

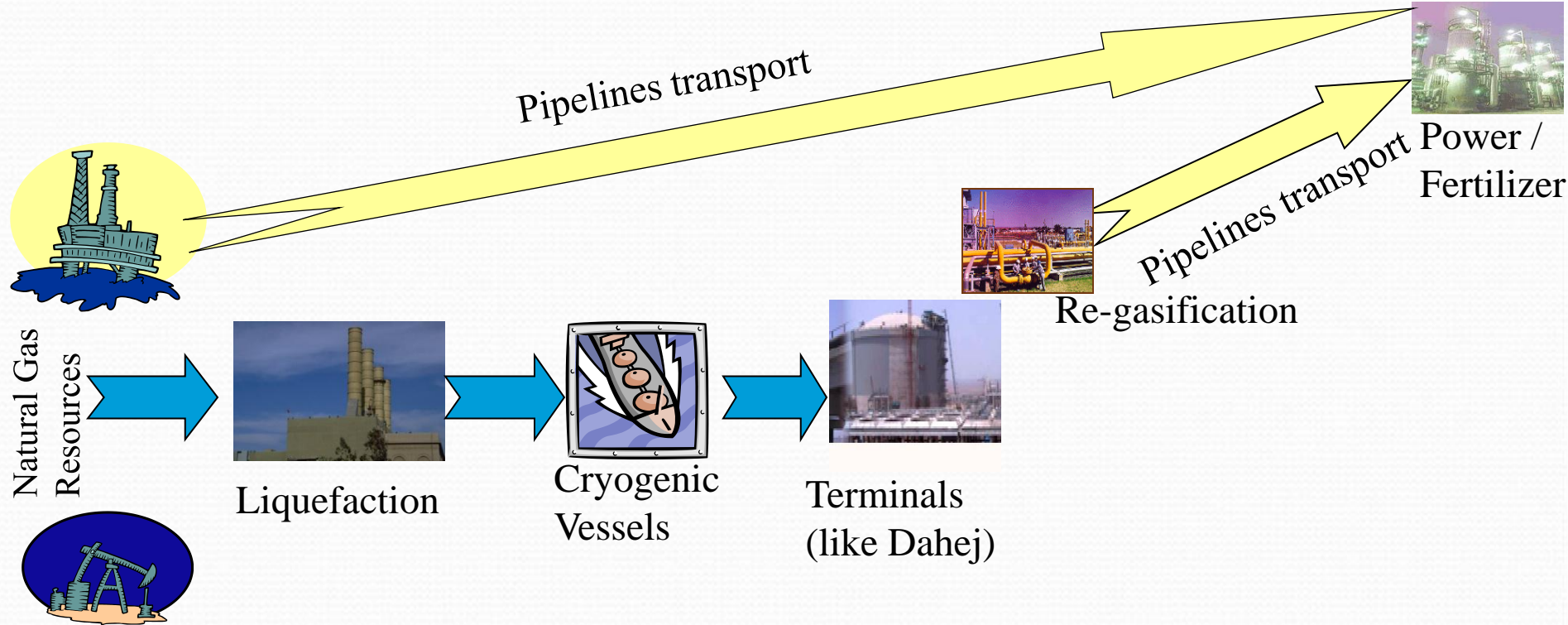
Design, Operation & Safety Aspects of LNG Road Transportation and LNG satellite stations

J P Misra
Chief Manager (LNG)
E Mail – misrajp@indianoil.in

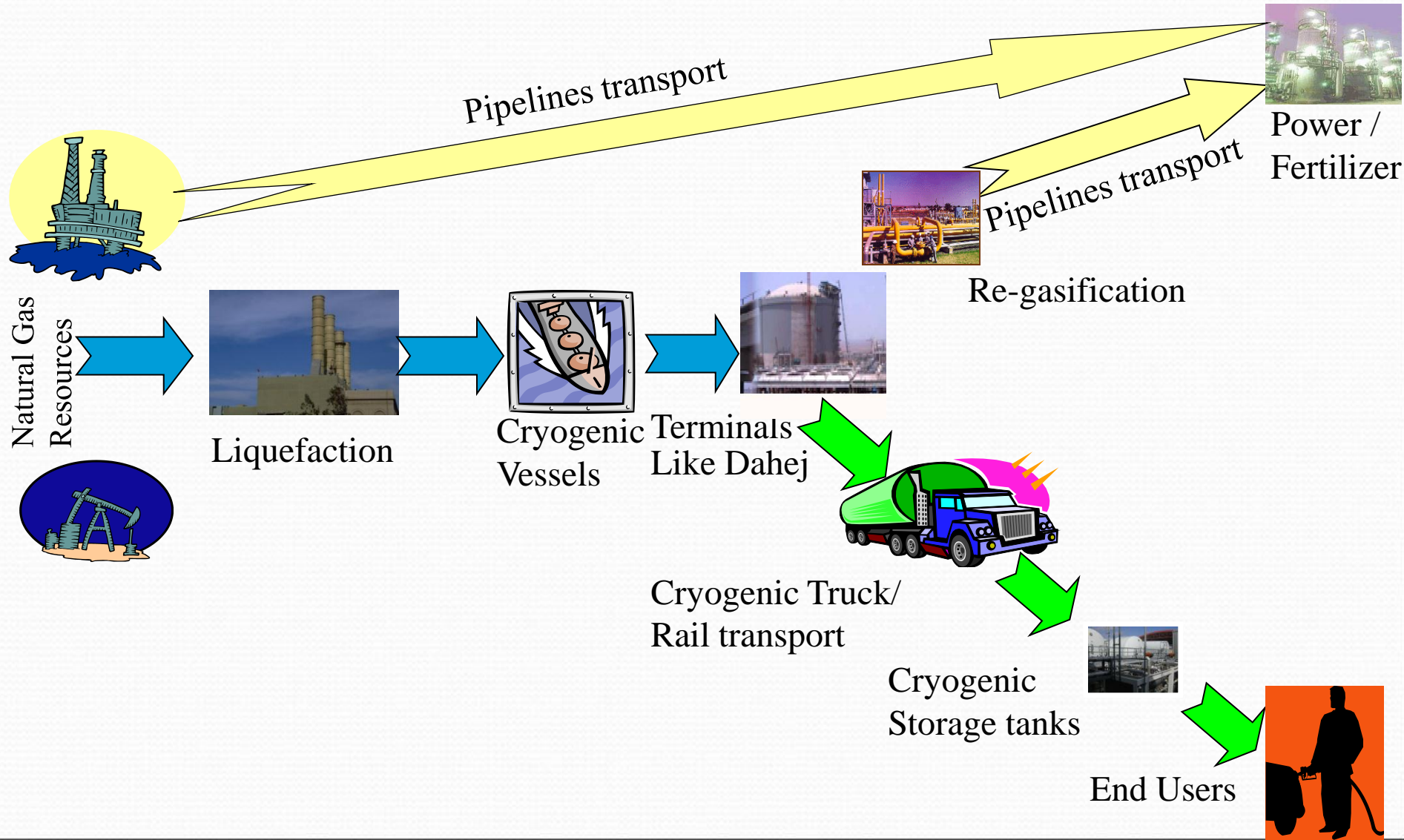
LNG at Doorstep System

- The Natural gas is conventionally supplied to various consumers through Pipelines.
- For the first time in India, Indian Oil has ventured into the supply of Natural gas in liquefied form using cryogenic movement of LNG to the customers, who are away from NG pipelines.
- Customer store LNG in Cryogenic Storage tank at their premises and on-site re gasification done there using ambient air vaporizers for Natural Gas supply to the end use equipment.

Concept predominantly in use



LNG At Doorstep concept



LNG at Doorstep : Benefits to consumer



- Attractive Savings / Economic benefits.
- Better combustion.
- Environmentally friendly clean fuel.
- Gas supply even without pipeline network.
- Site Gas storage possible.
- Better product quality.
- No fuel preparation / External heating needed.
- Cold heat recovery possible etc.
- Better Plant safety.

LNG At Doorstep - Benefits

- Locational Flexibility, LNG can be gainfully supplied upto 3000 Kms away without loss of BOG.
- Natural Gas in its purest form to the consumer.
- Low investment – Tailor made.
- Elimination of pilferage & adulteration.
- Avoids huge investment in pipeline network across cities & difficult terrains.

Safer energy solution for remote cities

Tanker on loading bay at PLL





Tanker loading facilities at PLL, Dahej



**LNG Storage & Regasification facility at
M/s H &R Johnson Ltd**



**LNG Storage & Regasification facility at
M/s Hindustan National Glass Ltd., Nasik**



**LNG Storage & Regasification facility at
M/s Rajashree Polyfill**

Business Components

- Following are the main components for the LNG at Doorstep business –
 - 1) LNG tanker loading facility.
 - 2) Cryogenic LNG road tankers.
 - 3) LNG Storage & re-gasification facility at customer location generally called LNG Satellite station.

LNG Cryogenic tanker

- 1) LNG is having a temperature of minus 162 Deg C .
- 2) To store this cryogenic liquid without the aid of any refrigeration needs a vessel having almost nil heat transfer from atmosphere so that the liquid can be stored for many days without any BOG loss.
- 3) This is possible if all the three modes of heat transfers i.e – Conduction, convection and radiation are reduced to the minimum possible levels.

Insulation in LNG tanker

- Cryogenic Containers are like thermos flasks. Double walled pressure vessel.
- To reduce the convective heat loss the annular space is evacuated to a vacuum level of 1×10^{-3} mbar or better levels.
- The radiative heat loss is reduced by using multiple radiation shields in the form of aluminum foils with separators. The Storage vessels are generally filled with perlite.
- The Conduction losses are nullified by using special insulative material which mechanically support the inner vessel into the outer vessel without any conduction.
- By doing the above super insulation the heat transfer from outside to the inner vessel is minimized, but practically per day BOG generation is in the range of 0.3 % for 40 KL tanker for LNG. The BOG generation in 100 KL storage tank is approximately 0.1% of

Salient Design features

- The cryogenic tanker or storage tanks are manufactured as per international standards like ISO 20421 / CGA 341 etc. In India the vessels should comply the PESO regulations of Static & Mobile Pressure vessel (Unfired) rules (SMPV) 1981.
- The Inner pressure vessel can be designed as per international pressure vessel codes like ASME Sec- VIII Div-1, EN 13530, EN 13458 etc.
- The inner pressure vessel is generally made of Austenitic Stainless steel grade 304. 9% Nickel steel is also used. Outer vessel which is just a vacuum jacket therefore is made of carbon steel.
- To contain the BOG inside the vessel, the inner vessel is generally designed for working pressure of 7 to 12 Bar depending on the mode of unloading method used at the satellite station.

Salient Design features

- The special design of the support system is such that the expansion and contraction of the inner vessel is taken care off in the operating range of -197 to +50 Deg C.
- The transport tanker vessel and insulation support should be designed for minimum vertical down of 2G, Vertical up for 1.5 G, Lateral and longitudinal 1.5 G combined loading conditions.
- The net volumes of the vessel is designed in such a way that the vessel should not get liquid full at maximum saturation pressure. The usable water capacity should be minimum 95% of the gross water capacity. Ullage space is kept minimum 5%.

LNG Cryogenic tanker

- Inner vessel is designed for Internal pressure and the outer vessel is designed for minimum collapsible pressure of 29 PSI absolute.
- All the weld joints are radio graphed and Mass spectrometer leak detection (MSLD) is carried out thoroughly.

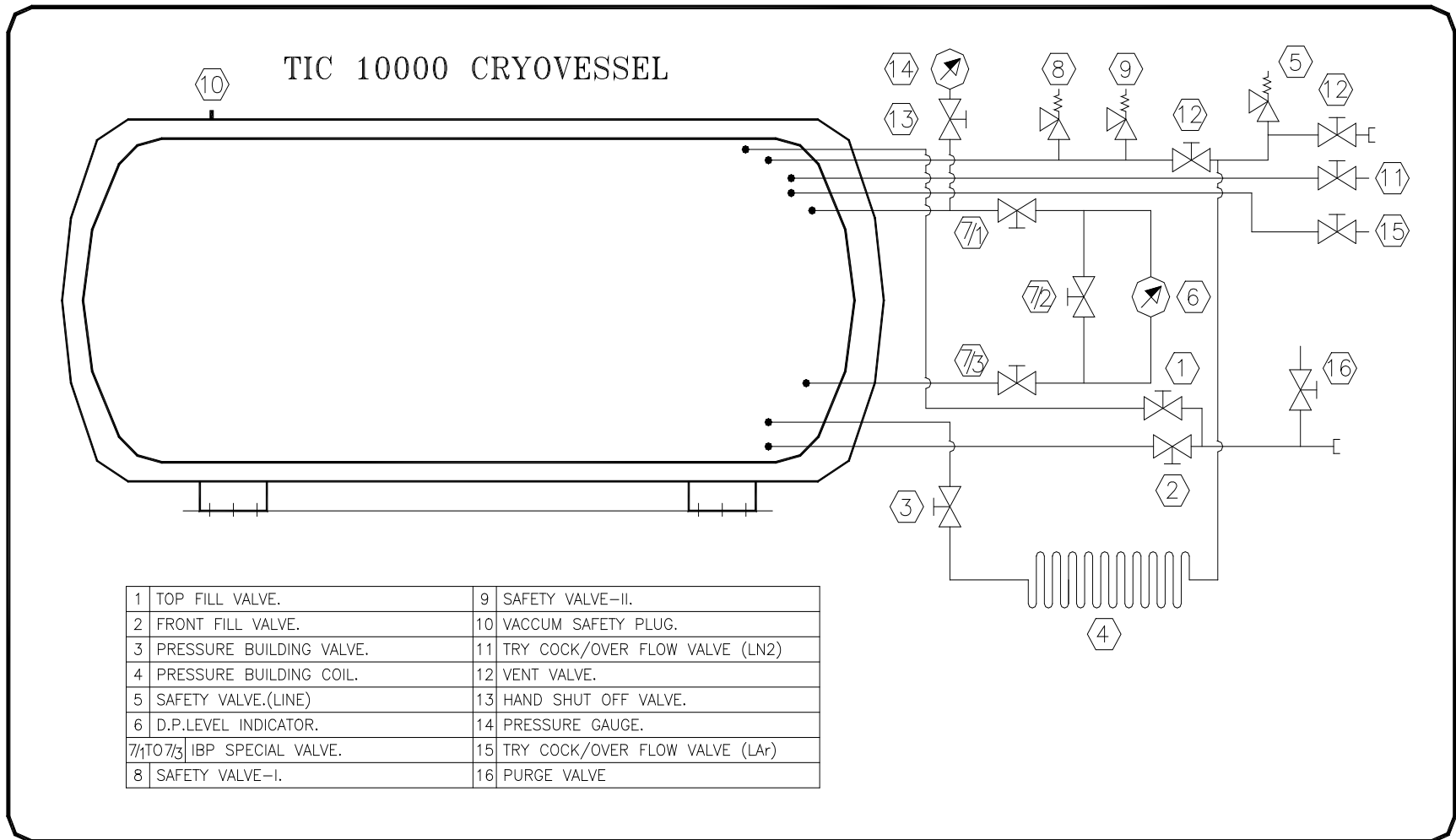
Safety Features in LNG tankers.

- Inner vessel is provided with minimum two safety valves connected at any point of time as per regulations. Therefore four safety valves with flow diverter valve is given.
- The safety valves capacities are designed for the condition of simultaneous occurrence of vacuum loss and when the vessel is engulfed in the fire condition.
- Outer vessel is provided with pop-up relief disc.
- Every vessel is provided with one Pressure Gauge and Liquid level gauge.
- Anti Tow away system is provided to avoid accidental running away of the tanker during unloading operation.

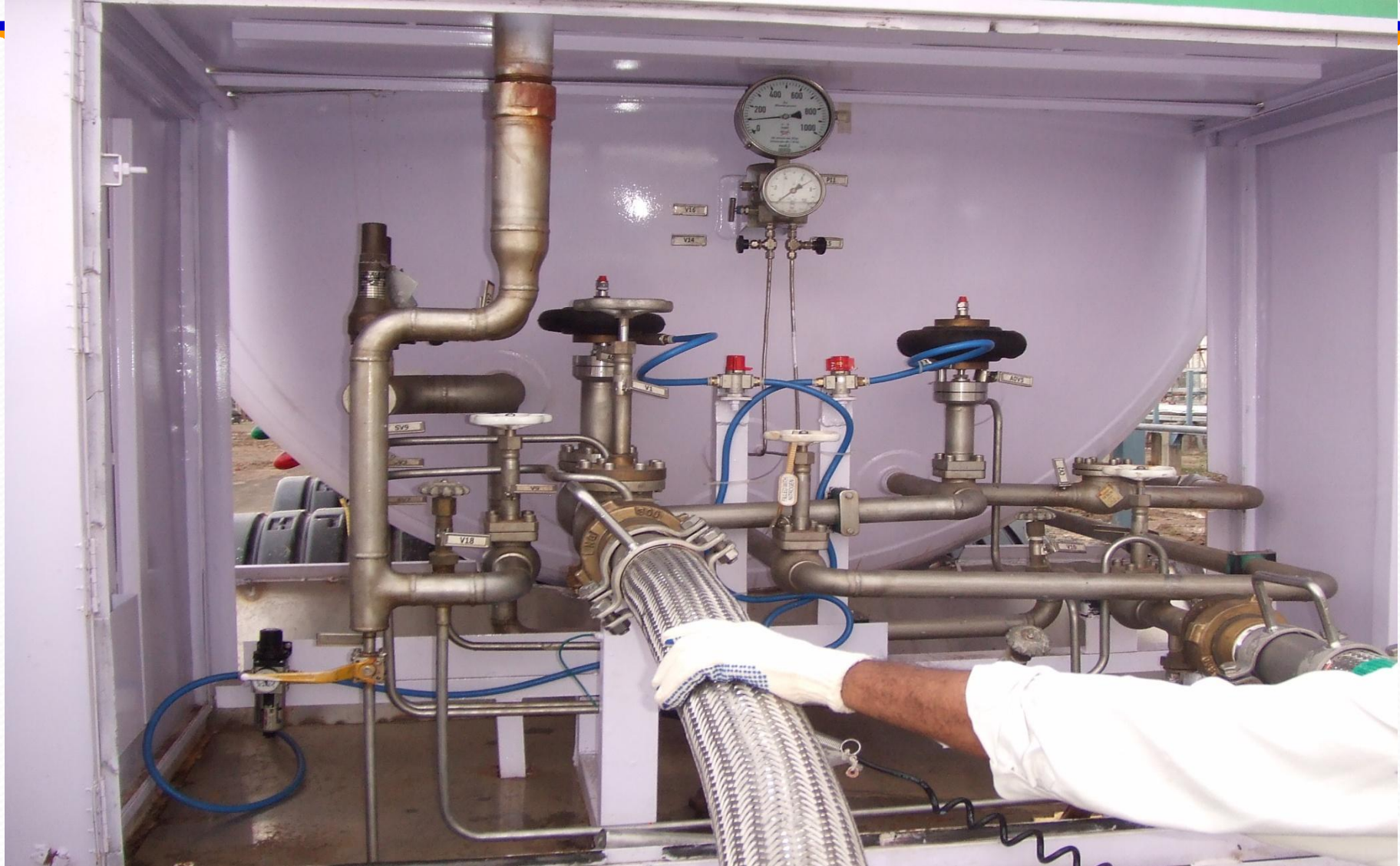
Safety Features in LNG tankers.

- Dual isolation valves provided. One manual and one fail safe air operated valves for Liquid fill and withdrawal lines.
- Emergency remote shut off valve provided.
- Speed monitoring of each vehicle with GPS.
- Build – in grounding mechanism in every tanker.
- Thermal relief valves on every lines where liquid may be trapped.
- Height Guard provided.

Typical Cryogenic Transport Vessel

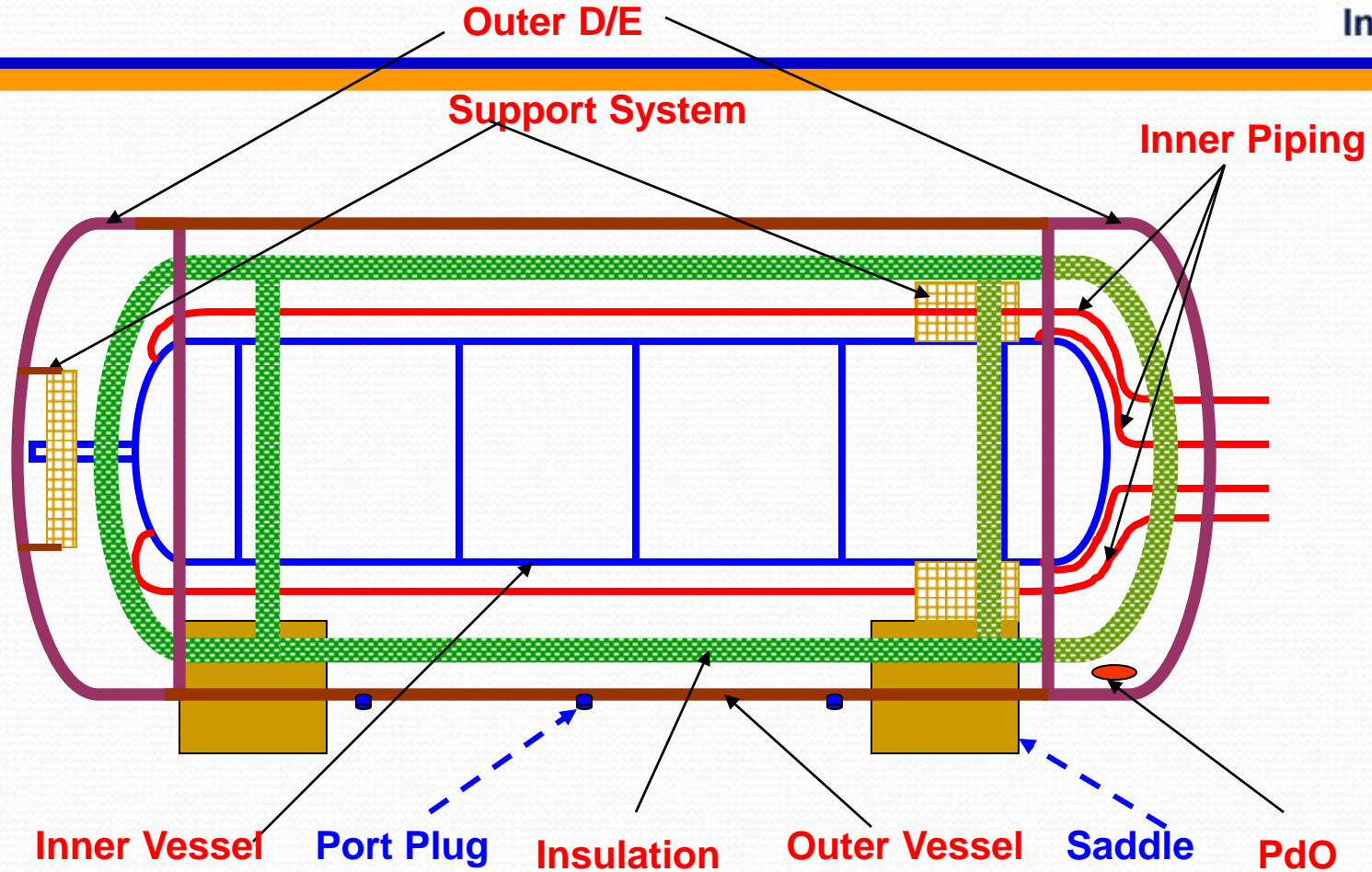


Control Valve Cabinet view





IndianOil



Cross Sectional View of the Cryogenic Tanker

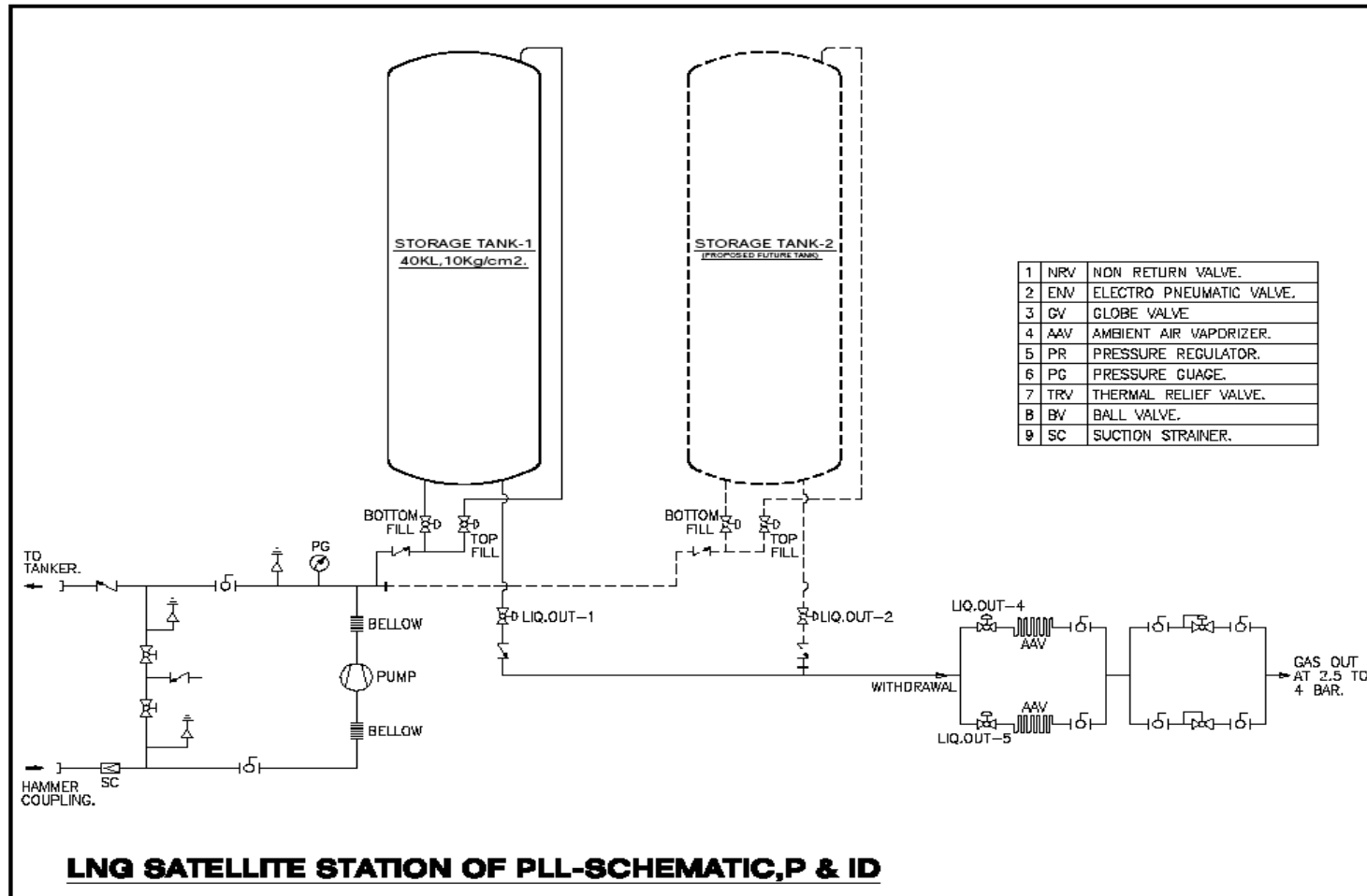
Operation & Safety Requirements for LNG Satellite Station



The Configuration

- In LNG satellite station following are the main components –
- LNG Storage tank
- LNG Unloading pump
- 2 Nos. - Ambient Air vaporizers
- Pressure Regulation skid.
- PLC Based control panel.
- Controls and other instrumentation.
- Fire Hydrant system
- Methane detectors and Flame detectors.
- Emergency shut down system.
- Dike, Fencing, Road etc.

Simplified Schematic-LNG re gasification system



General Requirements

- At present in India the LNG satellite station is designed as per the regulations of SMPV rules. A new draft rules are made but still to be gusseted. Otherwise internationally accepted NFPA 59 A standard is followed.
- Generally the requirements of SMPV to be complied almost same as any LPG installation.

General Requirements ...

- The safety distance required for LNG storage is follows –
Above 10 KL to 20 KL capacity : 10 M
Above 20 KL to 40 KL capacity : 20 M
Above 40 KL to 350 KL capacity : 30 M
- All the satellite station components like unloading pumps, vaporizers etc are installed inside the dyke area specially made to contain the liquid incase of any spillage.
- The unloading of LNG is possible by two methods. By pressure transfer and by Using unloading pump. Loading pump is generally preferred for logistic and gas loss point of view.

- The station is fully automatic, generally kept unmanned.
- All the safety features similar to any Gas installation is to be installed like Gas detectors, Flame detectors, ESD etc.
- Fire Hydrant as per CCE guidelines should be in place.

Training & Emergency response

- Regular training on 'LNG handling & emergency response' imparted to all the personnel involved in the LNG supply chain:
 - Drivers
 - Transport Supervisors
 - Customers' Operators
 - IOC Personnel involved
- Only well experienced and trained drivers deployed
- En-route IOC LPG bottling plant personnel are involved in emergency response
- On-site and Off-site Emergency Response Plans (ERP) and ERP for LNG transportation are in place

LNG Transportation is Safe – Incident History



1. June 1971 Waterbury, VT Capitol

- **Blowout, hit rocks by road, tore hole in tank, 20% spilled, no fire, remainder dumped. Single wall tanker?**

2. August 1971 Warner, NH Gas, Inc.

- **Driver fatigue, drove off road, rollover cracked fittings, small gas leak, no fire.**

3. October 1971 N. Whitehall, WI Indianhead

- **Head-on collision with truck. Gasoline and tire fire, no cargo lost.**

4. October 1973 Raynham, MA Andrews & Pierce

- **Truck side swiped parked car; brakes locked and trailer overturned. No cargo onboard, no fire.**

LNG Road Tanker Incidents

5. 1973 Rt. 80 & 95 JCT, NJ Chemical Leaman

- **Driver couldn't negotiate turn off. Rollover demolished tractor and severe damage to trailer. No fire. \$40,000 damage to trailer.**

6. February 1974 New Jersey Turnpike Gas, Inc.

- **Faulty brakes caused wheel fire. Check valve cracked 5% leaked out. No fire.**

7. February 1974 McKee City, NJ Gas, Inc.

- **Loose valve leaked LNG during transfer operation.**

8. January 1976 Chattanooga, TN LP Transport

- **Rollover, no fire, caused by oil spill on exit ramp. Truck righted and continued delivery of cargo.**

LNG Road Tanker Incidents

9. November 1975 Dalton, GA LP Transport

- **Rollover, no fire. Driver swerved to avoid pedestrian, hit guardrail and rolled over and down an 80 foot bank. \$18,000 damage to trailer.**

10. September 1976 Pawtucket, RI Andrews & Pierce

- **Car hit trailer at landing wheels, rollover, no LNG loss or fire.**

11. April 1977 Connecticut Turnpike Chemical Leaman

- **Truck parked (with blowout) hit by a tow truck in rear. No leak or fire.**

12. July 1977 Waterbury, CT LP Transport

- **“Single Wall” Lubbock hit in rear by tractor-trailer, axle knocked off. Rollover. No loss of cargo.**

LNG Road Tanker Incidents

13. December 1977 I5 & I10, Los Angeles Western Gillet /SDG

- **Rollover with little product loss, no vacuum loss, no fire.**

14. February 1981 Barnagat, NJ LP Transport

- **Driver failed to negotiate turn due to excessive speed on country road. Driver not hurt seriously. Loss of some product through relief valve resulted in serious damage to transport.**

15. September 1981 Lexington, MA Andrews & Pierce

- **Rollover, no fire, no product loss (empty), driver not seriously hurt. Extensive damage to transport. Cause: rain and poor road conditions.**

16. October, 1993 Everett, MA TransGas

- **Trailer slide off third wheel just before entering highway. No fire, no product loss.**

LNG Road Tanker Incidents

17. May 1994 Revere, MA TransGas

- **Trailer over turned when trying to negotiate a traffic circle at too high of speed. No product loss, no fire. Trailer emptied into second trailer without incident.**

18. October 1998 Woburn, Ma TransGas

- **Trailer traveling at high speed is sideswiped by car then careens into guardrail ripping open diesel fuel tanks. Ensuing diesel fuel fire traps driver in cab where he perishes. Fire engulfs LNG trailer until extinguished. No loss of product experienced. LNG partially transferred to second trailer. Trailer then up righted and sent to transport yard to complete the transfer of product.**

19. September 2003 Woburn, Ma TransGas

- **Trailer traveling too fast on a highway exit ramp overturned. There was no leakage of cargo from the overturned truck. The truck driver was slightly injured and received a speeding citation**

LNG Road Tanker Incidents

20. June 22, 2002 Tivissa, Catalonia, Spain

- An LNG road tanker overturned and caught fire on the C-44 road and subsequently (about 20 minutes later) suffered a boiling liquid expanding vapor explosion (BLEVE), the first such LNG-related incident reported.**
- However, the design of the trailer involved was very different. It was simply a pressure vessel insulated with unprotected polyurethane insulation, whereas cryogenic trailers are double-walled, vacuum-jacketed pressure vessels. When the trailer overturned the insulation was readily scraped off the pressure vessel and directly exposed to the fire, the typical scenario required for a BLEVE.**
- It is unclear what actually caused the leakage of LNG, but new trailers in addition to having the outer tank protection also have recessed protected piping further reducing the potential for leakage due to overturning.**
- In spite of the severe nature of the incident there was no report of**

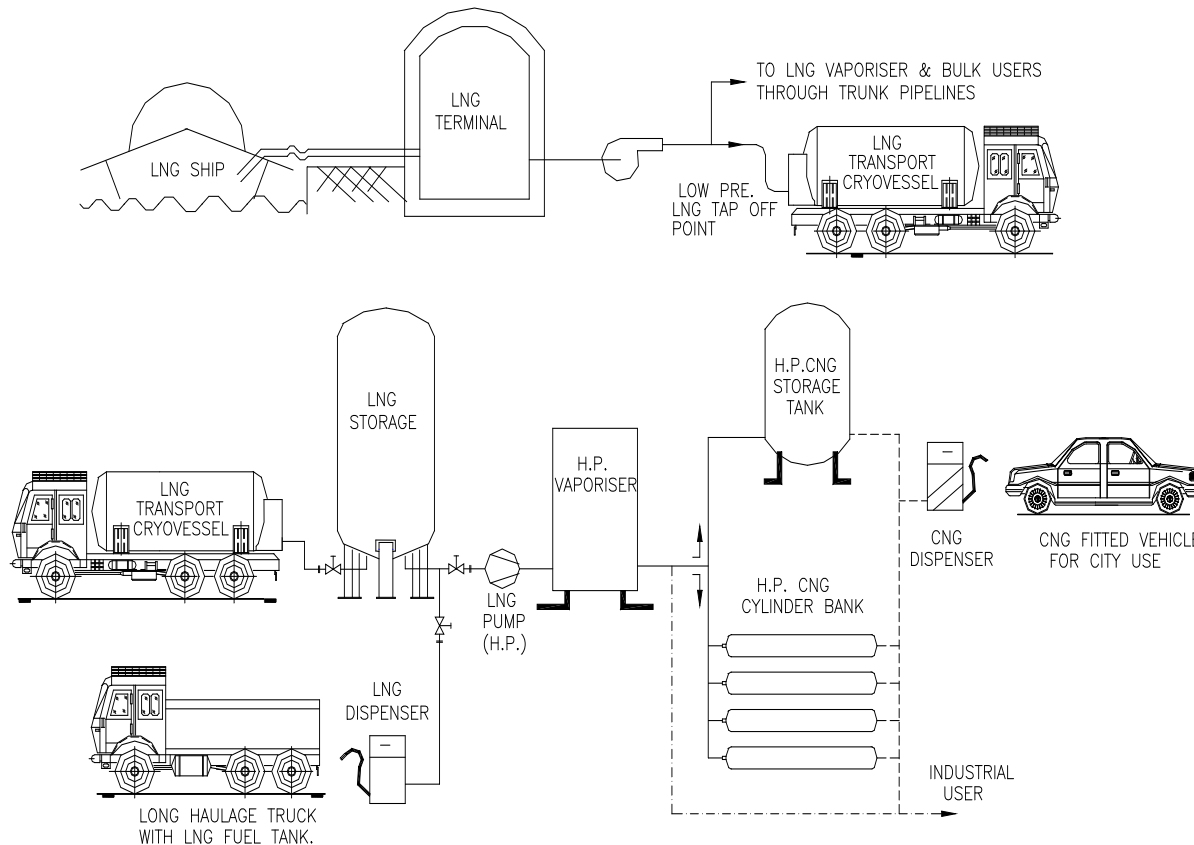
LNG Road Tanker Incidents

21. September 14, 2005 Near Reno, NV Logistics Express

- The driver of an LNG tractor trailer stopped at a truck stop on I-80 near Reno and noticed that LNG was leaking from the fire block valve. He notified the local emergency responders. Shortly after their arrival the LNG vapor ignited.**
- The on-scene emergency responders decided to first close the Interstate and evacuate people from local businesses and residences and then expand the evacuation area for about three hours.**
- When the fire subsided, the evacuation was cancelled. The trailer performed as designed and there was no loss of vacuum on the trailer. The trailer was removed from service for minor damage repair and returned to service within a week.**
- Unfortunately, the emergency responders did not understand LNG or the design of LNG trailers otherwise they would not have executed such a large evacuation.**

LNG by Road

Value added Applications

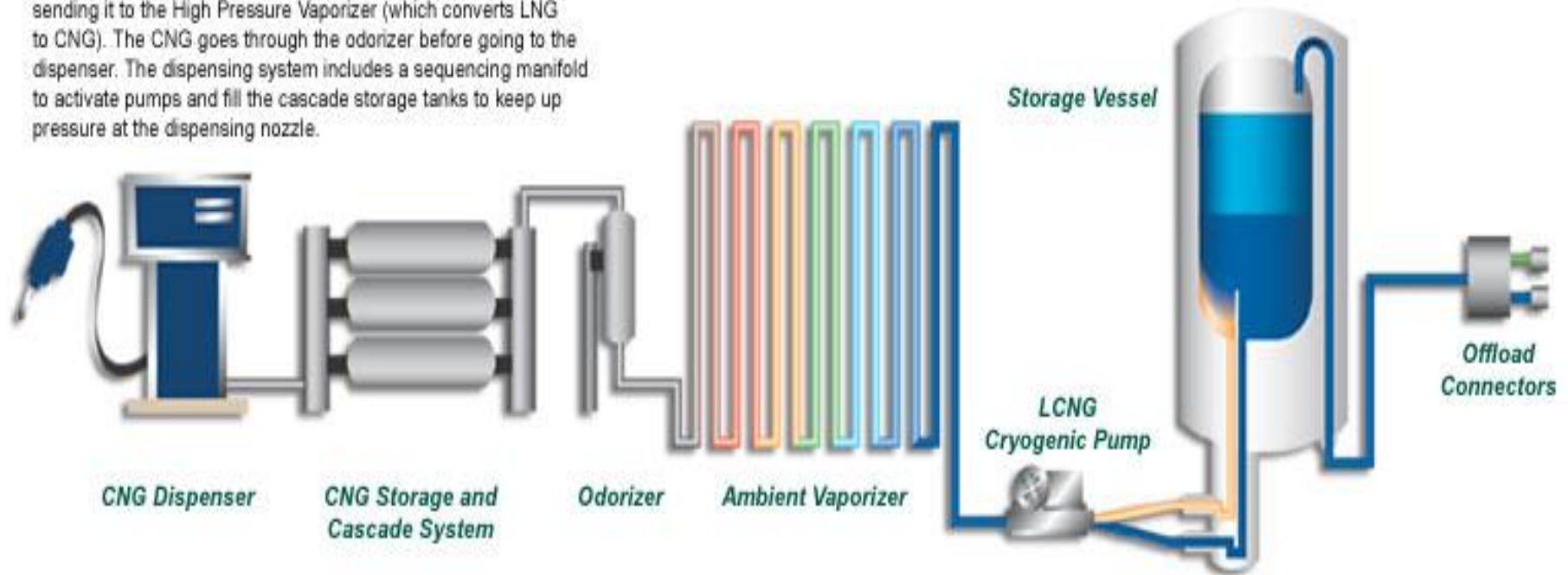


LNG DISTRIBUTION SYSTEM

LCNG Fuel Station schematic

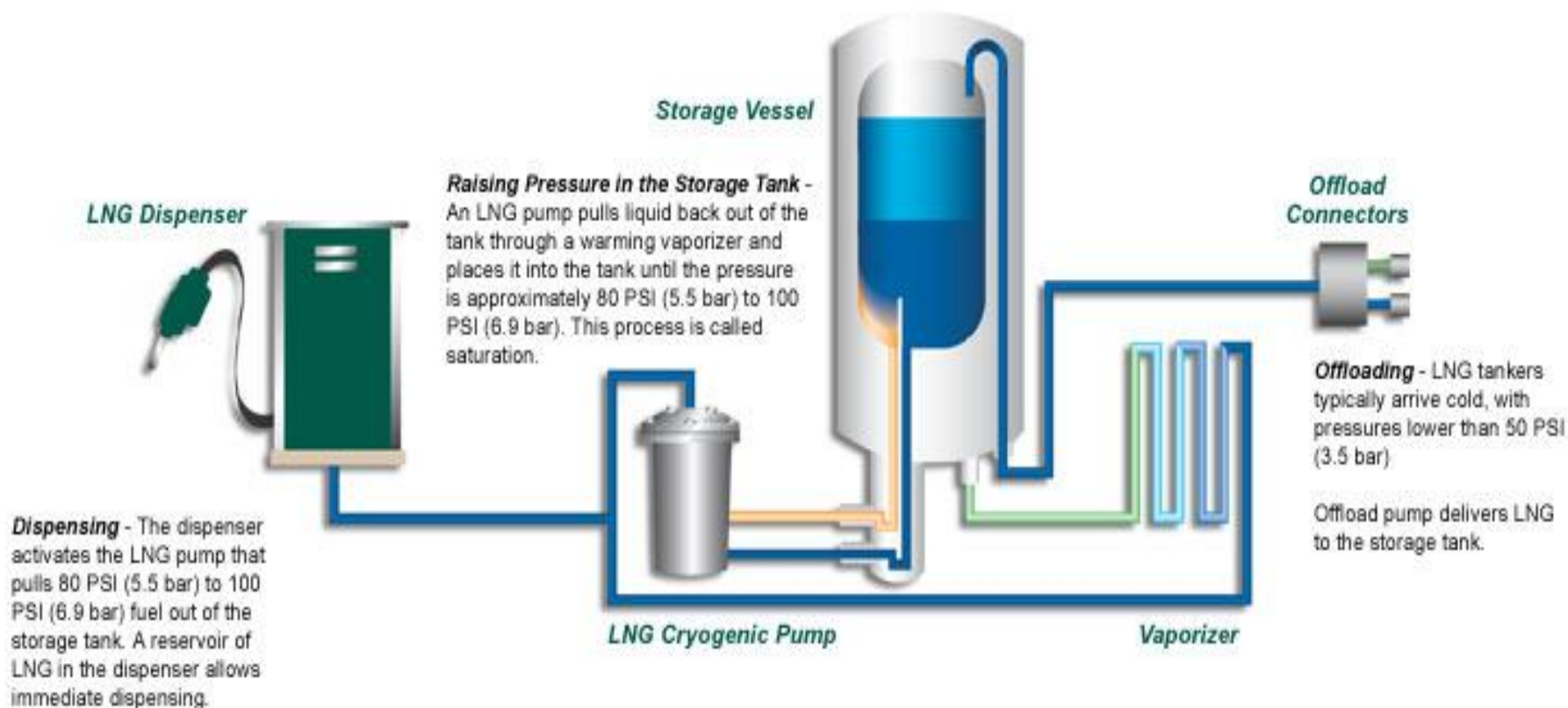
LCNG stations use LNG as a feedstock to deliver CNG to vehicles. May also be configured to dispense LNG.

Dispensing - The dispenser pulls initially from CNG stored in the cascade storage tanks, then activates the LCNG pumps. Those pumps raise the LNG pressure to 4,500 PSI (310.3 bar) before sending it to the High Pressure Vaporizer (which converts LNG to CNG). The CNG goes through the odorizer before going to the dispenser. The dispensing system includes a sequencing manifold to activate pumps and fill the cascade storage tanks to keep up pressure at the dispensing nozzle.



LNG on Board - Fuel Station

LNG stations are designed to deliver LNG to vehicle tanks at a pressure of 75 PSI (5.2 bar) to 120 PSI (8.3 bar), which is the pressure natural gas engines need to run properly.



Benefits of LNG as Automobile fuel as compared to CNG.



- **Less re-fueling required**
 - more kilometers covered per filling
 - Same space carries more fuel i.e. LNG
- **Better vehicle mileage**
 - better fuel quality
 - less dead weight of fuel tank
 -
- **More safe**
 - LNG is stored at very low pressure (6-8 bar) as compared to high pressure CNG cylinder (200-250 bar)

LCNG / LNG Fueling Station in US



LNG on Board Vehicle unveiled in AutoExpo 2014 at Greater Noida



Modes of Transporting LNG



How successful else where....



1) In China

- Approx. 2000 LNG tankers are in operation.
- More than 80000 “LNG on Board” trucks are on the road.
- Around 400 LNG filling stations.
- More than 100 satellite stations.

2) In Spain alone around 0.6 MMT (40000 truck loads) of LNG is distributed by trucks.

3) In Europe more than 800 LNG satellite stations are in operations.

LNG supply in China



A Typical Truck Loading station

Truck Loading Station Sodegaura - Japan



Modular L-CNG Station in China



A successful model in many countries : A LNG Satellite Station in China



LNG Satellite Station in China

CIMC- LNG Vaporization Station at
Guiyang – 12 x 150 CuM



NG supply in a restaurant using small LNG storage : Supply from Local LNG Hub.





Thank You