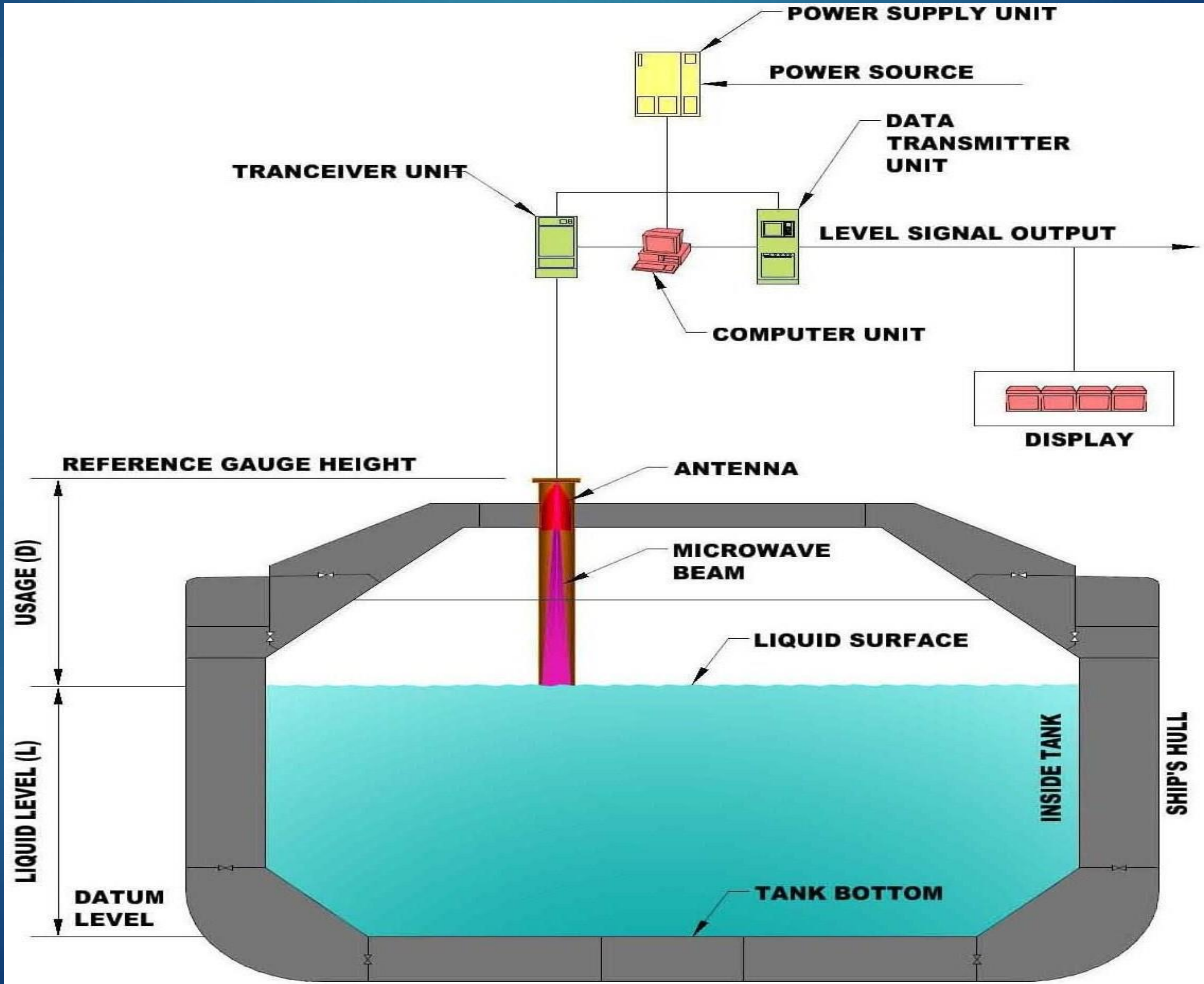
LNG SUPPLY AT MARINE TERMINAL VIA SHIP

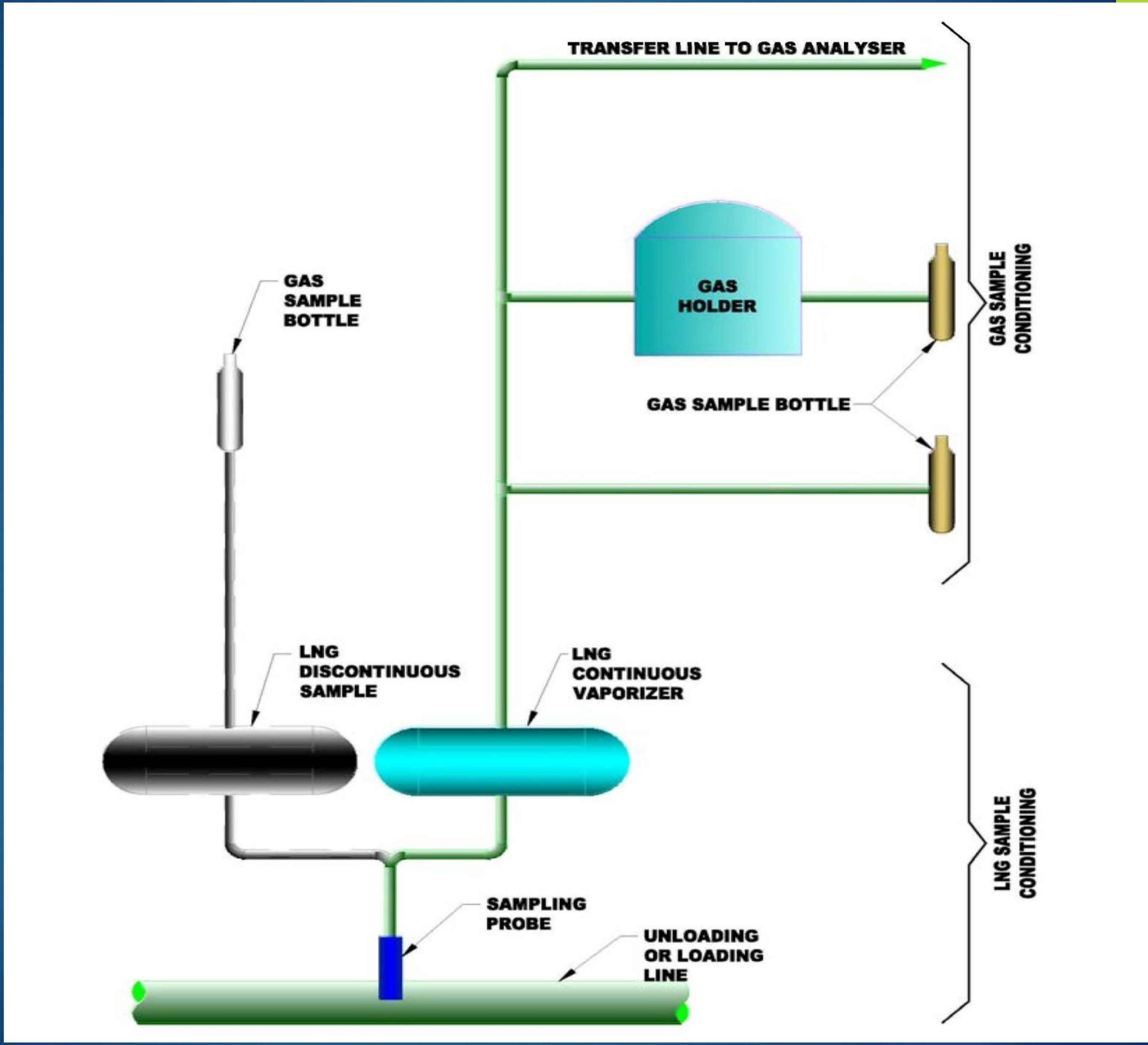
GIIGNL 2017 LNG CUSTODY TRANSFER HANDBOOK PROVIDES EXCELLENT REFERENCE

- AGREED UPON VOLUME AND LIQUID HEIGHT MEASURMENT AT LNG TERMINAL

RADAR (MICROWAVE) TYPE LEVEL GAUGE



LNG SAMPLING CHAINS



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APPENDIX LNG FACILITIES

TECHNICAL FACTS:

- History
- Design
- Siting
- Codes and Standards
- Equipment Selection

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HISTORY OF LNG

- 1941: First large-scale LNG liquefaction peak-shaving facility built by East Ohio Gas Company in Cleveland.

- 1944: Catastrophic LNG tank failure at Cleveland facility kills 128 people and sets back LNG industry in USA.

- 1954: First ship transport of LNG from Louisiana to Canvey Island (UK) where the first LNG import terminal was established by British Gas.

- 1964: First large-scale LNG trade began when British Gas began importing by ship from Algeria.

- Mid-1960's to Mid-1970's: Rebirth of peak-shaving LNG industry in the USA due to supply shortages during peak demand periods.
- 1980's: Deregulation of the gas industry in the USA increases LNG interest.

- Present: Predicted shortage of domestic gas supplies increases LNG interest.

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CODES & STANDARDS: LNG FACILITIES

- US DOT 49 CFR Part 193: Liquefied Natural Gas Facilities - Federal Safety Standards
- NFPA 59A: Standard for the Production, Storage & Handling of Liquefied Natural Gas (LNG)
- NFPA 59A - Chapter 10: Alternate Requirements for Stationary Applications Using ASME Containers
- NFPA 59A- Paragraph 2-3.4: Temporary Use of LNG Portable Equipment

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US DOT 49 CFR PART 193

LNG facilities used in the transportation of gas into pipelines or distribution systems regulated by 49 CFR Part 192 are subject to regulation by 49 CFR Part 193. There are approximately 95 LNG facilities in the USA, which fall under the jurisdiction of 49 CFR Part 193.

<u>I. FERC Regulated Facilities</u>
A. LNG Facilities Supplying Interstate Pipelines
B. LNG Marine Terminals

<u>II. DOT Regulated Facilities</u>
A. LNG Facilities Supplying Intrastate Pipelines or Distribution Systems

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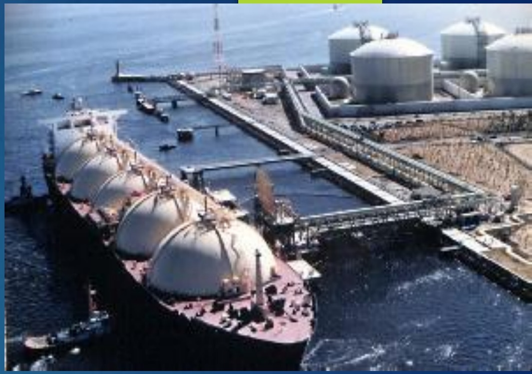
THREE MAJOR TYPES OF LNG FACILITIES



1. Marine Terminals (Import or Export)

- Ship Loading or Unloading
- On-Site Storage
- Liquefaction or Vaporization
- Truck Loading

2. Peak-Shaving

- Liquefaction or Truck Unloading
- On-Site Storage
- Vaporization
- Truck Loading

3. Base-Load

- Liquefaction or Truck Unloading
- On-Site Storage
- Vaporization
- Truck Loading

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OTHER TYPES OF LNG FACILITIES

1. Vehicular Fueling
    - Truck Unloading or Liquefaction
    - On-Site Storage
    - Vehicle Fueling

2. Stranded Gas Reserves
    - Liquefaction
    - On-Site Storage
    - Truck Loading

3. Land Fill Gas
    - Liquefaction
    - On-Site Storage
    - Truck Loading

TWO MAIN TYPES OF LNG STORAGE TANKS

1. Field Erected (API-620 Appendix Q):

- 1,000,000 to 42,000,000 Gallons (3,800 to 160,000 Cubic Meters)
- 0.5 to 2 psig Design Pressure
- Pre-Stressed Concrete
- Single Containment (9% Nickel Steel Inner Tank & Carbon Steel Outer Tank)
- Full Containment (Cryogenic Inner Tank & Concrete Outer Tank)
- External or Internal Sendout Pumps

2. Shop Fabricated (ASME):

- 30,000 to 70,000 Gallons (113.5 to 265 Cubic Meters)
- 70 to 250 psig Design Pressure
- 9% Nickel Steel Inner Tank & Carbon Steel Outer Tank
- Horizontal or Vertical Configuration
- Above Ground or Buried
- Differential Pressure Sendout or External Sendout Pumps

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TYPES OF LIQUEFACTION SYSTEMS

- **Natural Gas Expander**
- **Cascade Refrigeration**
- **Mixed Refrigerant**
- **Nitrogen Cycle**

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TYPES OF VAPORIZERS

- Direct Fired
- Indirect Fired Water Bath
- Indirect Fired Submerged Combustion
- Ambient Heat
- Remote Heated Shell and Tube
- Remote Heated Falling Film
- Open Rack Seawater

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DEVELOPMENT STEPS

1. Preparation of concise conceptual baseline foundation.
   - Determine need, design baseline, jurisdictions, cost/schedule, economics.
   - Include all cost centers: Land, Afudc, Overheads, Grossup, Utilities.
   - Project milestone: Go/No Go
2. Establish site and project control.
3. Preparation of filings, final design, and engineering.
4. Open seasons or revenue stream commitments.
5. Establish Supply.
6. Final design and EPC contracts.
7. Adjudicate permits.
8. Set up operating company.
9. Procurement, construction, commissioning, and future O&M.

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SITING ISSUES: 49 CFR Part 193 FIXED FACILITIES SUPPLYING 49 CFR PART 192 CUSTOMERS

Design, Construction, and Operations per 49 CFR Part 193 and by experienced, qualified and fit for duty people. The project must be implemented with 1.) Construction, 2.) Operating, 3.) Maintenance, 4.) Security, 5.) Fire, & 6.) Emergency Plans.

The design must also consider the following siting issues.

- THERMAL RADIATION
- VAPOR DISPERSION
- SEISMIC
- FLOODING
- SOIL
- WIND
- SEVERE WEATHER
- ADJACENT ACTIVITY
- SEPARATION
- AIRPORTS

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THERMAL RADIATION PROTECTION

Provisions shall be made to minimize the possibility of the damaging effects of fire reaching beyond a property line that can be built upon and that would result in a distinct hazard.

In calculating exclusion distances, the wind speed, ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for those values that occur less than 5% of the time based on recorded data for the area.

<u>1,600 Btu/hr/ft2</u> at a property line that can be built upon for ignition of a design spill.

<u>1,600 Btu/hr/ft2</u> at the nearest point located outside the owner's property line that, at the time of plant siting, is used for outdoor assembly by groups of 50 or more persons for a fire over an impounding area.

<u>3,000 Btu/hr/ft2</u> at the nearest point of the building or structure outside the owner's property line that is in existence at the time of plant siting and used for occupancies classified by NFPA 101®, Life Safety Code®, as assembly, educational, health care, detention and correction or residential for a fire over an impounding area.

<u>10,000 Btu/hr/ft2</u> at a property line that can be built upon for a fire over an impounding area.

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VAPOR DISPERSION PROTECTION

Provisions shall be made to minimize the possibility of a flammable mixture of vapors from a design spill, as appropriate, reaching a property line that can be built upon and that would result in a distinct hazard.

- Flammable mixture dispersion distances shall be calculated in accordance with the model described in Gas Research Institute report GRI 0242, “LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model.”

- The effects of provisions for detaining vapor or otherwise mitigating flammable vapor hazards (e.g., impounding surface insulation, water curtains, or other methods) shall be permitted to be considered in the calculation where acceptable to the authority having jurisdiction.

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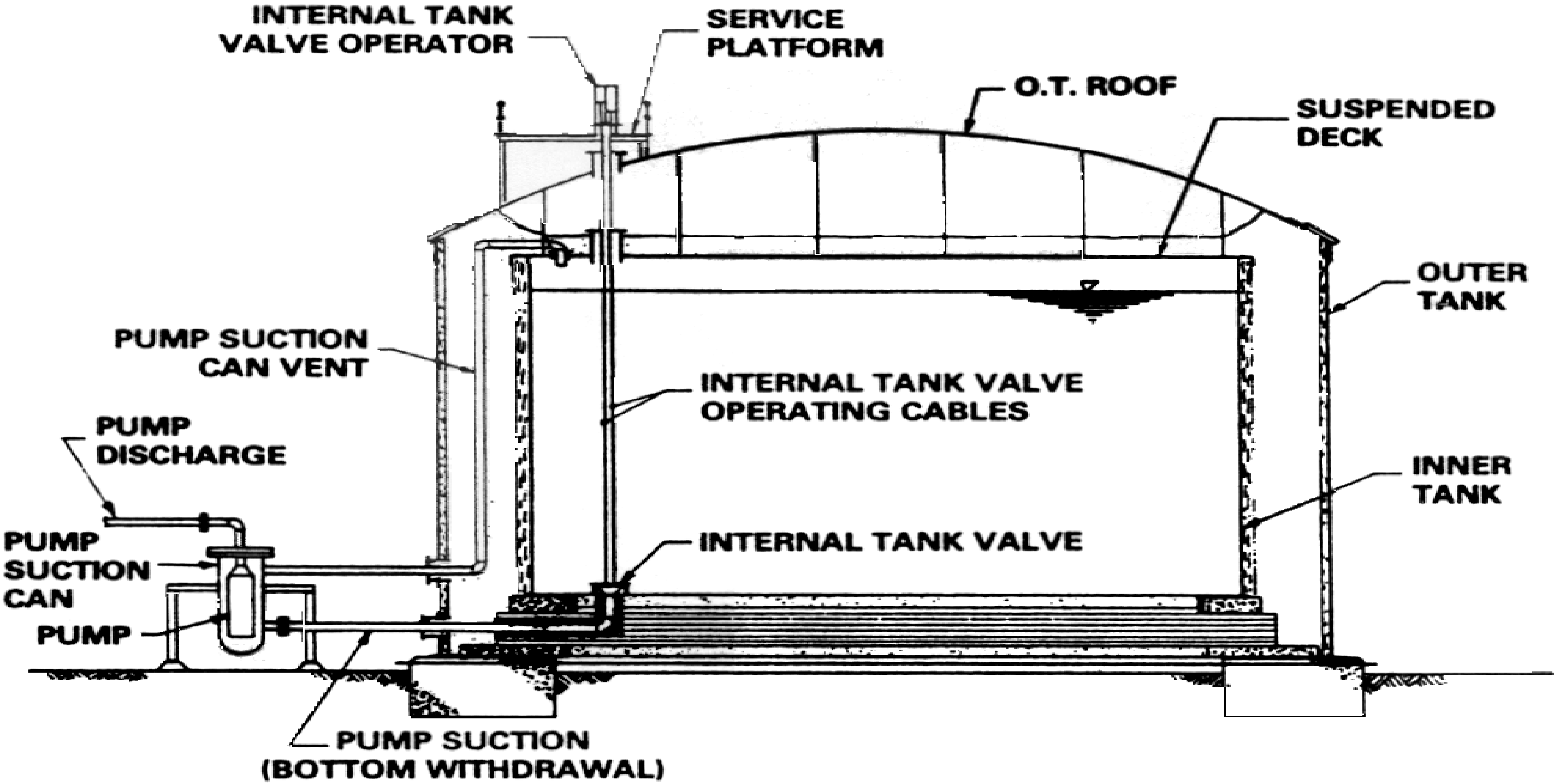
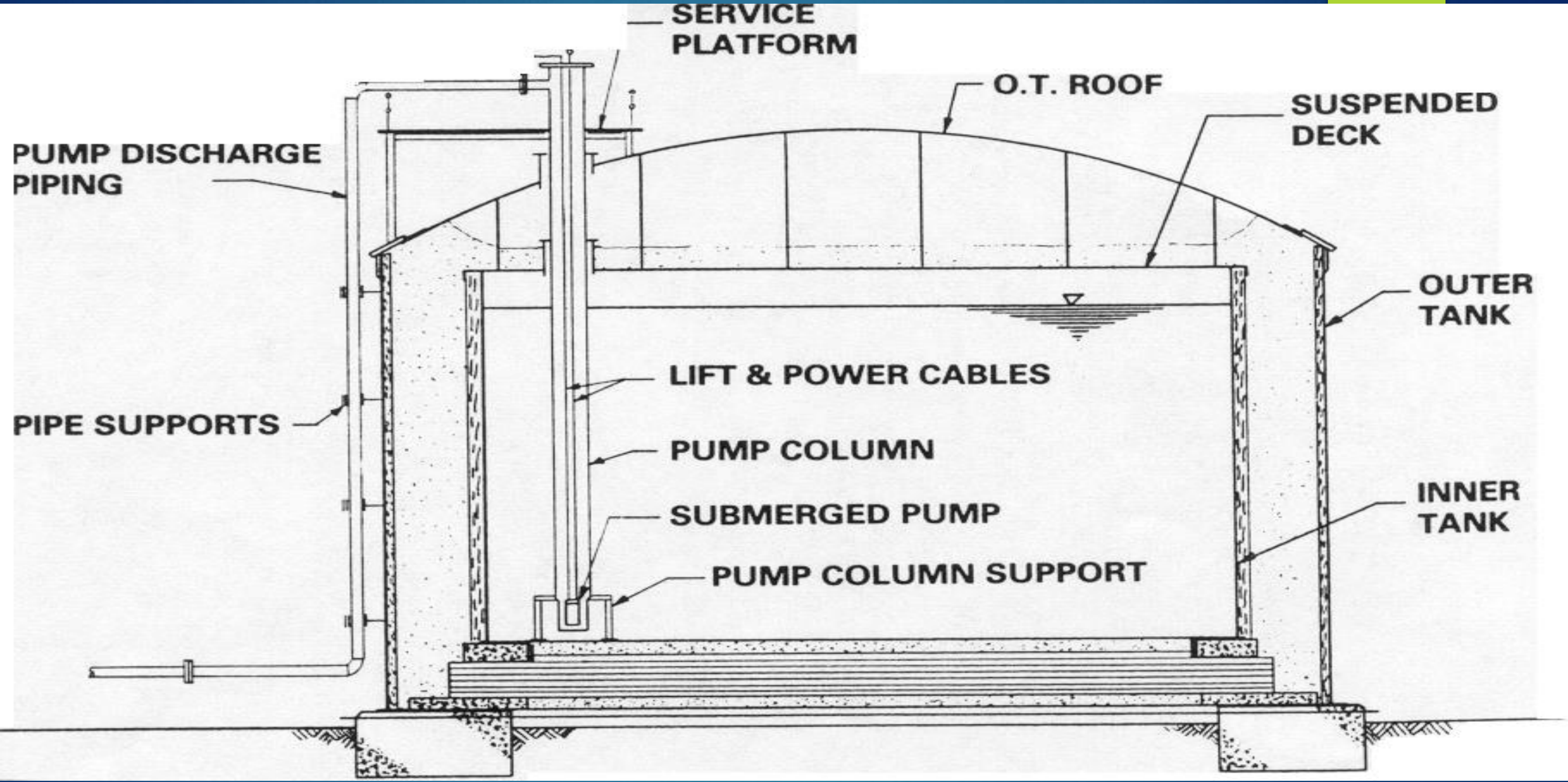
DESIGN SPILL: BOTTOM PENETRATION TANKS WITH INTERNAL SHUTOFF VALVES



<u>Design Spill:</u> A spill through an assumed opening at, and equal in area to, that penetration below the liquid level resulting in the largest flow from an initially full tank for one (1) hour.

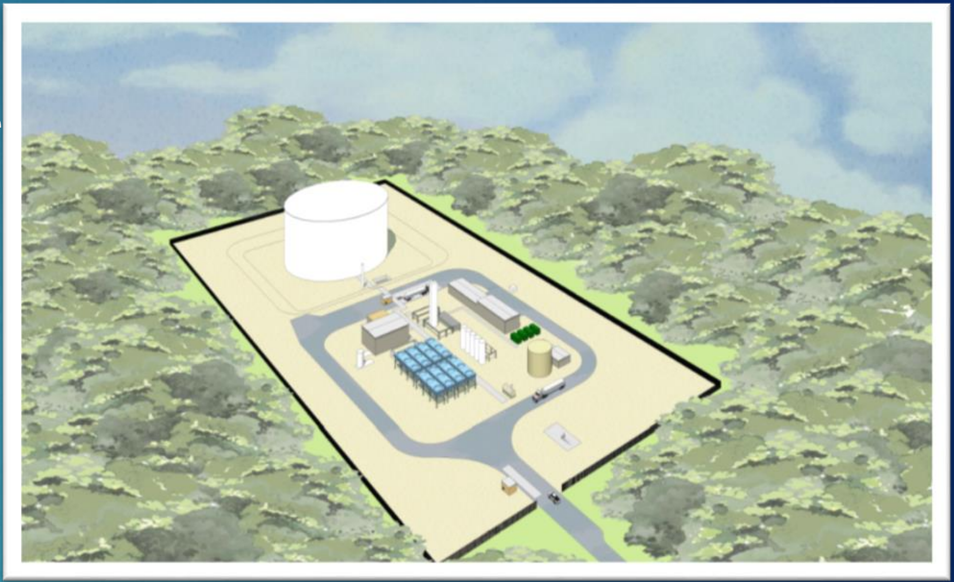
DESIGN SPILL: TANKS WITH PENETRATIONS ABOVE THE LIQUID LEVEL



<u>Design Spill:</u> The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) delivering the full rated capacity for ten (10) minutes.

INTERSTATE PROJECT OVERVIEW

- Feasibility Analysis
- Finance/Procurement/Lease/Purchase
- Pre-Filing Application
- Open Season
- Submission of Resource Reports
- Public Hearings
- Environmental Impact
- Receive FERC Permit and Conditions
- Balance of Final Design and Local Permits
- Pre-manufacturing
- Installation
- Project Documentation
- Procedures & Plans
- Commission & Train



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INTERSTATE APPROVALS

- STATE ENERGY SITING BOARDS
- STATE PUBLIC UTILITY COMMISSION
- STATE DEVELOPMENT LAWS
- FLAMMABLE STORAGE PERMITS
- CONSERVATION COMMISIONS
- COASTAL ZONE MANAGEMENT
- LOCAL ZONING & PERMITS
- FIRE AUTHORITIES
- EPA DISCHARGE & AIR
- EPA EMERGENCY RESPONSE

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