Review Paper

SAFETY OF NATURAL GAS CROSS COUNTRY PIPELINE NETWORKS, IN INDIAN CONTEXT

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ABSTRACT

Can Natural gas industry meet increasing customer needs? This question is very common these days amongst many Natural Gas customers and Natural Gas industry executives all over the country. Today Indian customer wants to know if there would be enough natural gas with an adequate transportation and distribution system to meet the growing needs of clean fuel.

When hazardous materials like Gaseous Hydrocarbon / Natural gas are transferred through pipelines, they pose severe hazard problems for human beings and property in vicinity. In view of this safeguard for pipelines are essential and one of important needs to be considered during designing, operating and maintaining a piping system. Initiating and contributing Hazards associated with pipeline carrying Hydrocarbons like Natural Gas can be mainly human errors, equipment failure, system or procedure failure, external reason and the Consequences of various hazards are gas leakage, fires, Health Hazard etc.

Operating the Cross Country Natural Gas pipeline system at high pressure, passing through thickly populated area, lack of public awareness, ongoing construction activities etc. poses significant hazard in Indian context on Safest Method of Transportation.

Hence, it is important to established robust mechanism for safe operation and maintenance of cross country pipeline in India. This includes: Health, Safety & Environment Management System; Awareness; Pipeline Maintenance and Fire Protection Systems.

The integrity of Natural Gas Pipeline System comes through the continuous efforts in all stages to ensure that pipeline is designed, commissioned, operates and maintained as per stipulated codes and standards. Further, technological up-gradation in operation, inspection and maintenance enhance the safety of pipeline system and increase the safety at a greater extend.

Keywords: Safety of Natural Gas, Hydro Carbons.

INTRODUCTION

Historically, India has relied on coal to power its electricity sector, liquid fuels as feed stock and oil for its transport sector. But for environmental reasons we need to focus on cleaner fuels. Gas is one of the cleanest fuels with less carbon dioxide per joule delivered than either by coal or oil and far fewer pollutants than other hydrocarbon fuels.

Natural Gas, is a new age fuel is the cleanest, efficient, non-polluting, environmental friendly and relatively economical of the fossil fuels in the modern day industrial society. Natural Gas Pipeline Infrastructure connects various gas sources to different gas markets to the meet the existing/ future natural gas demand of various Powers, Fertilizer, CGD and other industries in the Country.

A big challenge lies in bridging the physical gap between demand and supply centers in an efficient, safe and eco-friendly manner. Pipeline transportation of gas offers a safe, economic and environmentally sound

alternative to most other modes of energy transport.

NEED OF A LARGE NETWORK OF CROSS COUNTRY PIPELINE IN INDIA

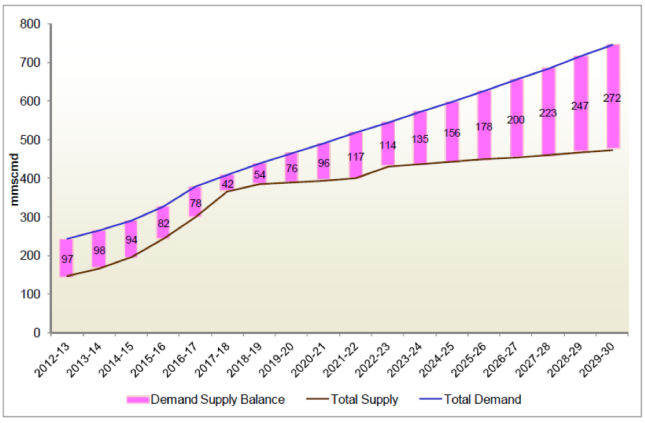

FIGURE: Demand Supply Balance of Natural Gas From 2012-13 to 2029-30

TABEL: List of Natural Gas Pipelines in India.

Sl. NO	Name of the Natural Gas Pipeline	Owner Entity	Length (KM)
1	Hazira-Vijaipur-Jagdishpur - GREP-Dahej-Vijaipur	GAIL(India) Limited	4222
2	Dahej-Vijaipur (DVPL)-Vijaipur-Dadri (GREP) Upgradation	GAIL(India) Limited	1280
3	Uran-Trombay	ONGC	24
4	Dahej-Uran-Panvel-Dhabhol	GAIL(India) Limited	815
5	Agartala regional network	GAIL(India) Limited	55.4
6	Dukli-Maharajganj pipeline	GAIL(India) Limited	5.2
7	Mumbai regional network	GAIL(India) Limited	125
8	Assam regional network	GAIL(India) Limited	8
9	K.G. Basin network	GAIL(India) Limited	878
10	Gujarat regional network	GAIL(India) Limited	609
11	Cauvery Basin network	GAIL(India) Limited	241
12	EWPL (Kakinada-Hyderabad-Uran-Ahmedabad)	Reliance Gas Transportation	1460
13	GSPL's High Pressure Gujarat Gas Grid network	Gujarat State Petronet	2100
14	GSPL's Low Pressure Gujarat Gas Grid network	Gujarat State Petronet	58
15	Hazira-Ankleshwar	Gujarat Gas Company Limited	73
16	Dadri-Panipat	Indian Oil Corporation Limited	132
17	AGCL's Assam regional network	Assam Gas Company Limited	105
18	Uran-Taloja	Deepak Fertilizer & Petrochemicals Corp. Ltd.	42
19	Dadri-Bawana-Nangal	GAIL(India) Limited	886
20	Chhainsa-Jhajjar-Hissar	GAIL(India) Limited	455
21	Dabhol-Bangalore	GAIL(India) Limited	1414
		Total:	**14987.6**

It is perceived that by 2017 India will have a natural gas pipeline grid of 30,000 km connecting consumption centers to source of fuel. A Natural Gas pipeline system may contain following element:

- ♣ Buried Pipelines
- ♣ Above Ground Pipelines
- ♣ Compressor Stations
- ♣ Isolation Valves – Manually, Remotely or Automatically activated
- ♣ Relief Valves – Pressure or Thermal
- ♣ Pipe Bridges or other Supports
- ♣ Casing Sleeves under Road/Rail Crossing
- ♣ Leak Detection System
- ♣ Pig Launchers/Receivers
- ♣ Control Systems

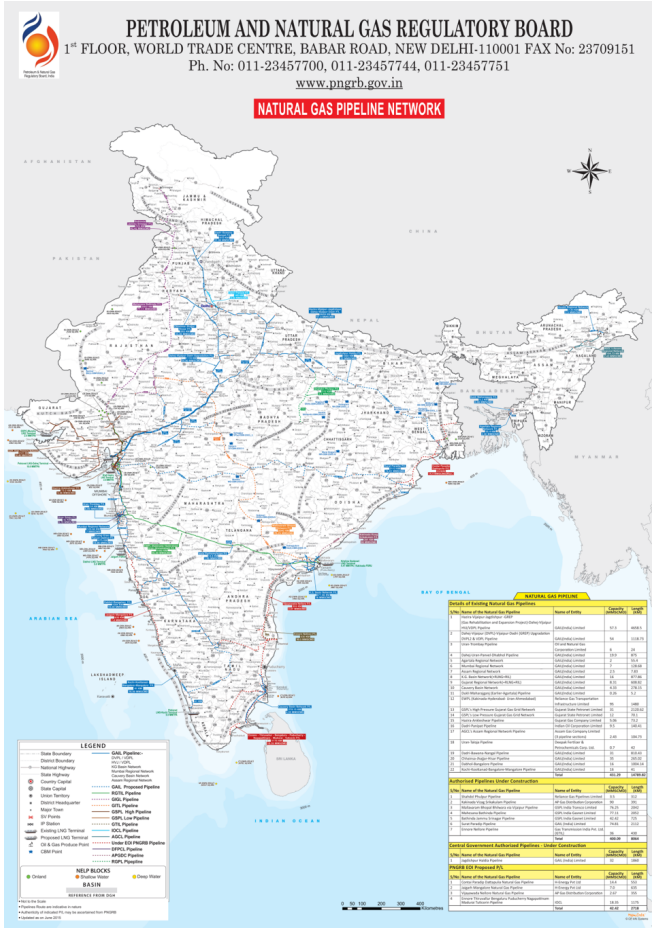

FIGURE: Natural Gas Pipeline Network

HAZARDS ASSOCIATED WITH NATURAL GAS CROSS-COUNTRY PIPELINES

When highly flammable hydrocarbons like natural gas are transferred through pipelines, they pose severe hazard problems for human beings and property in vicinity. In view of this safeguard for pipelines are essential and one of important needs to be considered during designing, operating and maintaining a piping system. Initiating and contributing Hazards associated with pipeline carrying Hydrocarbons like Natural Gas can be mainly following:-

Human Errors: during Pigging operation, hot tapping, Slug Operation, repair/ replacement of the sections, Valve

operation etc.

Equipment Failure: Due to Thermal Expansion, Internal corrosion, External corrosion, Fatigue, CP Failure, Failure of Support, Failure of gaskets, etc.

System or procedure Failure: Inspection, operation, Shutdown, Startup, Leak detection, Temporary repairs, Material specification and testing, etc.

External Reason: Accidental Excavation, Earthquake, Flood, Fire, Lightning, Rail / road accident, etc.

CONSEQUENCES OF VARIOUS HAZARDS

The consequence of failures of gas pipelines are of following types:

Gas leakage: In gas pipelines, gas will continue to release from the pipe leak. Sometimes, the high compressibility nature of gas results in a high level of energy remaining in the vicinity of puncture for a sufficient time to allow small holes to propagate to full bore rupture. However, in volatile liquids pipelines, say for LPG where material is conveyed as liquid under pressure, the loss of pressure due to rupture or leakage will flash the fluid to a mixture of vapour and liquid.

The slugs of liquid and gas are alternatively released producing a heavier than air flammable vapour cloud. Finally, all the liquid is evaporated and a simple gas release takes place.

Fires:

a) Jet fire: Generally gas inside pipe is at a very high pressure. In case it comes out into atmosphere it will be in the form of a jet. There is every likelihood that it will immediately catch fire either through some external heat source or through its own high temperature (if it has already been exposed and temperature has risen above its auto ignition temperature) and even through static electricity, which might generate due to high velocity at the tip of the rupture opening. Severity of this type of incident depends upon diameter of pipeline, pressure inside, size of rupture etc. Jet fire has potential to cause harm in following two ways:

- Cutting anything coming in its way and hence it may have domino effect.
- Adjoining area may get exposed and hence they may get their temperature risen at a very high pace.

b) Fire Ball: Fire ball scenario is because of immediate ignition of released gas. Thermal radiation from fireball is intense. The casualties from the fireball will depend on the thermal dose experienced by surrounding persons.

c) Delayed ignition: Gas release and fire hazards on immediate ignition are often considered as the safest scenario for flammable chemicals since the flammable material gets consumed in this process. Delayed ignition can occur in case the released gas is not immediately ignited but finds an ignition source after the gas has dispersed and its concentration is still in flammable range. Methane is lighter than air and hence will disperse more rapidly in open terrain on release and hence delayed ignition for methane can only result in flash fire with no overpressure wave.

d) Unconfined/ Confined vapor cloud explosion: On the other hand LPG, which is heavier than air due to presence of heavier fractions like Propane and Butane, may not disperse so easily, Due to terrain conditions if there is possibility of these gases getting accumulated or confined, on release from pipeline, there may be unconfined/ confined vapour cloud explosion, if a source of ignition is also available.

HEALTH HAZARD

a) Asphyxiation: Due to release of high volume of these gases into atmosphere, the concentration of oxygen may go down to unsafe level, i.e. below 19.5 %. In this atmosphere a person may fall unconscious or even die. The same is true for other fauna and animals that may come in contact of such atmosphere especially in country side.

b) Frost bite: In case temperature of

released gas is sub zero, there is likelihood of frost bite/ cold burn to living beings coming into contact.

SOURCES OF IGNITION

The minimum ignition energy for pure Methane at atmospheric pressure is 0.29 mJ, which is very low when compared to static discharge of 22 mJ (on walking) or Ordinary spark plug discharge of 25 mJ, hence ignition can occur at any time during the gas release. (Source: Crowl & Louvar, 1990).

Various sources of ignitions can be:

1. Electrical Spark: From Switches, lamps, motors, lamp boards, panels etc.
2. Friction: Vibrations of pipe lines, hot bearings, broken machine parts, etc.
3. Open flames: From Cutting and welding torches gas burner, etc.
4. Using match sticks, Smoking Cigarettes etc.
5. Hammering, scraping, digging, road cutting, etc.
6. Hot surfaces
7. Static electricity.
8. Lightening.

MITIGATIONS OF HAZARDS - PRECAUTIONARY MEASURES

Protection against External Corrosion – Cathodic Protection: To protect corrosion external coating should be used on the pipelines. Cathodic protection systems are designed to reduce the likelihood of external corrosion. In this system electrical potential difference are set up between the pipe and surrounding earth to prevent the formation of corrosion cells where the pipe external coating had failed locally.

Protection against Internal Corrosion – Chemical Inhibitors: Internal corrosion is a function of the contain and conveys of pipeline. Its mitigation can be done by injecting chemical inhibitors along with the product flow. However, selection of inhibitor type is very critical so that it will not change actual fluid properties or create unsafe conditions. Another method of safety against internal corrosion is to provide lining on the inner wall of pipeline with an inert protection material compatible with the fluid transported.

Protection against third party damage: This type of failure occurs because of unawareness of third party about the presence of pipelines. This type of damages can be reduced by ensuring the proper awareness amongst the public, landowners and state authorities. Pipelines crossing other utilities like telephone, electrical cables, water/ sewer mains etc nearby are more prone for damage, they should be duly provided with markers / pipeline indicators.

Protection for pipe supports: Appropriate usage of piping supports and expansion joints is very important in any piping system. These piping supports should be designed to take care self weight plus the transported fluid weight plus insulation and also to ensure the flexibility provided to take care of the thermal expansion of pipes.

Leak Detection system: the most basic method involves either walking, driving the pipe line right of the way, to look for evidence of discoloration of vegetation near the line or hear or see the leak. There are methods of leak detection in case of non-flammable products, i.e. addition of odorant to the fluid and detection of the leak by smell. This can also be done by checking the gross in-balance over hourly or daily basis, by line flow mass balance or by monitoring through a leak detection device, etc. Infrared detector are being used for finding out the leaks from pipelines, Leak Apps are being used by various industries.

Pig Based Monitoring System: Pigs are frequently used for pipeline commission-ing, cleaning, filling, de-waxing in general. But now a days "intelligent pigs" are available that travels internally along the pipeline

and measures the conditions of the pipe walls. These pigs are designed to carry special monitoring equipment for the purpose.

Protection against Overpressures: Over pressurization relief devices must be provided to piping system in order to prevent pipeline failure because of over-pressurisation. Installation of Pressure relief valves (PRVs) can be used as protection against over pressure.

Protection against Detonation Hazards: Flame arrestors are essential safety devices that stop the propagation of a subsonic flame front and cool the flame in order to sustain the combustion. Inline detonation arrestors are similar type of devices designed to prevent explosion in a piping system by detonation hazards.

SCADA SYSTEM - SAFE WAY OF PIPELINE OPERATION AND LEAK DETECTION SYSTEM

Supervisory control and data acquisition (SCADA) system is an extension of the instrumentation control system. The SCADA system consists of the following basic sub – systems.

1. SCADA Master Control Station (SMCS)
2. Remote Terminal Units (RTU)
3. Communications Link

SCADA Based Leak Detection System:

The SCADA package may include a leak detection system (LDS). LDS may be hardware based or software based. In a typical hardware based LDS, transducers are installed at regular intervals on the pipeline. Negative pressure waves generated during a leak are picked up by the transducers on either side of the leak location and on the basis of arrival time of signals, the leak location is determined. The LDS can also determine the size of the leak. Software based LDS takes flow, pressure, temperature, density, pipe characteristics etc. as inputs. The variation in flow and pressure are regularly computed and are compared with leak models already simulated and stored in the computer. Voting mechanisms are developed in order to minimize false leak alarms. The hardware based LDS can offer accuracy (leak location and leak detection time) better then software based LDS. However, if there is a communication break at the time of leak occurrence, the hardware based LDS is likely to miss the leak altogether.

PIPELINE EMEGENCY HANDLING

Proper Emergency action plan makes the handling of pipeline emergency easier and situations can be handled in less time and with minimum losses.

In case of Gas leakage:

In case of gas leakage following actions must be taken immediately:

a. Control consists of directing, diluting & dispensing the gas to prevent contact with persons, preventing it from infiltrating into structures if release is outdoors, and avoiding its contact with ignition sources, while if possible, simultaneously stopping the flow of escaping gas.

b. Air, steam & water have proven to be best for this purpose.

In case of Fire:

Don'ts

- ✯ Do not extinguish fire immediately.
- ✯ Do not close valve immediately.

Do's (in sequence)

- ✯ Try to minimize radiation and locate fuel supply valve simultaneously.
- ✯ Keep DCP Ext. ready near fire & close valve 95%.
- ✯ Extinguish Fire.
- ✯ Close remaining 5% of valve.

Control of Fire emergency is generally the control of heat from the fire by the application of water & if possible, by stopping the flow of escaping gas.

SAFETY FEATURES OF PIPELINE

Design and Construction:

1. Sizing of line pipe wall thickness according to the population density of the area, design pressure, specified minimum yield strength, diameter of pipe longitudinal joint factor and temperature derating factor, as per ANSI/ASME b 31.8.
2. Additional corrosion allowance of 2 mm of design wall thickness considering 30 years pipeline design life and moderate corrosion rate.
3. Providing minimum ground cover of 1m for the buried pipeline irrespective of pipeline diameter which is more than specified depth as per ASME b-31.8.
4. Line pipes are having 3 layer polyethylene external coating instead of conventional coat-tar coating.
5. Specifying and adhering to qualification of the welders and welding processes for enhancing pipeline safety.
6. 100% radiographic inspection of welded joints using x-rays and gamma rays. Destructive & ultrasonic testing for selected joints for ensuring quality work.
7. The total length of pipeline and its installations were hydrostatically tested at a pressure of 1.4 times of design pressure i.e., 128.8kg/cm2.
8. Installation of remotely operated sectionalizing valves (sv) at regular intervals of approx. 30-35 kms..
9. Sectionalizing valves installed across major river. Average distance between two valves approx. 20 kms.
10. Pressure safety valves at the intermediate pigging (ip) stations.
11. Installation of casing pipes at all railway crossings and highway crossings as per international standards.
12. Anti-buoyancy measures by providing saddle weight or continuous concreting for the pipeline sections which are passing through minor and major water crossing.
13. Bank protections for canals / minor river crossings by providing mattresses / cabions.
14. Lying of pipeline at a depth of 4-5 mtrs. Below the secure level at major river crossings by horizontal directional drilling method (HDD).
15. Pipeline markers like warning boards, kilometer / aerial, r.o.u. boundary pillars etc.
16. Fire detection & CO2 flooding system at all radio repeater stations.
17. Corrosion sensing probes (CSP) for monitoring external corrosion rate at every 10 kms.
18. Computerized test stations (CTS) at vulnerable locations where round the clock monitoring of pipe to soil potential is required.
19. Temporary C.P. till permanent C.P. system installed for protecting the pipeline against corrosion.

Operation & maintenance:

1. Supervising the operation of entire pipeline round the clock from MICC and regular health monitoring through SCADA.
2. Monthly helicopter surveillance of the entire pipeline route for possible encroachment in rou, soil erosion etc.
3. Monitoring the pressure profile of pipeline. In case of sudden pressure drop 0 0.5 kg/cm2 per polling cycle due to any leak / burst in pipeline, MCC will receive alarm.
4. Half yearly monitoring of corrosion sensing probes, & corrosion rate measurement.
5. Pipeline installations guarded round- the- clock by ex-servicemen guards who are being monitored shift-wise from maintenance bases.
6. Internal & external audit of the pipeline system being carried out as per ISO 9002.

7. External safety audits conducted by OISD.
8. Regular physical inspection of the above ground installations (SV, IP & RR stations) along the pipeline route.
9. Vulnerable locations identified and periodically checked.
10. Half yearly performance test of all valves including remote operations.
11. Quarterly monitoring of pipe to soil potenial and analysing the psp trend. Corrective actions taken accordingly.
12. Post-monsoon foot patrolling along the pipeline.
13. Dry chemical powder (DCP) type fire extinguishers installed at each IP stations and are periodically checked.
14. Removal of encroachments and maintenance of rou.
15. Operational mechanism of main line valves are kept under lock & key.

Pipeline Maintenance:

♣ **Right of Way Inspection and Maintenance:**
- Road and Highway Crossing – Once in a 3 months.
- River Crossing – Twice in a year (Before and after Monsoon)

♣ **Pipeline Patrolling:**
- Ground Patrolling – Once in a month
- Foot Patrolling – Line walk by Company Official twice in year (Before and after Monsoon)

♣ **Pipeline Pigging:**
- Pigging Activities for Wet Gas – Once in a year
- Pigging Activities for Dry Gas – Once in a 3 years

♣ Intelligent Pipeline Pigging to be carried out once in a 10 years and data must be compared with data obtained during Geometric Pigging before commissioning to ensure health of pipelines.

♣ **Inspection of Cathodic Protection System:**
- PSP (Pipeline to Soil Potential) at feeding point – Once in a fortnight
- PSP Reading at Test Lead Point all along the Pipeline – Once in a 3 months
- Cathodic Protection Rectifier – Once in a 2 months
- Installation of Corrosion Coupon and probe.

♣ **Coating Survey:** Pearson Survey / Direct Current Voltage Gradient (DCVG) / Continuous Potential Logging (CPL) survey / Current Attenuation Test (CAT) to be carried out once in 5 years.

Equipment Safety:

1. Programmable logic controllers & safety interlocks.
2. Use of zener barriers to protect hazardous areas from over voltage.
3. Compulsory use of double mechanical seals for all liquid hydrocarbon pumps.
4. Use of swivel joint metallic arms instead of hoses for tanker loading.
5. Remote/auto loading of tankers/ railway wagons through computer controlled batch, controllers called "accuload".
6. Going for mounded storage vessels instead of above ground storage bullets / Horton spheres.
7. Installation of flame proof & increased safety motors.
8. Fire proofing of structure, equipment base and support legs.

Other General Safety measures:

1. Area Classification is done as per following guidelines.
   (As per IS 5572: 1994 & Indian Electricity Code SP -30 (BIS)
   - Zone '0' area: dangerous atmosphere exists continuously.

- Zone' 1 ' area: dangerous atmosphere likely to occur during normal operation.
- Zone '2' area: dangerous atmosphere may arise through failure of the conditions.

2. Work Permit system must be followed.
3. Vehicle Movement Control
4. Restricted Smoking
5. Emergency Planning
6. Mock Fire Drill
7. Fire Safety Training
8. Personal Protective Equipment
9. Safety Auditing
10. Safety Committee

CONCLUSION

Operating the Cross Country Natural Gas pipeline system at high pressure, passing through thickly populated area, lack of public awareness, ongoing construction activities etc. poses significant hazard in Indian context on Safest Method of Transportation. Hence, it is important to established robust mechanism for safe operation and maintenance of cross country pipeline in India.

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