



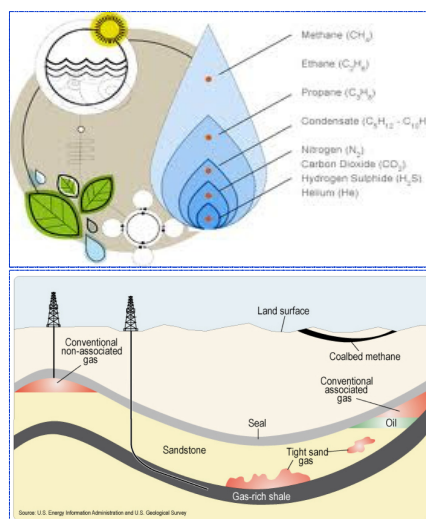
Measures adopted for Monitoring Safety of Natural Gas Pipelines during Operation & Maintenance

By
S. P. Garg
General Manager (HSE)
Corporate HSE Department
GAIL (India) Limited
Email: sp.garg@gail.co.in

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 1

Natural Gas

- Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly includes varying amounts of other higher hydrocarbons and a lesser percentage of carbon dioxide, nitrogen, and hydrogen sulphide.
- It is colourless, shapeless and odourless.
- Natural gas is an energy source often used as a fuel for heating, cooking, and electricity generation.
- It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.



“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 2

Pipeline System

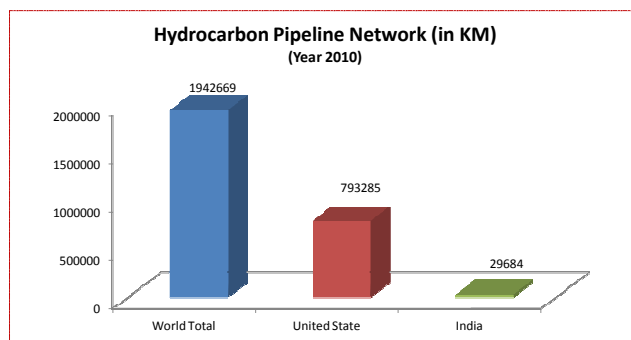
- The rapid growth of business all over the world requires increasing hydrocarbon transport capacity.
- A pipeline is actually a system of equipment designed to allow material to flow continuously or intermittently from one location to another.



- With sophisticated technologies providing increased applications, pipelines are gaining advantage over other means of transport due to economic and safety considerations.

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 3

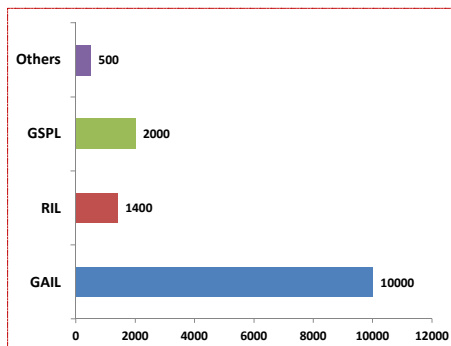
Hydrocarbon Pipeline Network in the World



- The United States has largest pipeline network in the world. Its natural gas pipeline network is a highly integrated transmission and distribution grid (548,665 km) that can transport natural gas to and from nearly any location in the lower 48 States.

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 4

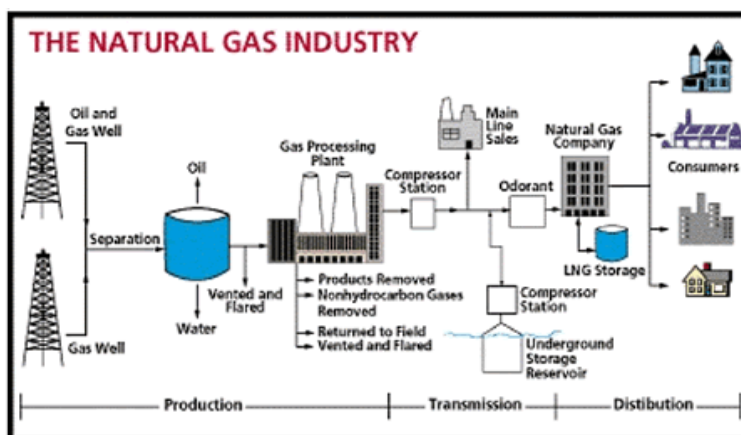
Natural Gas Pipelines (in KM) in India



- India has a country wide network of approx 14,000 kms of gas pipelines (and another approximate) 12,000 kms of pipelines are under construction.
- By 2017 India will have a natural gas pipeline grid of approx 30,000-kms connecting consumption centres to sources of fuel.

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 5

Natural Gas – Production, Transmission & Distribution



Source: Internet

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 6

Natural Gas Pipeline System

A Natural Gas pipeline system may contain following elements:

- 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

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 7

Hazards associated with NG Pipelines

- Natural Gas is highly flammable substance, transported through cross country pipelines at high pressure often close to centres of high population or through areas of high environmental sensitivity.
- Natural Gas pipeline system pose severe hazard problems for human being and property in the vicinity.
- Provision of protective measures are essential for safe operation of NG Pipeline system. The requirement is based on
 - Hazardous properties of Natural Gas.
 - Quantity of Natural Gas, which could be released and its effect.

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 8

| Properties of Natural Gas | | |
|---|--|--|
| NATURAL GAS : CHEMICAL FORMULA : C_nH_{2n+2}, n=1,2,..... | | |
| PROPERTIES | | OTHER CHARACTERISTICS |
| Type of chemical | : Flammable gas | Colorless, odorless gas can be compressed to liquid at very low temperature. |
| Physical form | : Gas | |
| Ignition temp. °C | : 535 °C | |
| Flash point | : Not available | |
| Explosive limits % Vol in air | : 5 to 15 | |
| Solubility in water | : Insoluble | |
| Vapor Density (Air=1) | : 0.6 | |
| Sp. Gravity | : 0.42 | |
| HAZARDS | PRECAUTIONS | EXTINGUISHING AGENT |
| FIRE: Highly Inflammable | No open fire, sparks, no smoking. | Shutting off supply is essential before extinguishing fire using dry chemical powder. |
| EXPLOSION: Gas forms an explosive mixture with air. | Use explosion-proof electrical Equipment Gas tests with LEL Meter suitable for methane. | |
| SYMPTOMS | PRECAUTIONS | FIRST AID |
| Inhalation : Dullness, breathlessness | Ventilation, local air extraction, use of respirator. | Remove the person to fresh air and resort to artificial respiration if necessary. Report for medical attention |
| DISPOSAL | STORAGE | ANTIDOTES |
| Intermittent cold flaring | Storage in cool, well ventilated place and isolate for oxidizing agents. Outdoor or detached storage is preferred. | NIL |
| Additional information: High concentration in air cause oxygen deficiency leading to unconsciousness. | | |

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ”

9

| Hazards of Natural Gas | |
|---|---|
| <ul style="list-style-type: none"> Fire Hazard : The fire is a process of burning that produces heat, light and often smokes and flames. The effect of fire on the people takes the form of skin burn on exposure to thermal radiation. | |
| Radiation Level (kW/m ²) | Observed Effect |
| 37.5 | Sufficient to cause damage to process equipment |
| 25 | Minimum energy required to ignite wood at indefinitely long exposures (non-piloted) |
| 12.5 | Minimum energy required for piloted ignition of wood, melting of plastic tubing |
| 9.5 | Pain threshold reached after 8s; second degree burns after 20s |
| 4 | Sufficient to cause pain to personnel if unable to reach cover within 20s; however blistering of the skin (second degree burns) is likely; 0: lethality |
| 1.6 | Will cause no discomfort for long exposure |

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ”

10

Hazards of Natural Gas



Flash Fire: A flash fire occurs when a cloud of flammable gas and air is ignited.



Jet Fire: A jet fire occurs when a flammable liquid or gas is ignited after its release from a pressurized, punctured vessel or pipe. (8kg/s – 35 m)

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 11

Hazards of Natural Gas

- Explosion (Unconfined Vapour Cloud Explosion):
- An accidental escape of flammable material to form a cloud and obtained delayed ignition.



Fire erupted in one of the Natural Gas Pipeline

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 12

Natural Gas Transmission – Failure Categorization

Characteristics of the Pipeline Failure:

- Pinhole/Crack: the diameter of the hole is smaller that or equal to 2 cm.
- Hole: the diameter of the hole is larger than 2 cm and smaller than or equal to the diameter of the pipe.
- Rupture: the diameter of the hole is larger than the pipeline diameter.

The Initial Causes of Incident:

- External Interference
- Corrosion
- Construction Defect/Material Failure
- Hot Tap made by Error
- Ground Movement
- Other and unknown

Source: EGIG Report

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 13

Natural Gas Transmission – Primary Failure Reason

| External Interference | Corrosion | Construction Defect | Ground Movement | Other |
|------------------------------------|-----------|--------------------------|----------------------------|------------------|
| Digging, Piling, ground works etc. | External | Construction or material | Dike Break, erosion, flood | Lightning |
| Achor, bulldozwer, excavator etc. | Internal | Welding defects etc. | Landslide | Maintenance etc. |
| Casing, sleeves etc. | Others | Failure of component | Mining & others | |

Source: EGIG Report

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 14

Calculation of Hazard Distances & Thermal Radiation

▪ **Example of estimated Failure Scenarios for Natural Gas Pipeline diameter 42” at line pressure 80 Kg/cm2. (NR – Not Reached)**

| Location | Release of Gas (Kg/Sec) | Distances for different Thermal Radiation (KW/m2) intensity and 3D weather condition. | | | LFL distance (m) for 3D weather condition. |
|------------------------------------|-------------------------|---|------|------|--|
| | | 4.5 | 12.5 | 37.5 | |
| Case 1 – 5 mm Diameter Hole (A/G) | 0.29 | 9 | 8 | NR | 5 |
| Case 1 – 5 mm Diameter Hole (U/G) | | 9 | 5 | NR | 3 |
| Case 2 – 20 mm Diameter Hole (A/G) | 4.56 | 39 | 32 | 26 | 29 |
| Case 2 – 20 mm Diameter Hole (U/G) | | 32 | 19 | NR | 10 |
| Case 3 – 50 mm Diameter Hole (A/G) | 28.51 | 90 | 70 | 54 | 89 |
| Case 3 – 50 mm Diameter Hole (U/G) | | 75 | 47 | NR | 24 |
| Case 4 – 20% CSA (U/G) | 2519 | 577 | 390 | NR | 211 |

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 15

Calculation of Hazard Distances & Thermal Radiation

▪ **Example of estimated Failure Scenarios for Natural Gas Pipeline diameter 42” at line pressure 80 Kg/cm2.**

| Location | Release of Gas (Kg/Sec) | Distances for different Thermal Radiation (KW/m2) intensity and 3D weather condition. | | | LFL distance (m) for 3D weather condition. |
|------------------------------------|-------------------------|---|------|------|--|
| | | 4.5 | 12.5 | 37.5 | |
| Case 2 – 20 mm Diameter Hole (A/G) | 4.56 | 39 | 32 | 26 | 29 |

- Location of gas leakage and fire
- 26 M distance of heat radiation of 37.5 KW/m2
- 32 M distance of heat radiation of 12.5 KW/m2
- 39 M distance of heat radiation of 4.5 KW/m2

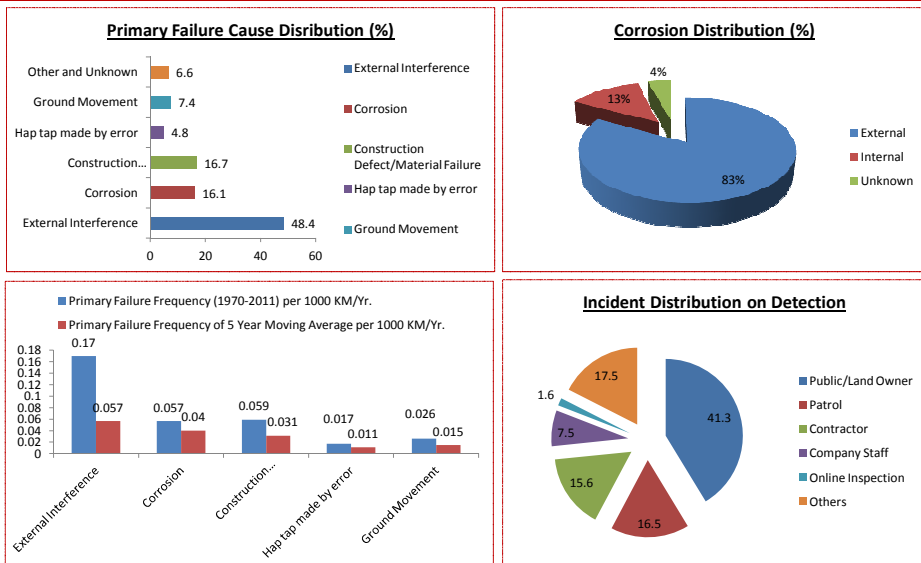
| Radiation Level (kW/m ²) | Observed Effect |
|--------------------------------------|---|
| 37.5 | Sufficient to cause damage to process equipment |
| 12.5 | Minimum energy required for piloted ignition of wood, melting of plastic tubing |
| 4 | Sufficient to cause pain to personnel if unable to reach cover within 20s; however blistering of the skin (second degree burns) is likely; 0: lethality |

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 16

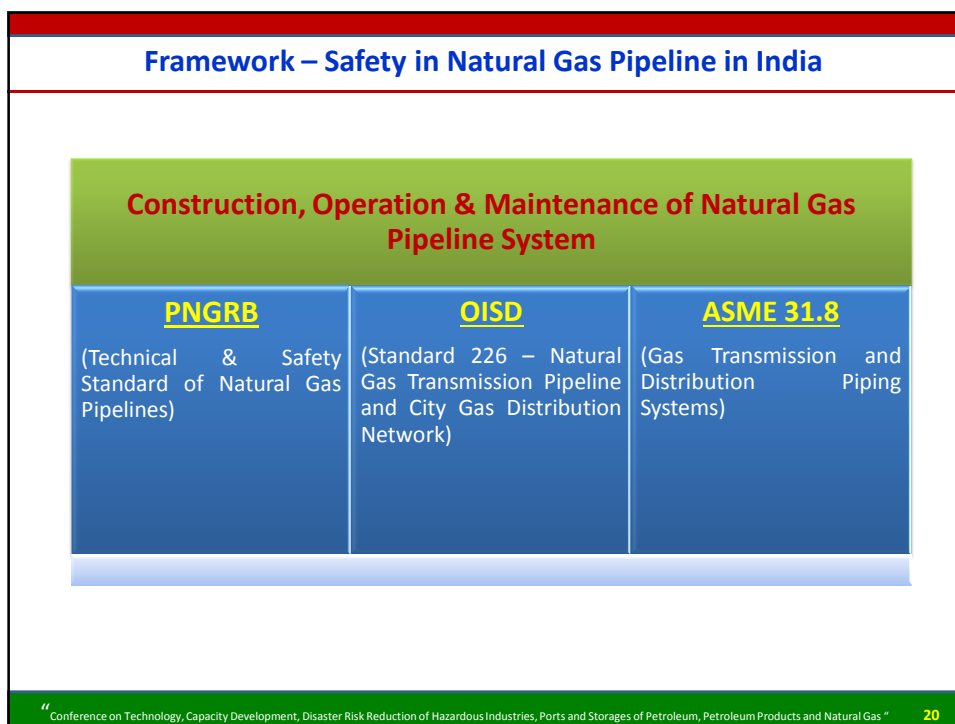
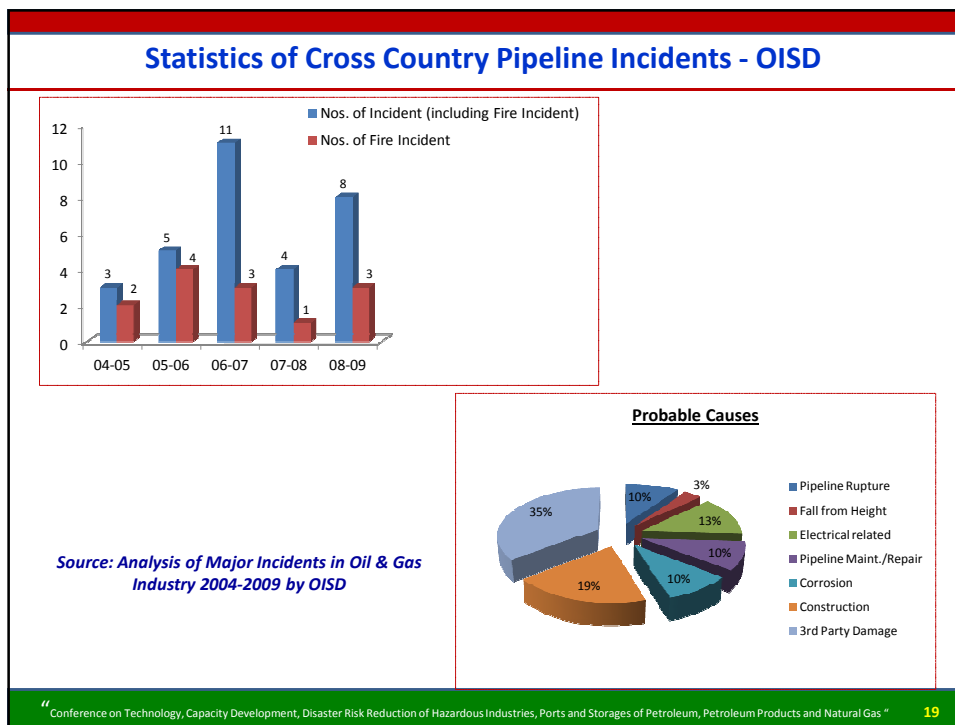
Statistics of Gas Transmission Pipeline Incident - EGIG

- In 1982 six European gas transmission system operators took the initiative to gather the data on the unintentional release of gas in their transmission pipeline system known as EGIG (European Gas Pipeline Incident Data Group) .
- EGIG has maintained the European Gas Pipeline Incident Database of fifteen European Countries on more than 135000 KM of pipelines every year.
- The statistics of incidents collected in the database give reliable failure frequencies. The overall incident frequency is equal to 0.35 incidents per year per 1000 Km over the period 1970 to 2010.

Statistics of Gas Transmission Pipeline Incident - EGIG



Source: EGIG Report



Applicable Statutory Compliances

- *Petroleum and Natural Gas Regulatory Board (PNGRB) Act'2006.*
- *Guidelines for Environmental clearance of new projects – 1981*
- *The Environment (Protection) Act -1986*
- *Water (Prevention & Control of Pollution) Act 1974*
- *Air (Prevention & Control of Pollution) Act 1981*
- *The Petroleum and Mineral Pipelines (Acquisition of Right of Users in Land) Act, 1962.*
- *Manufacture, Storage & Import of Hazardous chemical Rules-1989*
- *National Highway Act, 1956*
- *Railways Act , 1989*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 21

Safety Aspects of NG Pipelines - Construction

- *National & International Standards like OISD, PNGRB, IS, ASME 31.8B, API etc. are being followed during design, construction, operation & maintenance.*
- *Proper layout & inter distance of facilities are maintained as per OISD Std. 226 & PNGRB Regulations.*
- *Sizing of pipeline wall thickness according to the population density of the area, design pressure, specified minimum yield strength, diameter of the pipe longitudinal joint factor and temperature de-rating factor as per ANSI/ASME B 31.8.*
- *Additional corrosion allowance of minimum 2 mm of design wall thickness considering 30 years pipeline design life and moderate corrosion rate.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 22

Safety Aspects of NG Pipelines - Construction

- *Pipeline having 3 layer polyethylene external coating.*
- *Installation of remotely operated sectionalizing valves at regular intervals of approximate 8-32 KM based on Location Class.*
- *Provision of Intermediate pigging stations at the distance of approximate 90 KM along with the pipeline route to meet the pigging requirement of pipelines.*
- *Provision of slug catcher made at Compressor Station to collect the impurities, if any.*
- *Pressure safety valves at the Intermediate Pigging Stations provided to take care of excess pressure.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 23

Safety Aspects of NG Pipelines - Construction

- *Installation of casing pipes at all railway crossing and highway crossing as per International Standards.*
- *Pipeline markers like warning boards, kilo meter/aerial markers or boundary pillars along the pipeline route.*
- *Open Path Gas Detection System at Pipeline Installations area.*
- *Automatic fire detection and suitable fire extinguishing system is installed at all Installations.*
- *Cathodic Protection System provided for pipeline against corrosion.*
- *Corrosion sensing probes for monitoring external corrosion rate.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 24

Safety Aspects of NG Pipelines - Construction



Sample Natural Gas Pipeline Markers

Safety Aspects of NG Pipelines - Construction

- *Provision of SCADA to ensure effective and reliable control, management and supervision of the pipeline.*
- *Provision of Electrical Equipment based on Area Classification.*
- *Environmental consideration based on Environmental Impact Assessment (EIA) & and Risk Analysis (RA) study for the pipeline and stations before construction of pipeline.*

Safety Aspects of NG Pipelines – Operation & Maintenance

- **Health, Safety and Environment Management System**
 - *HSE Policy Statement & objectives to ensure implementation of the policy*
 - *Set of detailed processes supporting each activity of the HSE management system.*
 - *Development of Operation and Maintenance Procedures*
 - *Implementation of control and monitoring activities*
 - *Periodic, monitoring, review and reporting of performance*
 - *Compliance Audit - External and Internal Safety Audit*
 - *Accident Reporting system*
 - *Emergency Management System to safely handle emergencies with minimal risk (ERDMP).*
 - *Hazard Identification Processes such as HAZOP*
 - *Risk Analysis and Risk Assessment Process such as QRA*
 - *Work Permit System to ensure work is carried out in safe manner.*
 - *Structured Training System for O&M employees including contract workers, security etc.*
 - *Development of Management of Change procedures to identify and consider the impact of changes to pipeline systems and their integrity.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 27

Safety Aspects of NG Pipelines – Operation & Maintenance

- **Deployment of comprehensive Operation and Maintenance Procedures for Control System and Safety Interlocks.**
- **Operating Procedures mainly includes:**
 - *System Description*
 - *Operation set points*
 - *Initial start up*
 - *Normal operations*
 - *Normal shut down procedure*
 - *Temporary operations*
 - *Execution of emergency shut down in a safe & timely manner*
 - *Emergency shut down*
 - *Conditions under which emergency shutdown is required*
 - *Emergency operations*
- **Development of detailed maintenance procedure for entire pipeline system considering the manufacturer’s recommendations and stipulated Standards OISD/PNGRB.**

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 28

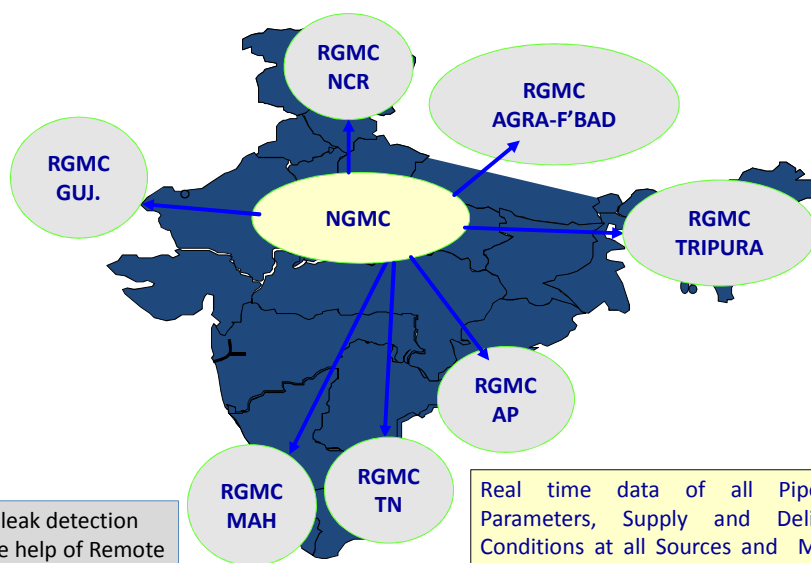
Safety Aspects of NG Pipelines – Operation & Maintenance

- **Establishment of *National and Regional Gas Management Centres* as part of holistic monitoring and control of pipeline system. It consists of**
 - *Monitoring of overall pipelines and installations*
 - *Maintaining Pipeline Hydraulics to meet customer requirement*
 - *Control on Remote Operated Valves of Pipeline Installations*
 - *Management of parameter deviation or alarm, if any*
 - *Healthiness of Fire Protection System of Installations*

- **Formation of integrity management program framework to ensure continual / periodic assessment. An evaluation process to measure effectiveness of the current health of the pipeline and to prevent any failures in future.**

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 29

Gas Management Centres - GAIL



“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 30

Safety Aspects of NG Pipelines – Operation & Maintenance

▪ **Right of Way for Inspection and Maintenance:**

- *Road and Highway Crossing – Once in a 3 months.*
- *River Crossing – Twice in a year (Before and after Monsoon)*

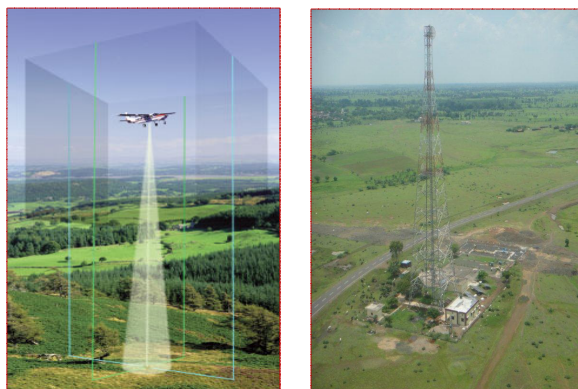


“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 31

Safety Aspects of NG Pipelines – Operation & Maintenance

▪ **Pipeline Patrolling:**

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



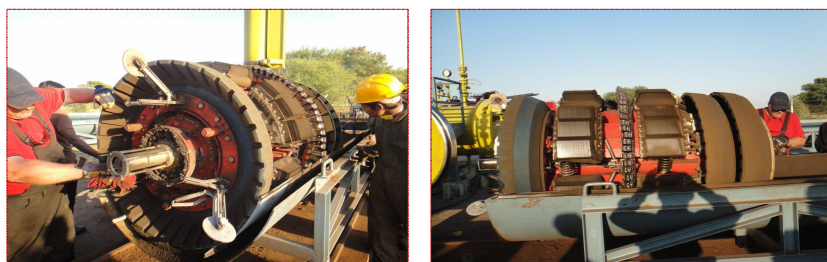
View of Aerial Patrolling of Pipelines

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 32

Safety Aspects of NG Pipelines – Operation & Maintenance

- **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.*



Intelligent Pigging of Pipelines

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 33

Safety Aspects of NG Pipelines – Operation & Maintenance

- **Inspection of Cathodic Protection System:**
 - *PSP (Pipe 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*

- **Coating Survey:**
 - *Pearson Survey / Direct Current Voltage gradient (DCVG) / Continuous Potential Logging (CPL) survey / Current Attenuation Test (CAT) once in 5 years to ensure the healthiness of pipeline coating.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 34

Safety Aspects of NG Pipelines – Operation & Maintenance

■ Awareness:

- Display of Do's & Don'ts
- Conducting a comprehensive public awareness program for consumers and general public. The educational material to be prepared in local Hindi and English language. Local audio visual media available should be used for such educational programs.



Safety Aspects of NG Pipelines – Operation & Maintenance

■ Fire Protection System:

- Installation of gas detection system equipped with audio and visual alarm.
- Provision of IR / Smoke detectors in control room, MCC, utility room and compressor enclosure with provision of indication, alarm and annunciation.
- Installation of Electric operated fire sirens with audible range of 1 km and/or hooters of F&G system audible within the compressor station premises.
- Installation of manual call points at strategic locations.
- Manual operated fire siren shall also be provided at strategic locations.
- Provision of Fire Fighting Equipment at Compressor Stations, Intermediate Pigging Station, Sectional Valve Stations, Gas Entry / Exit terminals and Metering Stations.
- Provision of Windsack on an appropriately elevated structure like the control room / fire-water pump house in such a manner so as to avoid blind areas.

Safety Aspects of NG Pipelines – Operation & Maintenance

■ *Fire Protection System:*

- *Adequate communicate system at all intermediate stations including IP stations / Repeater station.*
- *The Fire water system shall be provided at compressor stations consisting of:*
 - a. Fire water storage*
 - b. Fire water Pumps (Main and Jockey)*
 - c. Fire water distribution piping network*
 - d. Fire hydrant / Monitors*
 - e. Water sprinkler / deluge system.*
- *Fire water system should be designed to fight two major fires simultaneously anywhere in the installation and designed on the basis that the city fire water supply is not available close to the installation.*
- *Water requirement for fire fighting to be met through water storage tanks. The effective capacity of the tanks above the level of suction point should be minimum 4 hours aggregate capacity of the pumps.*

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 37

The integrity of Natural Gas Pipeline System is achieved through continuous efforts at all stages to ensure that pipeline is designed, commissioned, operated and maintained as per stipulated codes, standards and guidelines.

Continual technological up-gradation in operation, inspection and maintenance enhances the safety of pipeline system and increases overall safety to great extent.

“ Conference on Technology, Capacity Development, Disaster Risk Reduction of Hazardous Industries, Ports and Storages of Petroleum, Petroleum Products and Natural Gas ” 38