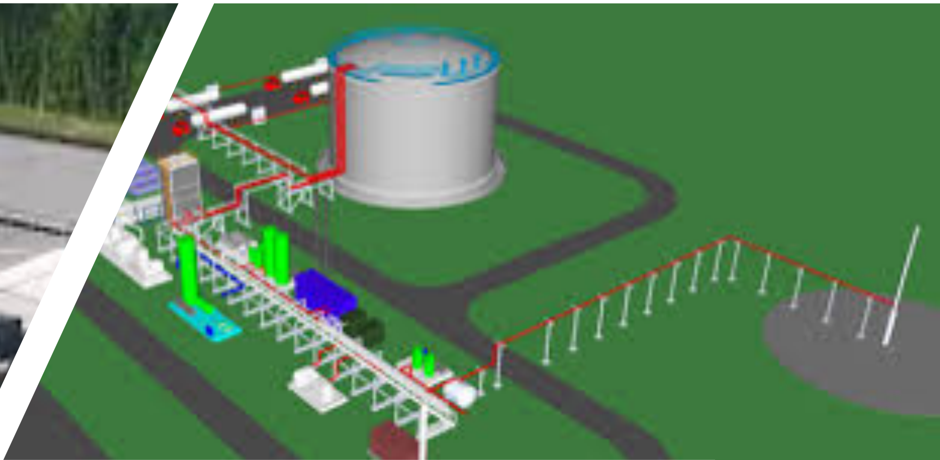
AMERICAN SCHOOL OF GAS MEASUREMENT TECHNOLOGY
AN OVERVIEW OF THE GAS INDUSTRY
AND LNG MEASUREMENT AND CONTROL



Agenda

1. History and Supply Chain of natural gas pipelines, Underground Storage and LNG facilities in US
2. LNG Plant Liquid and Vapor Custody Transfer and Process Measurement and Controls
3. Appendix of LNG Facts and Opinions
4. Contact Information:

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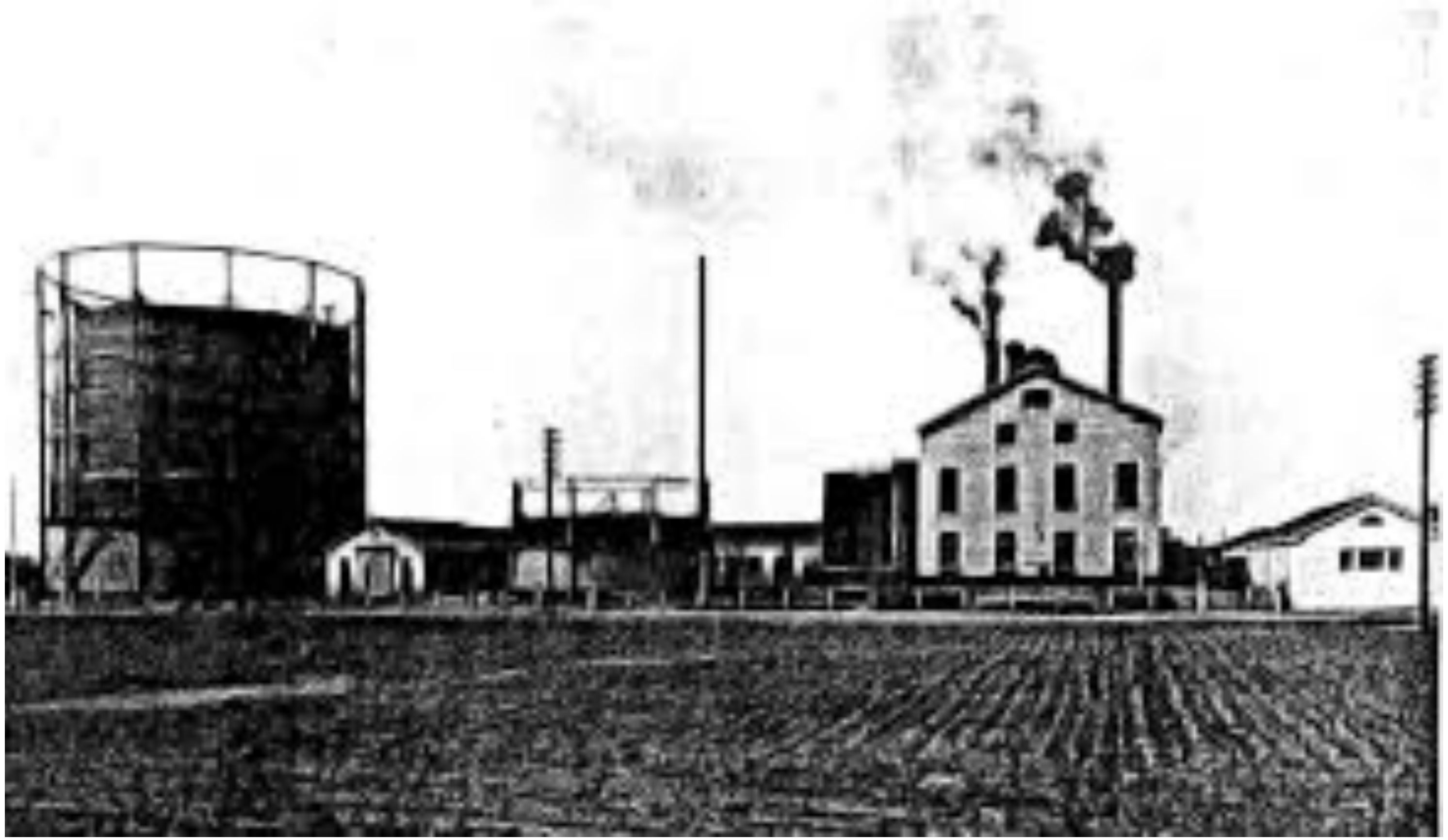
HISTORY OF NG, UG STORAGE AND LNG IN US

ORIGINAL LNG PLANTS IN 1960'S ARE ALL ABOUT AVOIDED PIPELINE CAPACITY CHARGES

NEW ENGLAND LNG ASSETS ILLUSTRATE AVOIDED CAPACITY.

- PEAK DAY IS 6,000,000 DEKATHERMS PER DAY(6BCFD)
- 2,000,000 DEKATHERMS PER DAY (2 BCFD) IS LNG
  FROM 20 BCF OF LNG STORAGE IN 38 PLANTS
- THE LNG PLANTS IN NEW ENGLAND SAVE CONSUMERS ABOUT $1.8 B / YEAR.
- 100,000 DEKATHERMS PER DAY OF NEW CAPACITY WOULD COST $90 MM/Year



MANUFACTURED GAS AND NG HISTORY 1850- PRESENT

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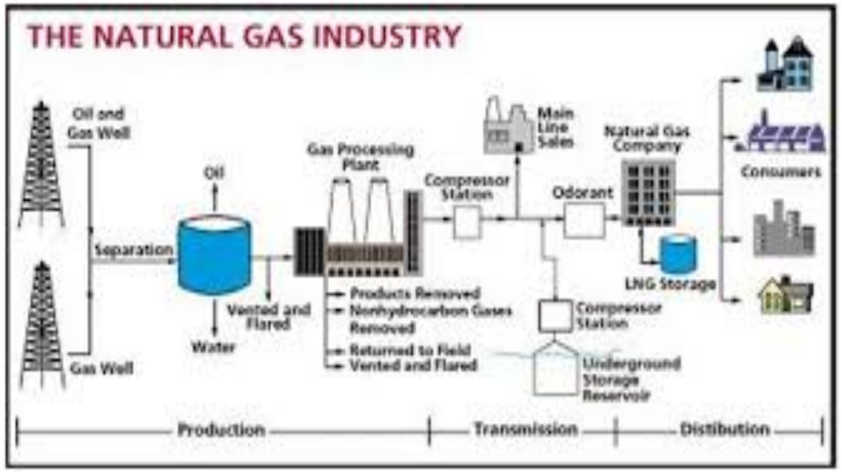
- 1960's: Propane Air was quickly identified as a peak shaving Fuel.
- 1960/70's: LNG and NY/PA Midstream Gas Storage was Developed in Parallel.
- 1999: LNG Import peaked at 800 BCF/Y
- 21st Century Fracking Technology Shale Plays Make Import LNG unattractive
- Current Abundant Supply of Natural Gas lowers prices and creates Commodity Market

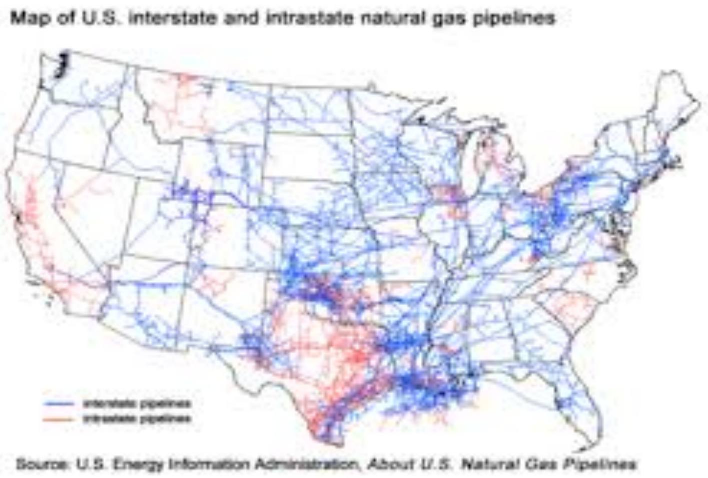
SOME REGULATORY MILESTONES

- Natural Gas Act 1938: First Gas Industry Federal Regulation for Defined 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 became federal law in 1970.
- 49CFR 193: Minimum Federal Safety Standards for LNG became Federal Law in 1978.
- FERC Order 636 decoupled capacity and commodity and created Open Access in 1992.
- Energy Policy Act 2005: Established Pre-Filing Process.

NATURAL GAS SUPPLY CHAIN: US PIPELINES, UNDERGROUND GAS STORAGE AND LNG FACILITIES

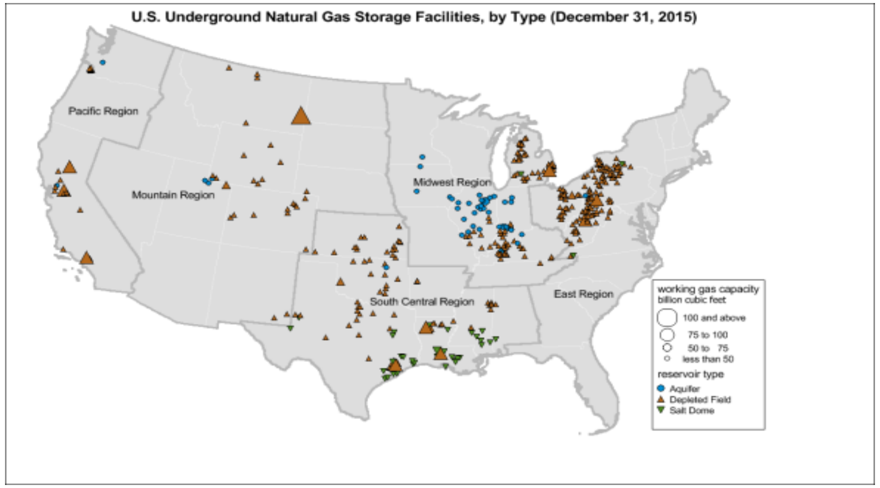
Interstate Pipelines in Red 250,000 Miles
Intrastate in Blue 2.25 MM Miles





100 LNG plants in US 100 BCF

400 Natural Gas Storage Fields in US with 30 TCF Storage



US GAS SUPPLY SUMMARY

1. 1 TCF of Natural Gas is equivalent to 1 Quadrillion BTU's of Energy.
2. US LARGEST NG PRODUCER IN WORLD: 30 TCF/Y / 30 Quadrillion BTU's.
3. US Consumes Approximately 40 Quads/Year as Oil and half of it is imported.
4. Ironically the oil is about twice the cost of NG yet we import 20 Quads/Year.
5. Approximately 100 LNG Facilities in US.
6. Approximately 100 BCF of LNG Storage in US.
7. 38 LNG **Plants** located in Northeast.
8. Approximately **4** TCF of Underground Storage in US.
9. Approximately 400 gas storage fields in US.
10. Gas costs per MMBTU: approximately $2.60/dekatherm or MMBTU
11. In approximate numbers oil/gas/coal/renewables are converging.

LNG PLANT JURISDICTION

LNG facilities that provide LNG vaporization into pipelines or distribution systems regulated by 49 CFR Part 192 are subject to regulation by 49 CFR Part 193. There are approximately 100 LNG facilities in the USA, which fall under the jurisdiction of 49 CFR Part 193.

INTERSTATE /FERC Regulated Facilities are LNG Facilities Supplying Interstate Pipelines OR LNG Marine Terminals for import and export.

Intrastate DOT Regulated Facilities are LNG Facilities Supplying Intrastate Pipelines or Distribution Systems. Some states have their own LNG regulations for intrastate and Private facilities.

Private LNG facilities not subject to 49 CFR 193. Other LNG facilities that are not subject to above would need to determine the local and state authorities having jurisdiction. In some case NFPA-59A would dictate standards. In others not.

LNG MEASUREMENT AND CONTROL

SOME LNG RULES OF THUMB

For Leak Detection:	LNG is Odorless and Colorless
Boiling point at Atmospheric P:	-260 Degrees F.
Expansion Ratio from Liquid to Vapor:	618 to 1
As a Comparison 9,100 PSIG CNG:	618 to 1
Gallons LNG liquid per dekatherm:	12.1 Gallons
Dekatherms 10,000 Gallon LNG Trailer:	826 dekatherms
GPM LNG for 100,000 DEK/D Vapor Flow:	840 US GPM
10 Minute Design Spill at 100,000 Deks/D	8,400 US Gallons
Specific Gravity of LNG (Water = 1):	.46
Specific Gravity of NG Vapor -260 F (Air = 1):	1.43
Latent Heat Vaporization Atmospheric P:	219 Btu’s / #
Specific Heat of Vapor at Atmospheric P:	.52 Btu’s / # / Degree F.

NATURAL GAS HEATING VALUE: HHV, LLV

The heating value of natural gas is the amount of energy available for the combustion process.

During combustion , natural gas reacts with oxygen to form carbon dioxide, water, and heat. Heating value is measured in units of BTU/volume. For billing, the heating Value is expressed in three different ways HHV, LHV,: (The scale to be used, should be defined in IA. RTU load consistent.)

HHV:
The quantity known as higher heating value does not account for the fact that water vapor is formed in combustion and that the heat of vaporization of water consumes some of the heat : 980 BTU's per pound of water.

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.

Why is this an issue? The contract specifies $/Dekatherm. The contract needs to specify the LHV or HHV or other method.

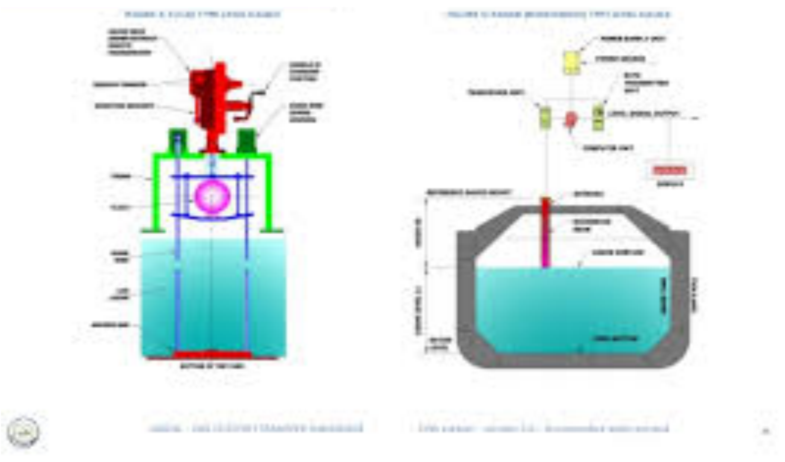
CUSTODY TRANSFER OF LNG LIQUID

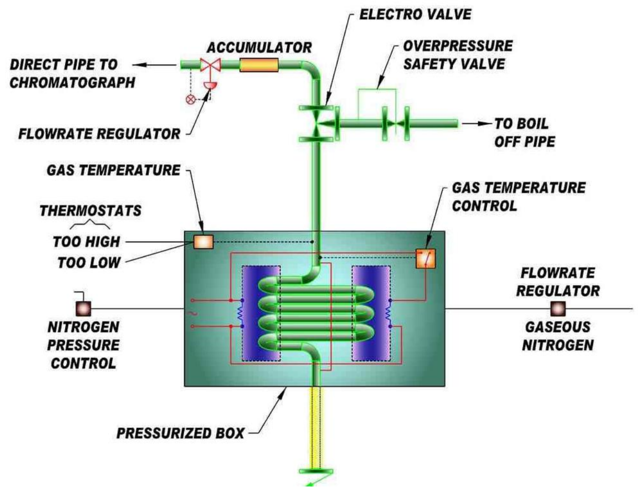
-
- *1. LNG VOLUME: COMBINE WITH LNG BTU PER UNIT VOLUME.*
- For example: $/US Gallon based upon BTU/Gallon: DEK purchased
- Chromatograph Sample for Energy Content then either:
- -Agree on the volume of the delivery vessel.
- -Use LIQUID custody meter (Coriolis, USM)

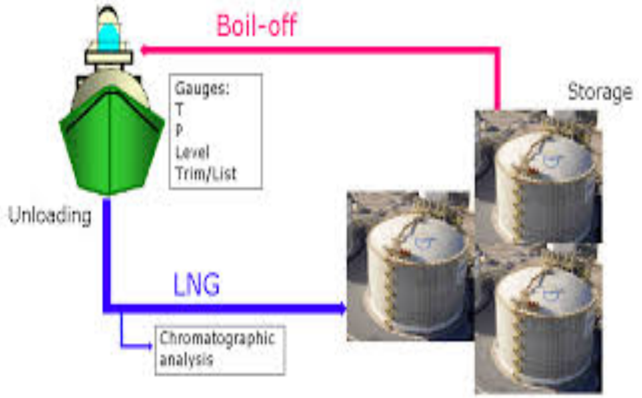
- *2.LNG WEIGHT: COMBINE WITH BTU PER UNIT WEIGHT*
- For example: $/pound based upon BTU/Pound: DEKS purchased.
- Chromatograph Sample for Energy Content then weigh the truck
- empty and weigh the truck full.

- The Key is to contractually Design all these ingredients ahead.

ESTABLISH LNG AND VAPOR CUSTODY TRANSFER METHODOLOGY, VOLUME, SAMPLING, CALCULATIONS CONTRACTUALLY AHEAD OF TIME.

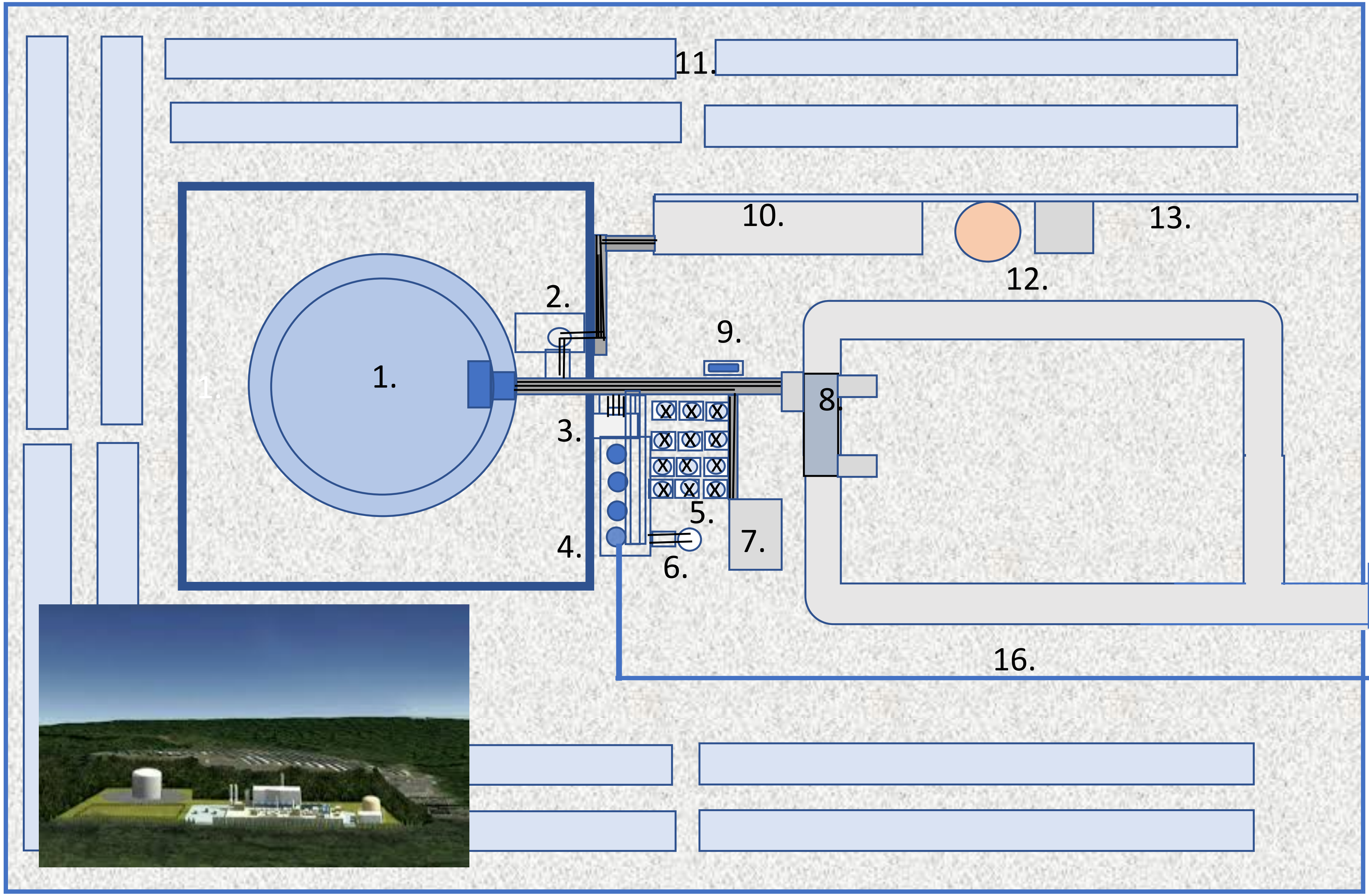






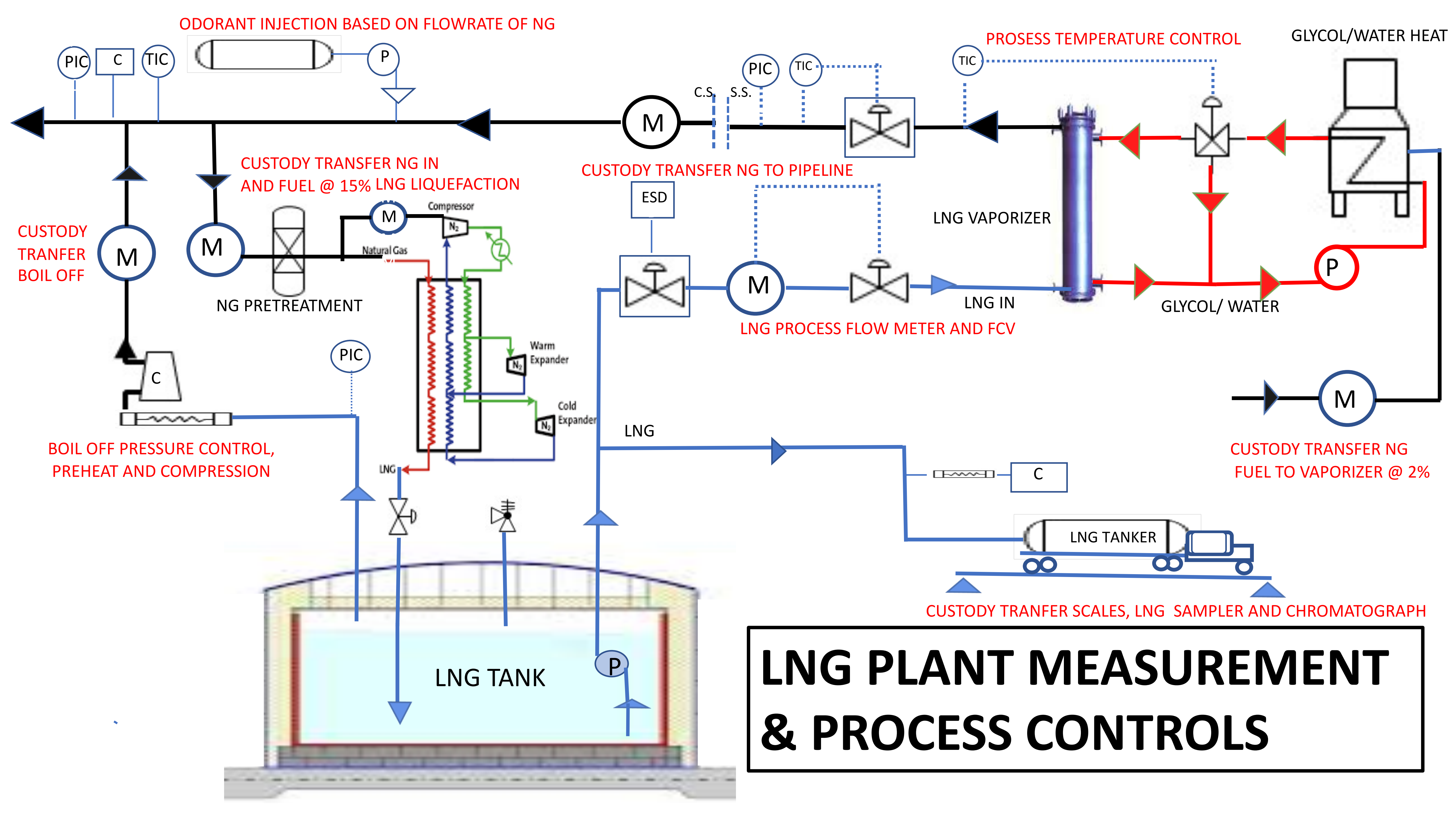
LNG FACILITY: PRE-TREATMENT, LIQUEFACTION, TRAILER LOADING, VAPORIZATION

15 ACRE FOOTPRINT WITH 100 ACRES EXCLUSION/BUFFER ZONES



LNG FACILITY EQUIPMENT LIST

1. LNG Storage Tank
2. LNG Heat Vaporizer and Sub-impound
3. LNG Cold Box and Expander Skids
4. LNG Pretreatment
5. LNG Refrigeration Cooling Fans
6. LN2 Storage Tank and Vaporizer
7. N2 Compressor
8. LNG Load, Scale, Sub-impound, Shelter
9. Odorant Storage and injection system
10. Control, Heaters, Electrical and Aux Bldg.
11. Solar Array
12. 12. Fire Prot. Water and Pump House
13. Site Water, Electric, Comm., Sewer
14. M&R Facility and EGM Building.
15. Security Gate
16. Natural Gas Supply Line



ODORANT INJECTION BASED ON FLOWRATE OF NG
PIC
C
TIC
P
C.S.
S.S.
PIC
TIC
M
TIC
PROSESS TEMPERATURE CONTROL
GLYCOL/WATER HEAT
CUSTODY TRANSFER NG IN
AND FUEL @ 15% LNG LIQUEFACTION
CUSTODY TRANSFER NG TO PIPELINE
ESD
CUSTODY
TRANFER
BOIL OFF
M
M
Compressor
N2
Natural Gas
NG PRETREATMENT
LNG VAPORIZER
M
LNG IN
GLYCOL/ WATER
P
LNG PROCESS FLOW METER AND FCV
PIC
Warm
Expander
C
Cold
Expander
LNG
M
BOIL OFF PRESSURE CONTROL,
PREHEAT AND COMPRESSION
LNG
C
CUSTODY TRANSFER NG
FUEL TO VAPORIZER @ 2%
LNG TANKER
CUSTODY TRANFER SCALES, LNG SAMPLER AND CHROMATOGRAPH
LNG TANK
P
LNG PLANT MEASUREMENT
& PROCESS CONTROLS

PROJECT DEVELOPMENT PROCESS DEFINED

- Establish business case and credit
- Perform Preliminary Engineering
- Site Selection and Options in Friendly Places
- Meet or Exceed Siting Requirements
- Execute Precedent Agreements
- Procure Equipment and Professional Services
- Seismic, Geotech, Fire Studies
- HAZID/HAZOP
- Complete Engineering Design
- Adjudicate Permits and Approvals
- Prefabricate Components/Buildings
- Conduct Field Construction,
- NDT Testing
- Commissioning, Training, Documentation
- Commercial Operations

49 CFR Part 193 and NFPA-59A SITING CONSIDERATIONS

- THERMAL RADIATION ZONE
- VAPOR DISPERSION ZONE
- FULL SEISMIC INVESTIGATION LIMIT
- 100 YEAR FLOODING
- SOIL CONDITIONS
- DESIGN WIND SPEED
- OTHER SEVERE WEATHER
- ADJACENT ACTIVITIES TO THE SITE
- PROPERTY LINES AND EQUIPMENT SEPARATION
- PROXIMITY TO AIRPORTS
- LOCAL SITE ZONING

PRACTICAL SITING CONSIDERATIONS

- MEET OR EXCEED SITING REQUIREMENTS
- OVER SIZER SITE TO LIMIT EXCLUSION ON SITE
- SITE FACILITIES IN COMMUNITIES THAT SUPPORT

THERMAL EXCLUSION ZONES:

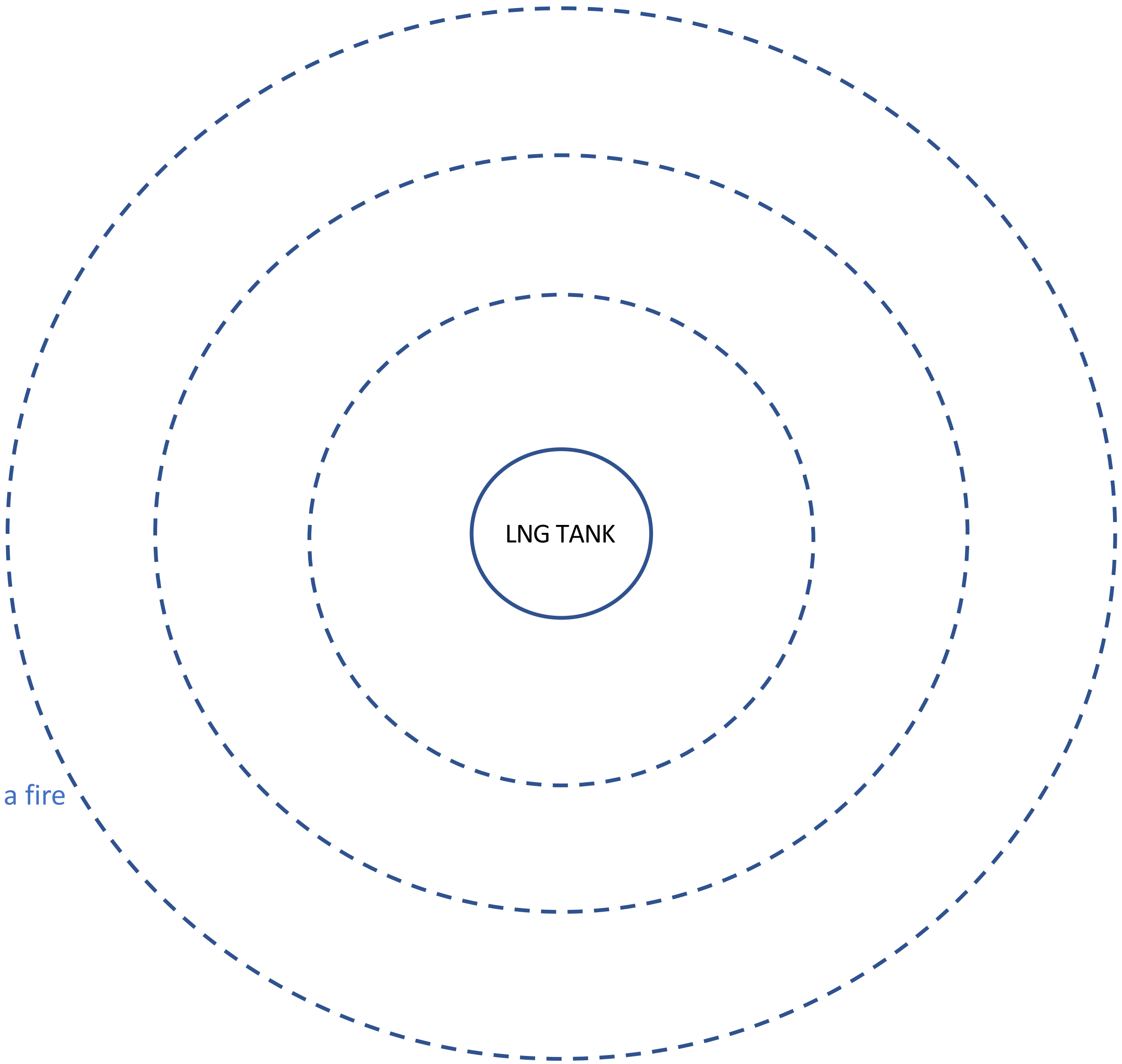
The Following are Defined:

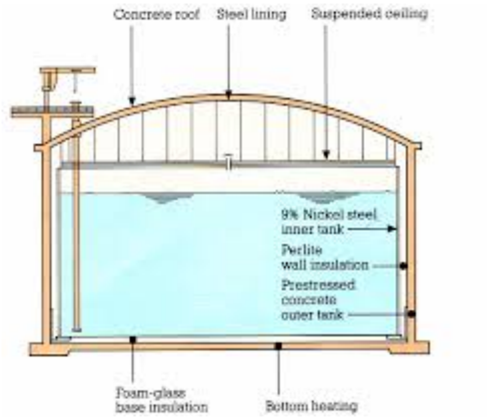
1,600 Btu/hr.ft2
At a property line that can be built upon for ignition of a process design spill.

1,600 Btu/hr.ft2:
At the nearest point located outside the owner's property line that, IS used for outdoor assembly by groups of 50 or more persons

3,000 Btu/hr.ft2:
at the nearest point of the building or structure outside the owner's property line used for occupancies

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

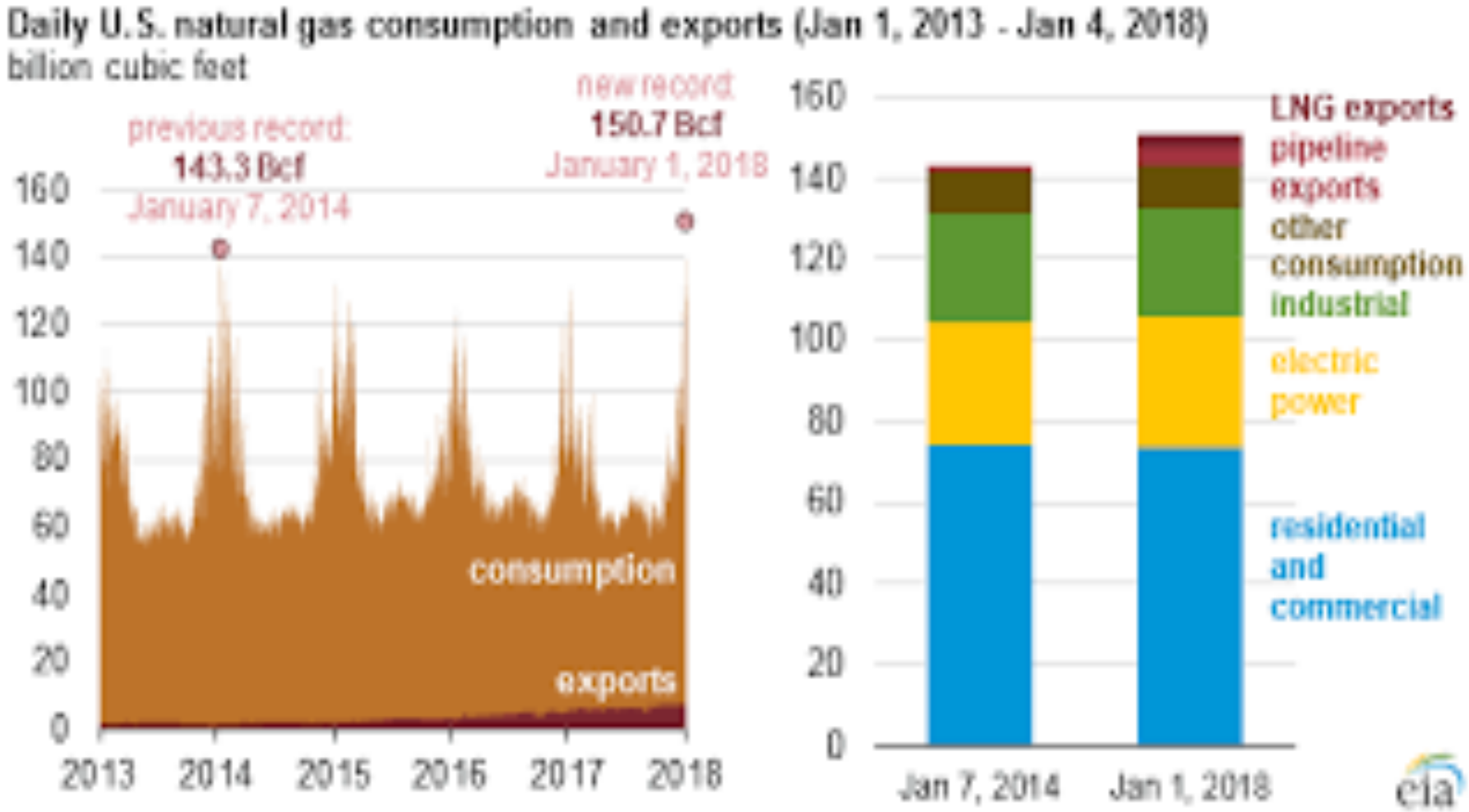


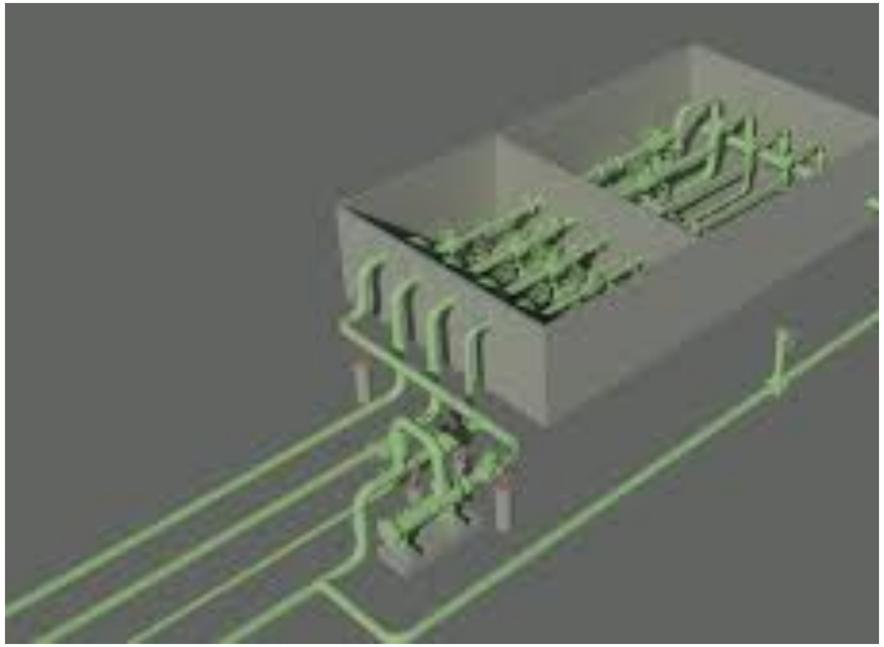


VAPOR DISPERSION PROTECTION

The regulations instruct that provisions need to be made to minimize the possibility of a flammable mixture of vapors from a design spill, from reaching a property line that can be built upon that would result in a distinct hazard.

For LNG tanks with no bottom penetrations, the design spill for calculating vapor dispersion is a 10-minute spill. Even at 100,000 dekatherms per day of flow, that is less than a 10,000 USG spill. Very manageable.


Daily U.S. natural gas consumption and exports (Jan 1, 2013 - Jan 4, 2018)
billion cubic feet
previous record:
143.3 Bcf
January 7, 2014
new record:
150.7 Bcf
January 1, 2018
160
140
120
100
80
60
40
20
0
consumption
exports
2013
2014
2015
2016
2017
2018
Jan 7, 2014
Jan 1, 2018
LNG exports
pipeline exports
other consumption
industrial
electric power
residential and commercial
eia



AMERICAN SCHOOL OF GAS MEASUREMENT TECHNOLOGY

Historical and Present-Day Natural Gas, Gas Storage and LNG in US.

Overview of Design of 21st Century M&R Facilities in US

Agenda

1. History and Supply Chain of natural gas pipelines, Underground Storage and LNG facilities in US
2. Ideal Project Cycle from Concept to Commercial Operations
3. The Ideal P&ID: Safe Reliable and Cost Effective
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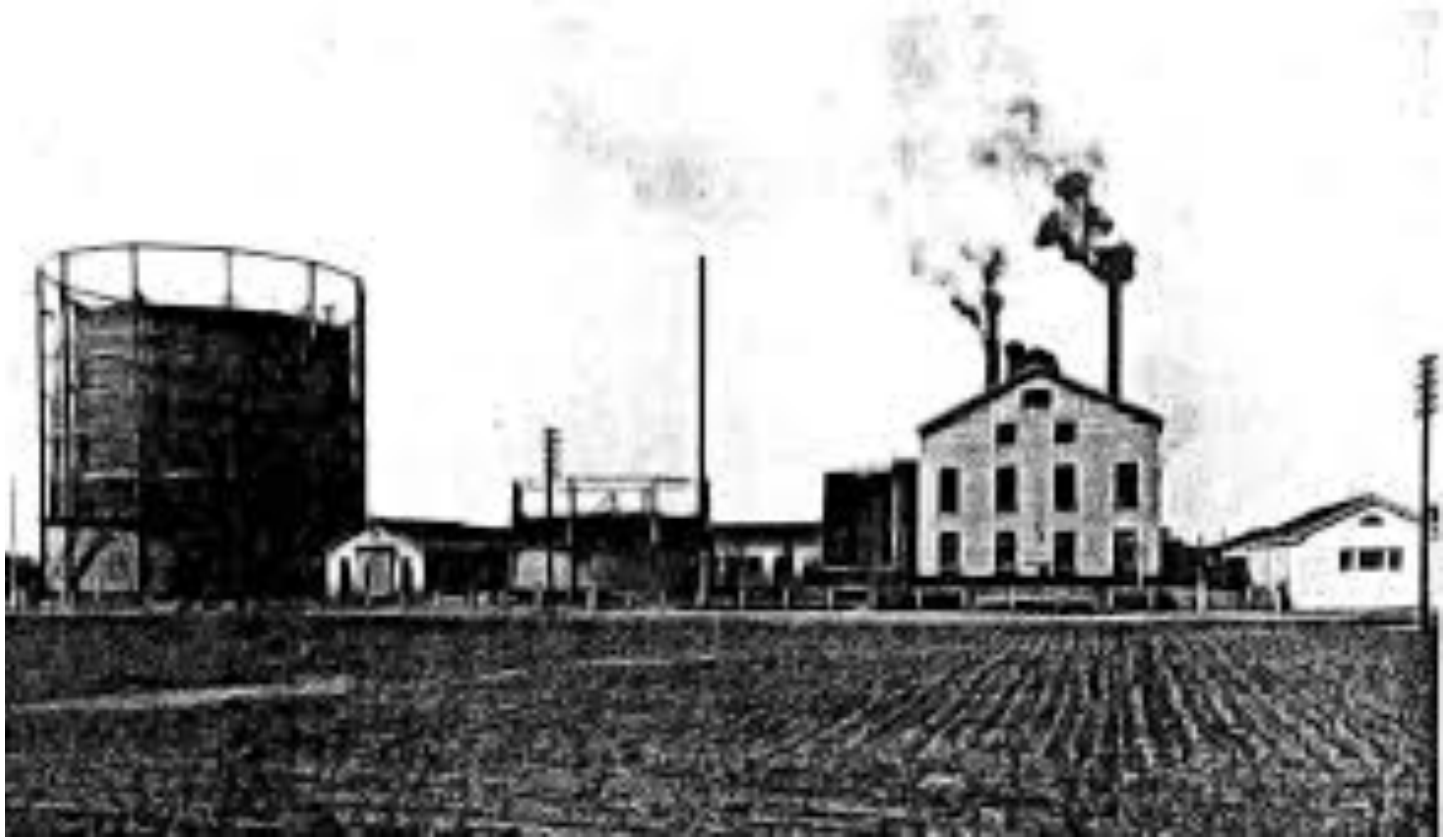
US HISTORICAL OVERVIEW:

NATURAL GAS, UNDERGROUND STORAGE AND LNG DEVELOPMENT



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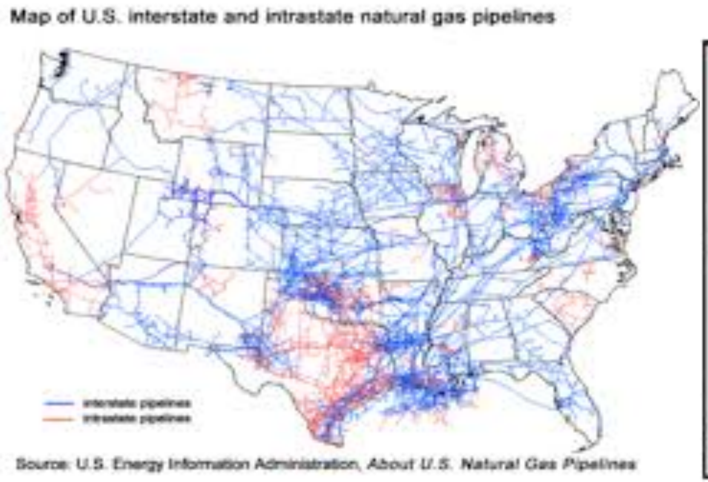
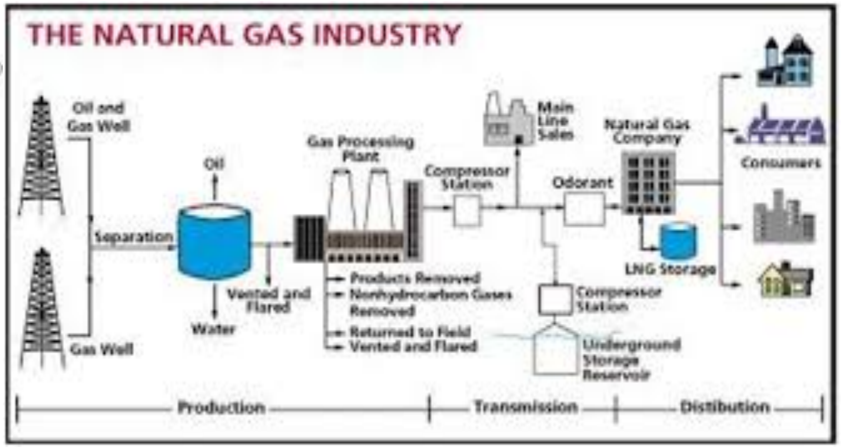
- **49 CFR 192: Minimum Safety Standards for Gas Distribution and Transmission established as Federal law in 1970.**
- **49CFR 193: Minimum Federal Safety Standards for LNG Established as Federal Law in 1978.**
- **FERC Order 636 Unbundling and Open Access in 1992.**
- **2005 Energy Policy Act.**
- **2014 Export Terminals begin receiving approvals**

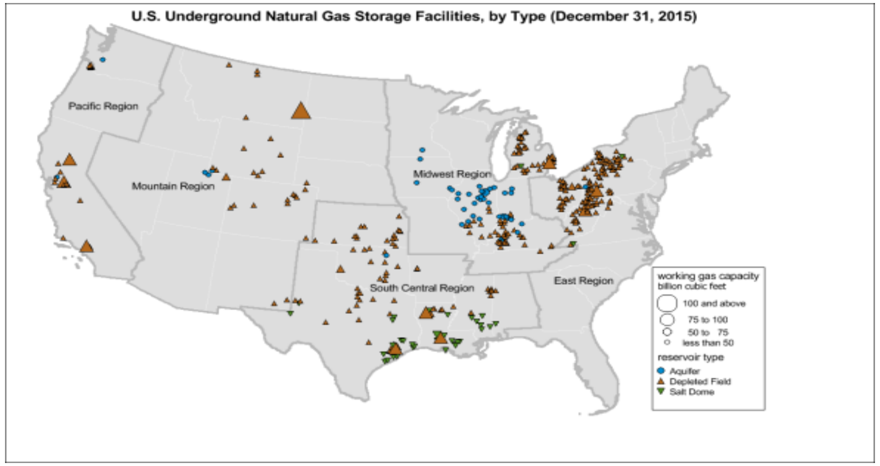
US PIPELINES, UNDERGROUND GAS STORAGE AND LNG FACILITIES

Interstate Pipelines in Red 250,000 Miles
Intrastate in Blue 2.25 MM Miles

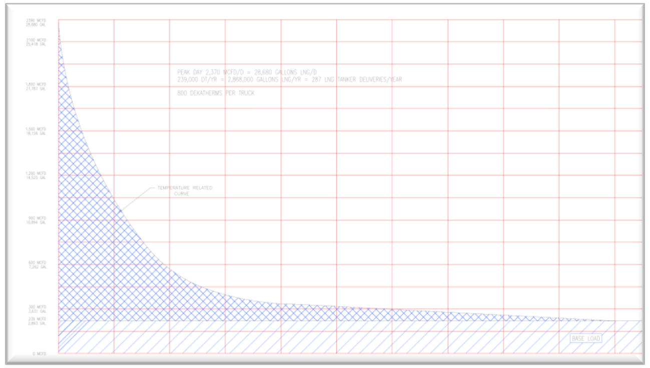
400 Natural Gas Storage Fields in US with 30 TCF Storage







100 LNG plants in US 100 BCF



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3. Daily Production is 80 BCF/D
4. The record daily consumption was 150 BCF/D
5. US Consumes Approximately 40 Quads/Year as Oil and half of it is imported.
6. Ironically oil is about twice the cost of NG yet we import 20 Quads/Year.
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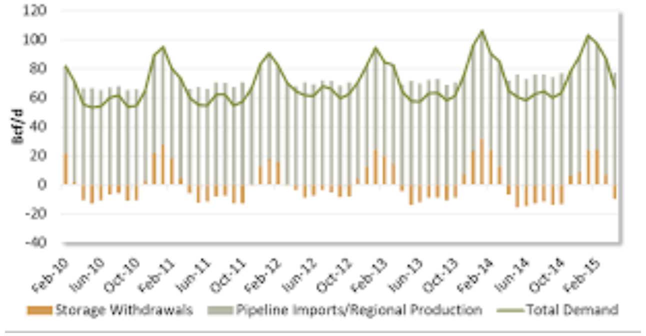
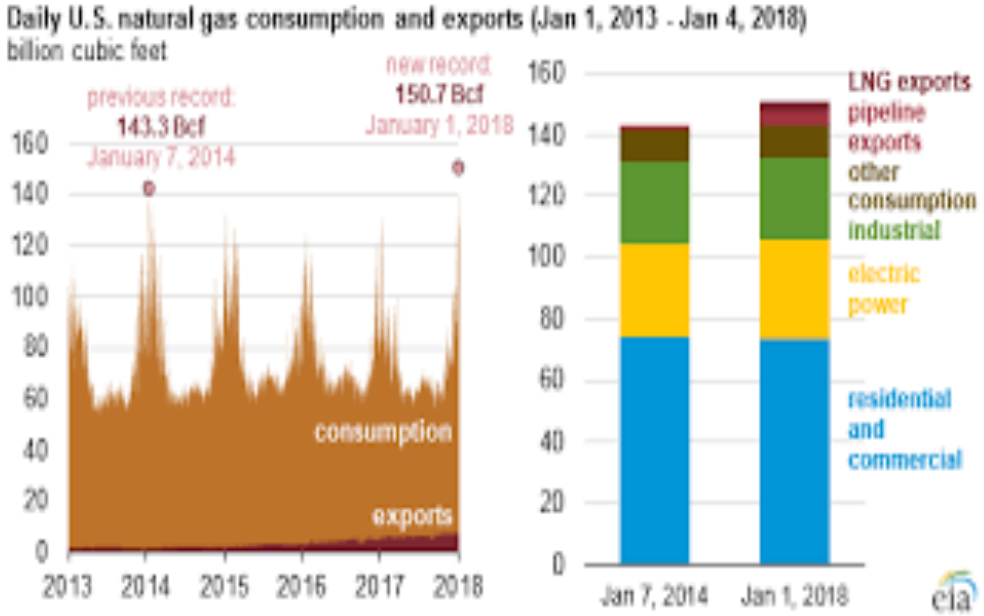
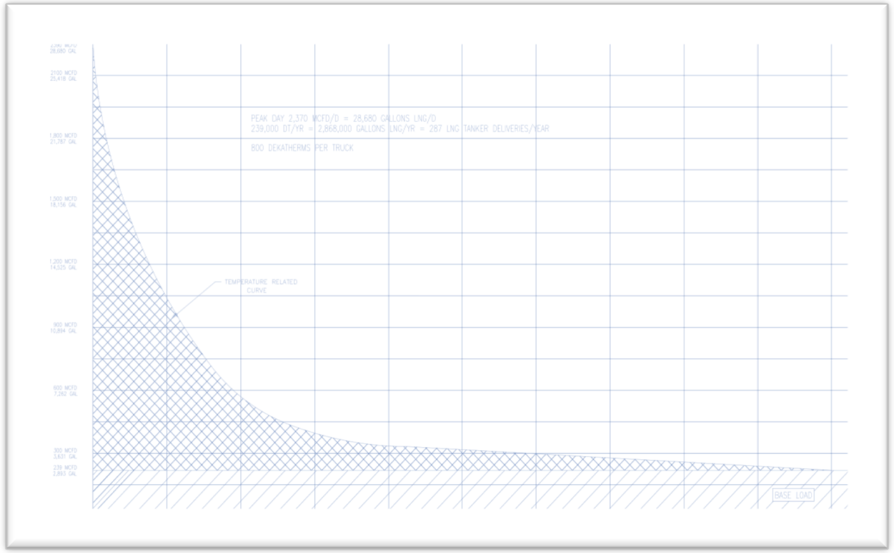
11. Approximately 400 gas storage fields in US.
12. Gas costs per MMBTU: approximately $2.60/dekatherm or MMBTU
13. In approximate numbers oil/gas/coal/renewables are converging.
14. **The Next New thing is LNG Source sites for Domestic use and export.**



US PEAK NG DEMAND 150 BCFD
Production is at 80 BCFD





DEFINE THE PROJECT CYCLE FROM CONCEPTUAL TO COMMERCIAL OPERATIONS

EVERY SUCCESSFUL PROJECT BEGINS WITH FOUNDATION DOCUMENTS

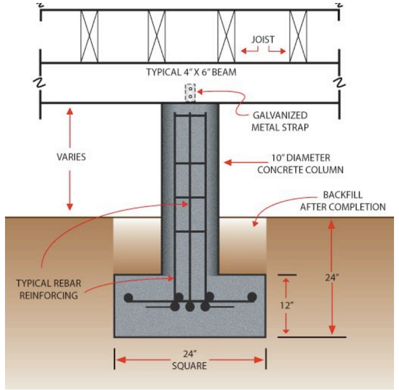
DESIRED FEATURES OF M&R FACILITIES

Safe, Reliable, Cost Effectiveness

- Safe, Reliable, Cost Effective
- Solid business case.
- Performs to required design conditions.
- Ergonomic
- Appropriate Levels of Redundancy

PROJECT DEVELOPMENT PROCESS DEFINED

- Establish business case and credit
- Perform Preliminary Engineering
- Negotiate IA & Responsibility Matrix
- Procure Equipment and Services
- Complete Engineering Design
- Prefabricate Components/Buildings
- Adjudicate Permits and Approvals
- Conduct Field Construction,
- NDT Testing
- Commission, Train, Documentation
- Commercial Ops



PRELIMINARY ENGINEERING IS THE TECHNICAL FOUNDATIUON FOR A SUCCESSFUL PROJECT

- Codes/Standards/Authority Having Jurisdiction: Interstate or Intrastate
- Design Basis: Hydraulics, Mechanical, I&C, Electrical, Civil, Structural, SCADA, CP, AC Mit.
- Sizing and Calculations
- Responsibility Matrix
- Site Selection
- Material, Instrumentation, Buildings and Equipment Selection and Specifications
- Approval Process Defined
- Cost and Schedule
- Drawings Needed in Early Phase 1:
  - -P&ID's
  - -Site Layouts
  - -Hazardous Area Plan
  - -Electrical One-Line
  - -I/O List
  - - SCADA/Communications Drawing

Determine First the Authority having Jurisdiction.

Are the facilities interstate, intrastate or a mixture of both between the Pipeline and the End User?

Some Examples Below of Typical Codes and Standards

- US DOT 49 CFR Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards,
- Many States have there own natural gas distribution and transmission safety codes.
- IBC International Building Code
- NFPA 70, NEC, National Electrical Code
- ASTM A53, Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
- API 5L, American Petroleum Institute - Specification for Line Pipe
- API 6D, American Petroleum Institute - Specification for Pipeline Valves
- API-6FA:, American Petroleum Institute - Specification for Fire Rated Pipeline Valves
- API 1104, American Petroleum Institute - Welding of Pipelines and Related Facilities
- AGA-XF-0277, American Gas Association - Recommended Practices Classification Gas Utility Areas Electrical Installations
- ASME-B31.8 Gas Transmission and Distribution Piping Systems
- Gas Measurement - Part 8, American Gas Association - Electronic Flow Computers and Transducers
- AGA-9, Measurement of Gas by Multipath Ultrasonic Meters : Meter type Dependent

INERCONNECT AGREEMENT PURPOSE

- The Interconnect Agreement (IA) Defines which party provides Ownership, Engineering, Construction, Operations and Maintenance.

- The Party Requesting the interconnecting generally pays for all pipeline costs and their own costs: So the IA also provides schedule and the reimbursement cost amount that the pipeline will be prepaid.

- The Requesting Party generally concedes that the pipeline party’s codes and standards apply

- The Requesting Party concedes that the counter party gets O&M of custody transfer measurement and FCV.

- Most pipelines recognize that ownership of assets is not required. End user can own the metering building and equipment and get benefits from that ownership such as depreciation and avoided tax gross-up

INTERCONNECT AGREEMENT DEFINES HOW WE JOIN TOGETHER FROM

It Defines who Provides Ownership, Engineering, Construction, Operation and Maintenance for the Following Items

- Hot tap Site
- Site Utilities
- Site Work
- Access Roads
- Permits and Easements
- Metering and FCV
- Pre-heating and Regulation
- Electronic Gas measurement.

CUSTODY TRANSFER CONCEPTS

When we transfer custody of Natural Gas, we are concerned with establishing a common standard to define volume of flowing gas and the energy content for each SCF of the flowing gas.

Ideal Gas Law (Compressible fluid) : PV = nRT: Pressure, volume, amount of gas, gas constant and temperature. Originally empirically derived. (Super-compressibility and gas composition are factors as natural gas is not an ideal gas)

Standard Cubic Foot (SCF) : In order to transfer custody of gas, we convert the gas to an agreed standard pressure and temperature such as 60 degrees Fahrenheit and 14.73 pounds atmospheric temperature for billing. **(Should be defined in IA. RTU load consistent)**

BTU (British Thermal Unit): Amount of heat required to raise the temperature of one pound of water by one Fahrenheit Degree.

Therm: 100,000 BTU's

Dekatherm (from Greek number ten, DEKA): Ten Therms or 1,000,000 BTU's

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, 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 two different ways HHV, LHV: (The scale to be used, should be defined in IA. RTU load consistent.)

HHV:

The quantity known as higher heating value does not subtract loss of energy when water vapor is formed in combustion and that the heat of vaporization of water consumes some of the heat .

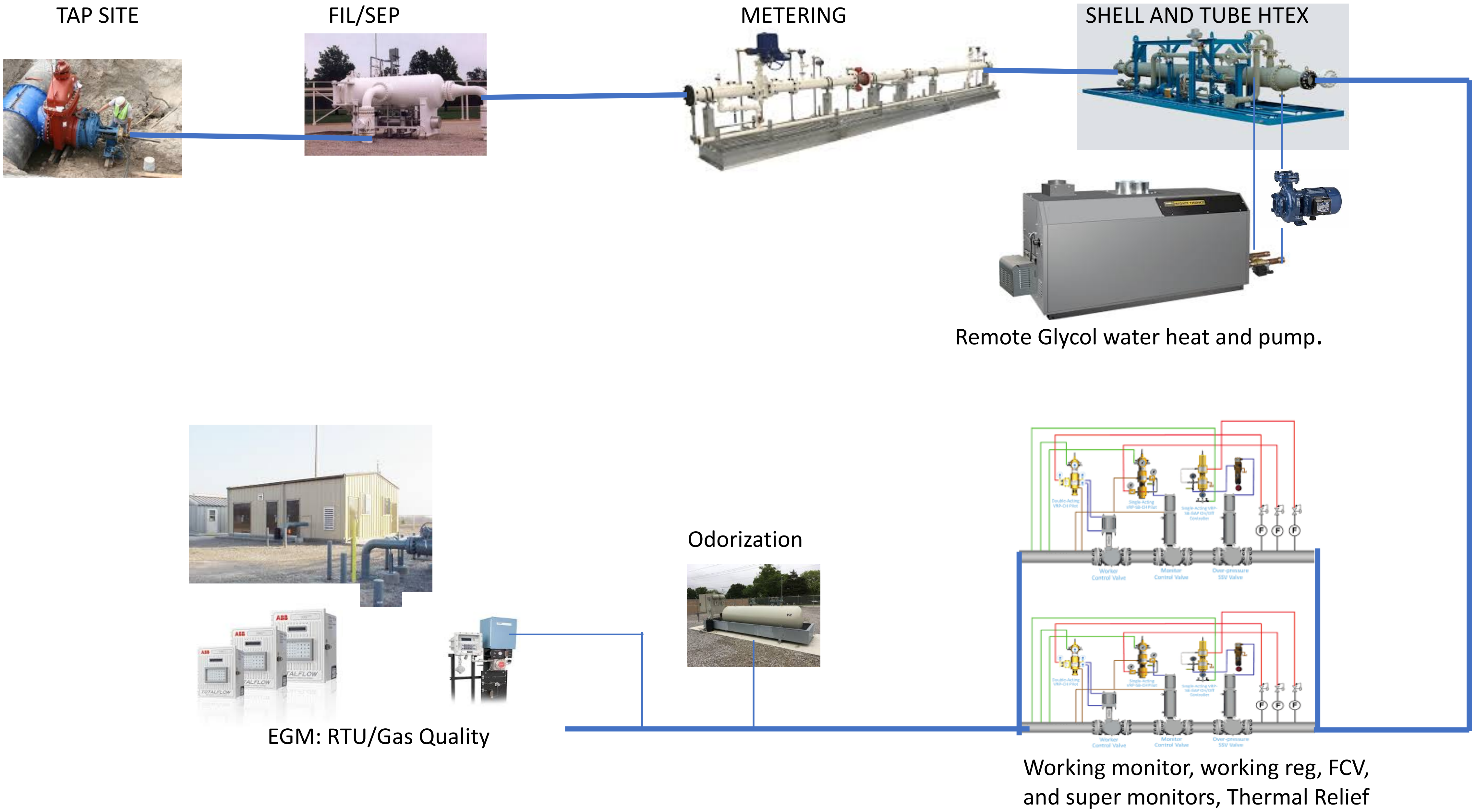
LHV:

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.

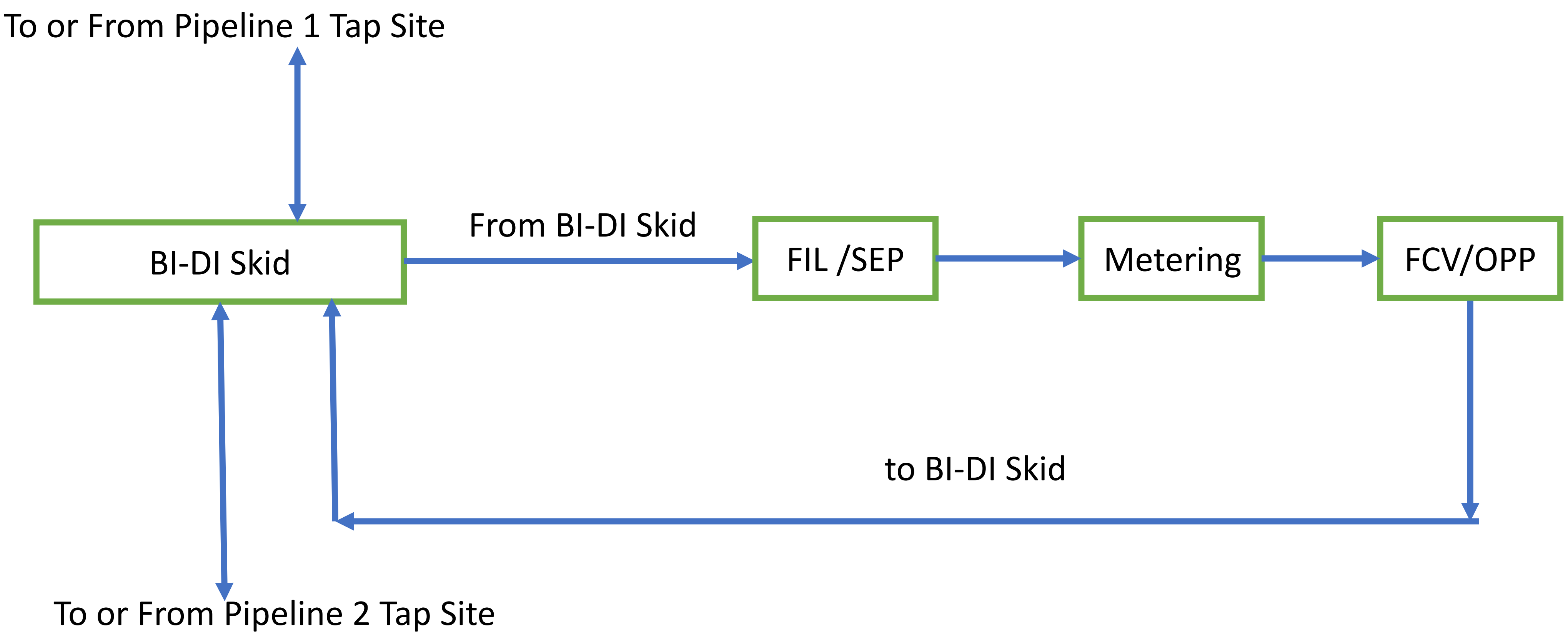
WHAT IS THE IDEAL P&ID FOR
UNI- DIRECTRIONAL AND BI DIRECTION M&R?

SAFE, CODE COMPLIANT, RELIABLE, AND COST EFFECTIVE
CONCEPT OF SINGLE INCIDENT PROTECTION

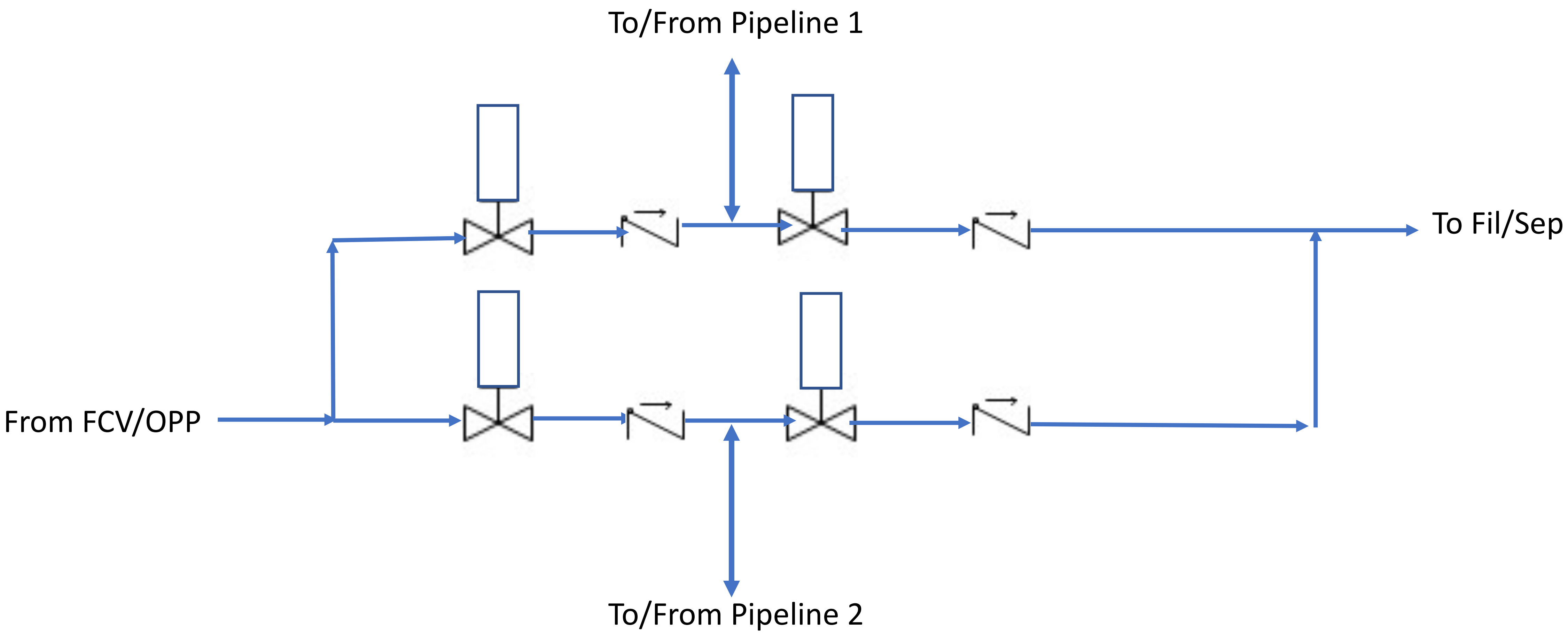
PRIMARY COMPONENTS OF M&R SYSTEMS



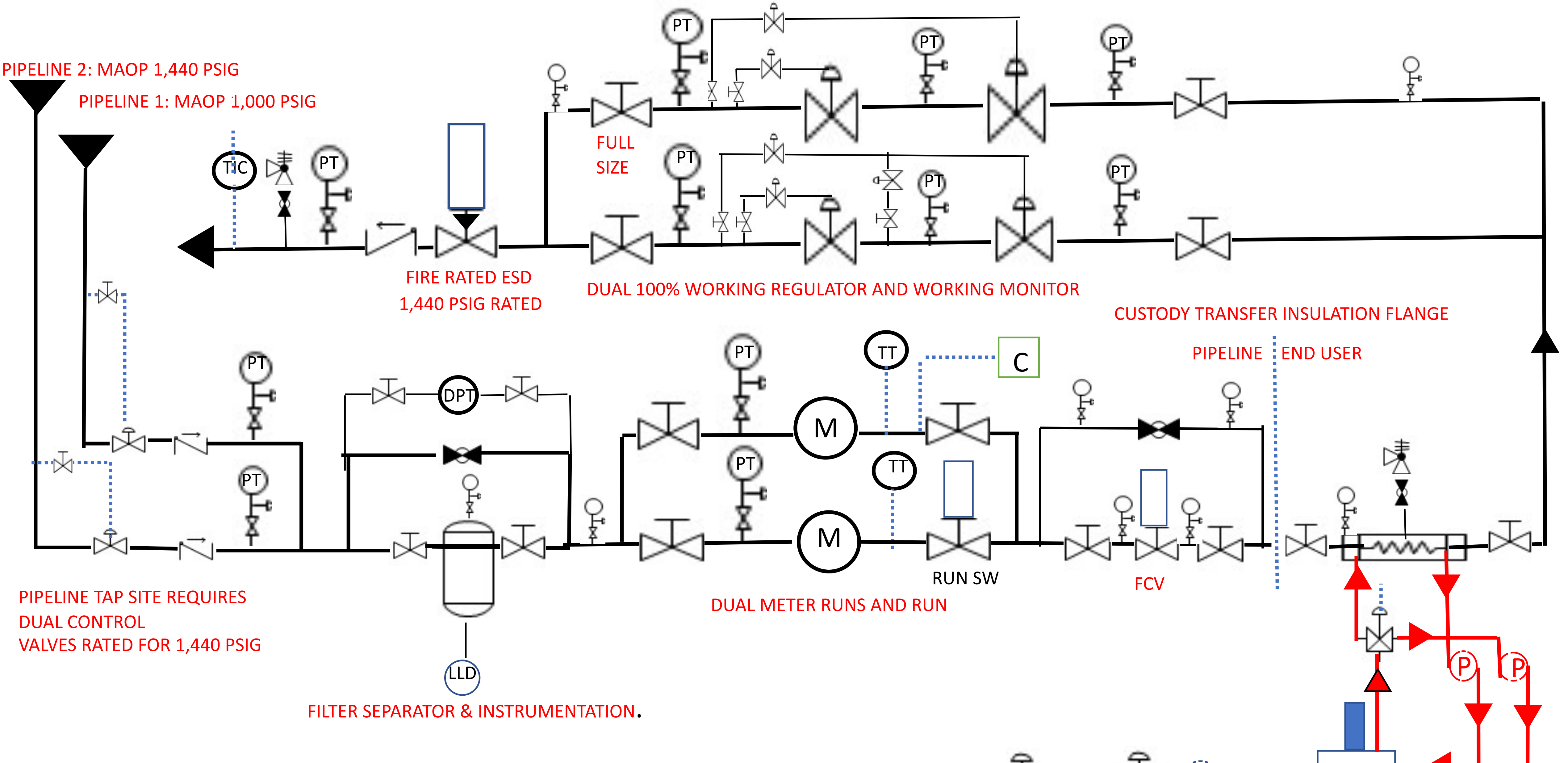
BI-DIRECTIONAL GULF STYLE FIL/SEP, METERING, FCV/OPP



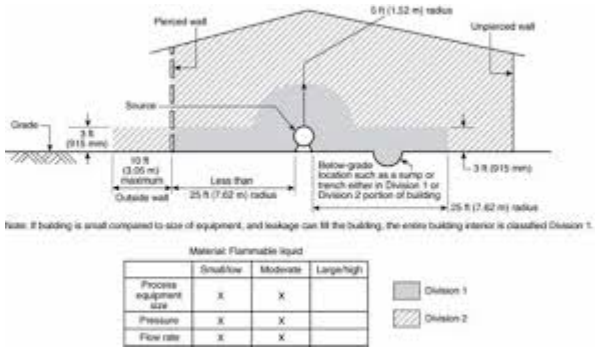
BI-DIRECTIONAL SKID SCHEMATIC

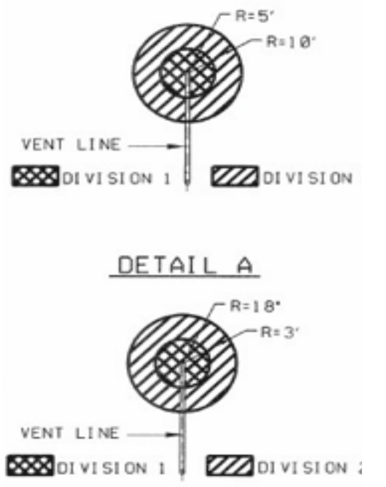


THE IDEAL P&ID



ELECTRICAL HAZARDOUS AREA CLASSIFICATIONS



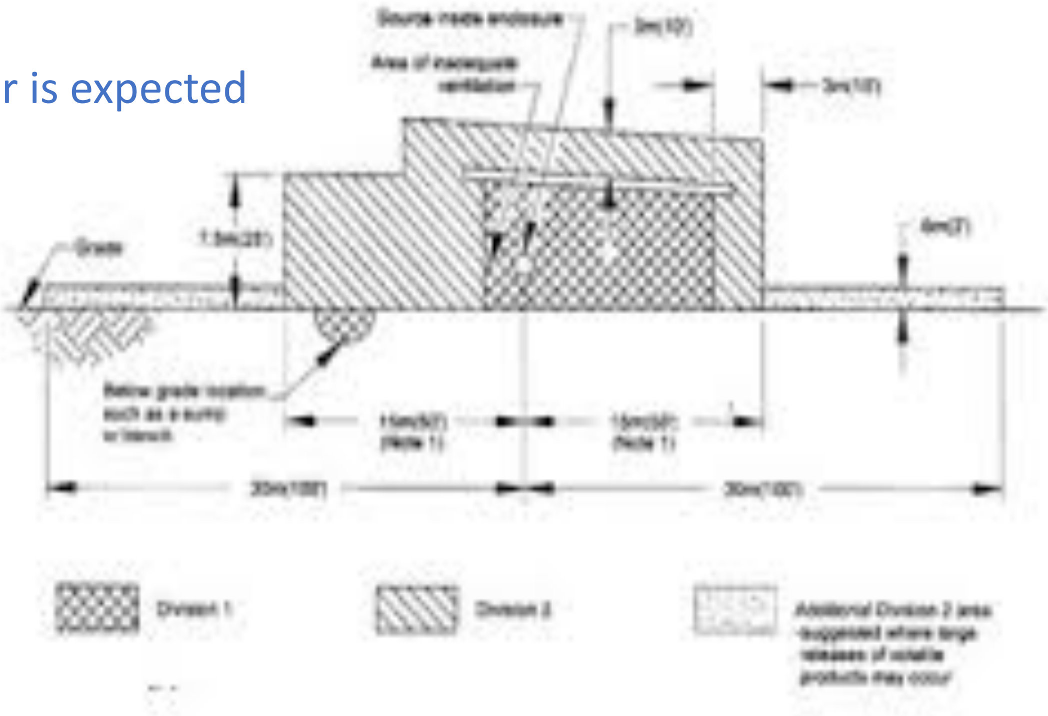


Class I, Division I, Group D:

When natural gas vapor and air flammable mixture is routinely expected.

Class I, Division II, Group D:

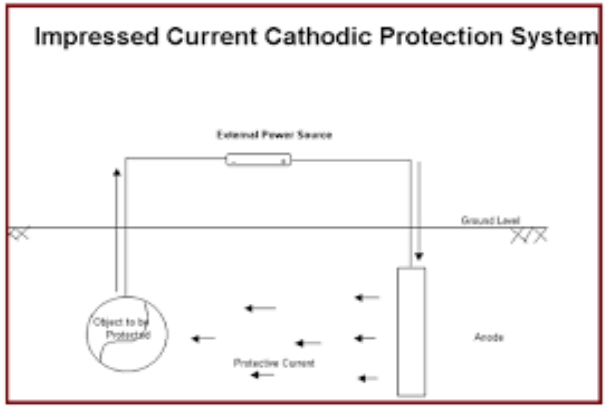
When a flammable mixture of natural gas vapor is expected during upset condition.



Non-Hazardous General Purpose:

When a Flammable Mixture is not Expected.

AC MITIGATION, SURGE PROTECTION AND CATHODIC PROTECTION
PROTECTING FACILITIES AND PEOPLE



Corrosion occurs when the iron in unprotected carbon steel pipe has a free electron space available for oxygen for Ferrous Oxide. An Impressed current CP system puts DC current and electrons on the pipe and iron and inhibits corrosion formation.

AC Surge Protection

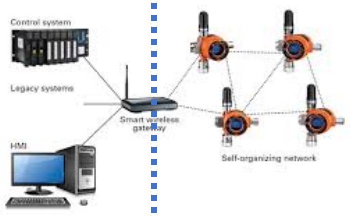
AC Current can be induced on gas facilities. Capacitive devices and grounding create short circuit to ground for AC while preventing the DC CP from leaving the pipe.

SCADA

- DEVELOP CONTROLS PHILOSOPHY
- DEVELOP P&ID
- DEVELOP I/O LIST
- DEVELOP SYSTEM ARCHITECTURE
  - Select Equipment
  - Determine HMI
  - Select Communication Link

LOCAL RTU 1

LOCAL RTU-2



Hardware/software
Distributed Versus Local
SCADA
Communications
Field Devices
Local HMI
Remote HMI

CONCLUSION

This natural gas industry is a great business that we've chosen.

The US needs stable pricing and reliable energy supply supply
for our security and growth.

The implementation of a successful project depends upon a capable team performing preliminary engineering, design, procurement, installation, training, and documentation. Deregulation has added new pipeline interconnects, shortened the schedules, created the need for new types of facilities and created market based projects.

The successful players in this century will accomplish
their objectives in concert with customers and suppliers by sharing facilities, sharing information, finding win-win situations and ....

UNDERSTANDING OUR ROLES IN THE MARKETPLACE