

# Risk Associated with Cross-Country Natural Gas Pipeline

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## **Abstract: -**

In today's modern world, Natural Gas & Diesel are profoundly used as fuels. The increasing demand of over 8 % per year & the distance between the sources of supply to consumer points has necessitated the transportation of the gas across the length and breadth of the country. Both Natural gas & Diesel are highly flammable fuels & naturally there would be risk factor involved in transporting them in pipelines. This paper is intended to compare the risk posed by transportation of Natural Gas & Diesel in a cross country pipeline. Risk is quantified as the threat posed by the installations to Man, Materials & Environment.

## **Background: -**

Natural gas is the cleanest burning fossil fuel used mostly by the power and fertilizer Industry in India. Cross-country pipeline transportation seems to be the most preferred convenient, economical & reliable option. High pressure of NG (30 -100 bar) and inherent hazards of fire and explosion associated with NG handling poses a major threat to the users and the society at large.

Natural Gas & Diesel are profoundly used as fuels, some of the major uses are listed below

## **Uses of Natural Gas: -**

- |                            |   |
|----------------------------|---|
| <b>Power generation</b>    | – Electricity generation through use of Gas turbines & Steam Turbines.              |
| <b>Domestic use</b>        | – Cooking, Heating, Cooling, Drying, etc.   |
| <b>Transportation Fuel</b> | – Cleaner alternative to other fuels like petrol, gasoline, etc.                    |
| <b>Fertilizer</b>          | – Major feedstock in production of ammonia, which is important feed to fertilizers. |
| <b>Aviation</b>            | – New aircraft models to be run on LNG.   |

Natural gas is preferred over other fuels like diesel since;

1. It is a **clean** fuel,
2. **High Calorific Value.**
3. **Cheap** as compared to other conventional fuels like Diesel, Petrol, etc.

The above paragraphs depict the profound uses of both diesel & Natural Gas. But what about the

hazards associated with them?

**Hazards associated with Natural Gas: -**

The hazards associated with natural gas are predominantly flammable in nature. Natural gas is relatively less toxic.

**A) Various kinds of Fires are as follows**

**Jet fire: -**

Typically, Jet fire is associated with release of Natural gas. Jet fire scenario depends upon the diameter of pipeline & the leak size. If the natural gas pipeline has a leak at a certain point in its path and given that an ignition source is available, Jet fire consequence occurs. Jet fire is usually not associated with Rupture of pipeline.

**Pool Fire: -**

Pool fire is usually not associated with natural gas. Pool fire occurs when a flammable liquid spills & forms a pool over a surface and given that a ignition source is present.

**Flash Fire: -**

Flash fire occurs due to a sudden intense fire caused by ignition of flammable materials. It is characterized by high temperature, short duration, rapidly moving flame front, & considerable shock waves. Flash fire is usually more prominent with leak of natural gas rather than rupture.

**B) Explosion : -**

**Vapour cloud explosion / Late explosion: -**

Late explosion usually occurs if the fluid accumulates in confined area. In case of Underground Cross country pipelines, the release of natural gas can find confinements in the form of dense vegetation and buildings, however because of this and lighter nature of Natural gas this is relatively a rare occurrence.

Late explosion occurs when a flammable material is dispersed in atmosphere & after some delay an ignition of the vapour cloud. Late explosion usually requires a confinement for the gas to get accumulated. Since cross country pipelines are usually underground, late explosion is less prominent for natural gas.

Recent incidents related to natural gas are presented in Box 1

**Box 1 : Recent incidents with Natural Gas Pipelines:**

S.No	Date	Location	Brief Description	Damage
1	30 <sup>th</sup> July 2004	Belgium	A underground Natural Gas Pipeline about one meter (yard) in diameter operated by FLUXYS exploded at around 8.30 a.m.	Numerous buildings & cars in the immediate area have been destroyed by the blast, at least 15 people including 5 fire personnel died & more than 120 were injured.
2	21st August 2004	Pennsylvania	A domestic natural gas pipeline explosion caused by the rupture of 2 inch dia pipeline at butt joint	Residence destroyed killing two people
3	2nd July 2003	Wilmington	A natural gas service line was dug with a backhoe. Although the service line did not leak where it was struck, the contact resulted in a break in the line inside the basement of a nearby building, where gas began to accumulate.	The explosion destroyed two residences and damaged two others to the extent that they had to be demolished

**Some Common Causes of Failure for Natural gas pipelines: -**

The reports on natural gas pipeline incidents for the 10-year period have been reviewed under the auspices of the Pipeline Research Committee of the American Gas Association.' For the review, the failures were categorized by causes and the prevention measures are discussed below.

**1. External Force**

- Encroachment
- Weather Related

**2. Corrosion**

- External Causes
- Internal Causes
- Grooving Corrosion Of Electric-Resistance Welded Pipe

**3. Defective Pipe and Welds**

**4. Equipment Malfunction and Operator Error**

**5. Other Causes – Miscellaneous**

Due to the above mentioned reasons the natural gas pipelines poses risk to Man, Material and Environment.

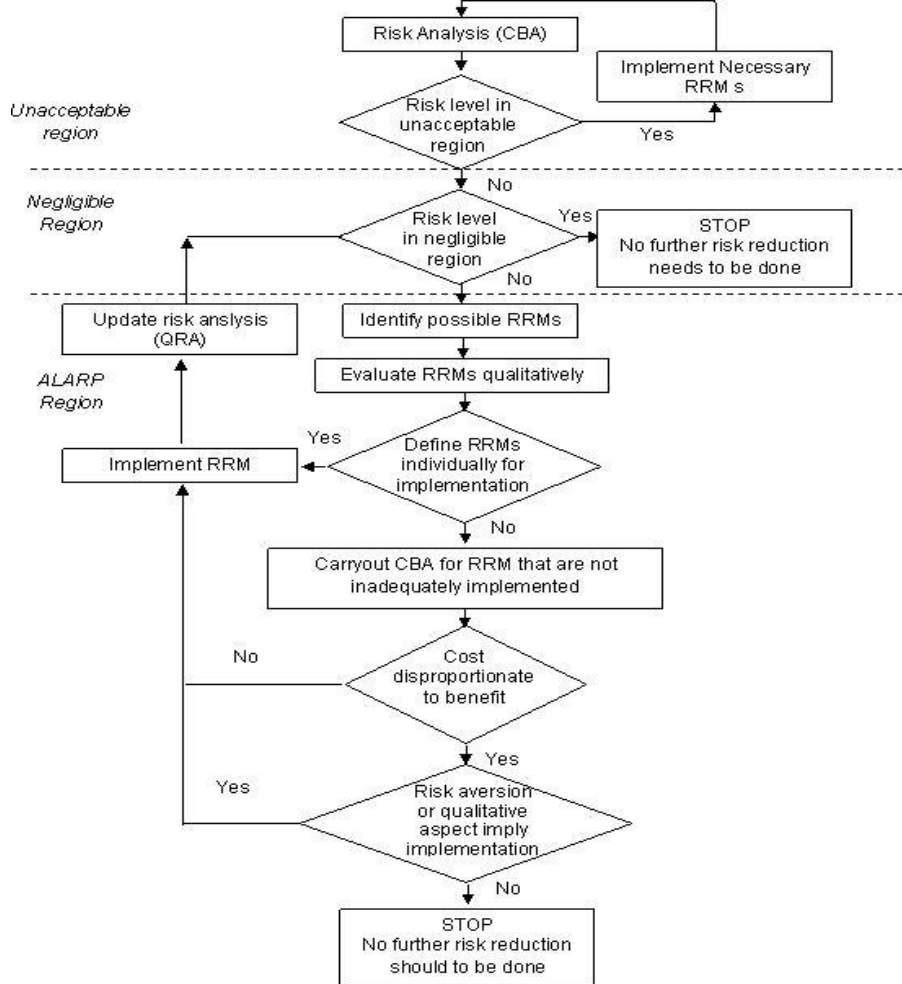
## Methodology of Quantitative Risk Assessment

U.S. Environmental Protection Agency considers risk to be the chance of harmful effects to human health or to ecological systems. Risk consists of two variables, magnitude of consequences and the probability of occurrence. The harmful effects can then be either effects on individuals or effects on groups (society). Thus, Risk is usually represented as Individual risk & societal risk. **Individual risk** is the frequency at which an individual or an individual within a group may be expected to sustain a given level of harm (typically death) from the realization of specific hazards. **Societal risk** involves the concept of the summation of risk within specific population groups

As discussed above, with such huge demand of natural gas, certain risks are bound to occur. The question arises as to how should we mitigate & minimize these risks. **Quantitative risk assessment** is used worldwide as an efficient tool to evaluate & minimize risk. Quantitative Risk Assessment (QRA) provides a quantitative estimate of the risks posed as well as enabling risk mitigation methods to be evaluated so that risk can be reduced to acceptable levels.

In case of QRA, risk is usually calculated by estimating the risk of fatality per year for an individual. Two main inputs required are; firstly, likelihood of occurrence of certain event & secondly, measure of consequence of the event, which is the effects in distances from the facility. Risk is a product of two which gives the individuals & society's fatality per year.

### Model Flow Chart for Risk Evaluation and acceptance



### Is the risk associated with Natural Gas pipeline Acceptable or Unacceptable?

Estimation of the risks posed by the pipeline transportation has always been a valuable input both the designers and statutory authorities are looking at. Various sophisticated models approved by EPA, USA, Netherlands Disaster Prevention Committee are in use in estimation of damage distances arising due to fire, explosion and gas dispersion etc. The selection of suitable software and parameters for consequence modeling is crucial for risk estimation. Care must be exercised in selecting the scenarios and consequence effects to be pragmatic in the risk assessment as far as Natural Gas is concerned. Some of the earlier assumptions that the explosion would not happen in case of Natural gas leak because of its lower gas density have been proved wrong by past experiences. Similarly the buried pipelines of Natural gas are not completely free from significant consequences. Gas leaks in the underground pipelines have caused craters and also fires in the past.

To find out whether the risk associated with a natural gas pipeline is in acceptable or unacceptable region; let us have a case study for transportation of natural gas in a cross country pipeline.

In order to justify the utility of Natural gas over other conventional fuels like diesel, gasoline, etc. let us compare the consequences analysis results of Natural gas and a conventional fuel like diesel.

The conditions for transporting Natural Gas through a pipeline of length 150 KM at ambient temperature & pressure of 40 bar & transporting Diesel through a pipeline of same dimensions at ambient temperature & pressure of 10 bar.

The prominent accident scenarios in case of Cross country natural gas pipeline are: -

1. Leak of pipeline.
2. Rupture of pipeline.

Reputed software **PHAST 6.51** and **SAFETI Micro V 6.51** developed by **DNV UK** is used for evaluation of risk

#### Summary of Input parameters and possible outcomes

Scenario	T Deg. C	P Bar	F m <sup>3</sup>	Late Explosion(m)	Jet Fire(m)	Late Pool Fire (m)
Leak of Natural Gas pipeline.	35	40	41.667	Available	Available	Not Available
Rupture of Natural Gas Pipeline.	35	40	416.67	Available	Available	Not Available
Leak of Diesel pipeline	30	10	41.667	Available	Available	Available
Rupture of Diesel pipeline.	30	10	416.67	Available	Available	Available

#### LEGEND:

- T → Temperature  
P → Pressure  
F → Flow Rate

With the above details & considering weather conditions of 1.5 F & 6 D, we arrive at the following results,

### Summary of Results for Late Explosion:-

S.No	Scenario	Damage Distances in mtrs					
		1.5 F			6 D		
		0.03 bar	0.1 bar	0.3 bar	0.03 bar	0.1 bar	0.3 bar
1	Leak of Natural Gas pipeline.	145.51	113.67	101.82	140.10	111.37	100.67
2	Rupture of Natural Gas Pipeline.	510.47	366.82	313.34	478.50	347.45	298.66
3	Leak of Diesel pipeline	143.06	87.24	73.23	95.25	57.83	43.90
4	Rupture of Diesel pipeline.	440.95	285.17	254.27	285.95	173.57	131.73

### Analysis of results

The following results are calculated assuming that the confined is available for natural gas & diesel. From the above table it is evident that Rupture of natural gas pipeline creates a damage distance which is higher than that of diesel pipeline. For a leak in pipeline leading to late explosion under weather condition of 1.5 F the damage distances for Natural gas and diesel are almost same for an overpressure of 0.03 bar.

### Summary of Results for Jet Fire

S.No	Scenario	Damage Distances in mtrs					
		1.5 F			6 D		
		4 kw/m <sup>2</sup>	12.5 kw/m <sup>2</sup>	37.5 kw/m <sup>2</sup>	4 kw/m <sup>2</sup>	12.5 kw/m <sup>2</sup>	37.5 kw/m <sup>2</sup>
1	Leak of Natural Gas pipeline.	61.88	47.69	37.35	62.10	48.73	38.66
2	Rupture of Natural Gas Pipeline.	212.95	147.29	109.03	212.41	152.63	113.92
3	Leak of Diesel pipeline	16.81	NR	NR	27.96	26.65	NR
4	Rupture of Diesel pipeline.	16.81	NR	NR	27.96	26.65	NR

### Analysis of Results:-

The Heat of Combustion of Natural gas (54 KJ/g) is higher than diesel(45 KJ/g) and naturally the damage distances for natural gas is higher than that of diesel.

Frequency of occurrence of Jet fire is equally prominent in both Natural gas & Diesel. Rupture of Natural Gas Pipeline will cause the maximum damage. Damages due to natural gas pipeline are significantly higher than diesel especially in case of an rupture

### Summary of Results for Late Pool Fire

S.No	Scenario	Damage Distances in mtrs					
		1.5 F			6 D		
		4 kw/m <sup>2</sup>	12.5 kw/m <sup>2</sup>	37.5 kw/m <sup>2</sup>	4 kw/m <sup>2</sup>	12.5 kw/m <sup>2</sup>	37.5 kw/m <sup>2</sup>
1	Leak of Natural Gas pipeline.	NA	NA	NA	NA	NA	NA
2	Rupture of Natural Gas Pipeline.	NA	NA	NA	NA	NA	NA
3	Leak of Diesel pipeline	110.78	52.85	NR	126.35	52.71	NR
4	Rupture of Diesel pipeline.	284.35	161.71	NR	313.09	160.49	NR

**Legend: -**

NA → Not Available

**Analysis:**

For a late pool fire scenario to occur, a pool of the fluid should essentially be formed. In case of Natural gas, this is not usually possible. Hence, late pool fire scenario is not available for Natural gas. Rupture of Diesel pipeline will cause the maximum damage.

**Risk Presentation for Natural Gas & Diesel: -**

For evaluating the risk posed by a facility we need to see both the frequency of occurrence and the consequence. This is expressed in terms of Individual Risk and Societal risk i.e The risk posed by the facility to an Individual and to a group of people, this is usually expressed in terms of Probability of death per year.

These values are calculated based on the base event frequency, ignition probability, population density in the area etc. The accident event frequency details taken from Purple book (CPR 18 E). Based on the inputs the results evaluated are as shown below: -

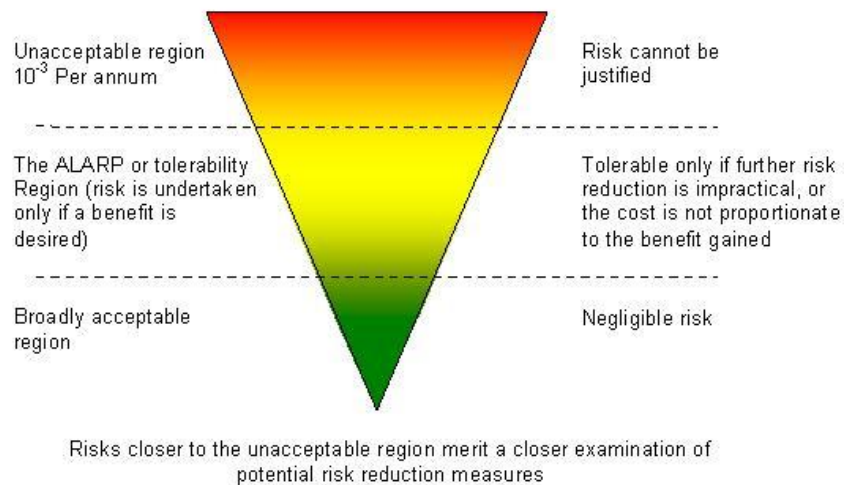
Scenario	Leak of Natural Gas pipeline	Leak of Diesel pipeline	Rupture of Natural Gas Pipeline	Rupture of Diesel pipeline
Individual Risk per Year	1.1941 E-4	3.0923 E-3	9.3742 E-5	1.4607 E-3

**Analysis:**

Comparing the risk posed by both the installations, the Rupture of Diesel pipeline has the highest Individual risk values. The Individual risk for this scenario is 1.3091 E-3 per year. The risk posed by the Leak of Natural Gas pipeline is the lowest. The risk for this scenario is 1.5884 E-4. This

analysis shows that the risk posed by Diesel pipeline is more as compared to Natural Gas pipeline. The reasons for this because of the difference in probability of occurrence of incidents, lighter nature of Natural gas and dispersion nature of Natural Gas as compared to diesel.

Risk criteria denote whether a specified risk is acceptable or unacceptable. The acceptable risk criterion is yet to be defined in the Indian context, but the values employed in other countries can be employed as stated in IS 15656: 2006 (Code of practice on Hazard Identification and Risk Analysis). In this context a term ALARP (As Low as Reasonable Possible) is generally used. The below diagram describes the ALARP methodology: -



The risk posed by natural gas falls under ALARP region but we need to take measures to ensure that it falls under acceptable limits.

Although the damage distances for Natural gas are more, the likelihood of occurrence of the events is quiet low for Natural gas as compared to diesel.

Comparing the Individual risk values for both natural gas & diesel, we can conclude that the risk posed by the Rupture of Diesel pipeline is high as compared to that of other facilities

The above evaluation for transporting Natural Gas & Diesel in a long pipeline of the same length but at different conditions reveals that although the damage distances for Natural gas pipeline are more as compared to that of Diesel, the individual risk values are high for Diesel.

**Conclusion: -**

From the above discussion we can conclude that apart from the explicit advantages of being a cleaner fuel with high calorific value it is safer from transportation risk point of view also.

### Acknowledgement: -

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### 7. References: -

S. No	Description
	<b>National Standards</b>
1	Indian Standard IS 15656:2006 – Code of practice on Hazard Identification and Risk Analysis
2	OISD 138 – Inspection of Cross country pipelines – On shore
3	OISD 139 – Inspection of Pipelines – Off Shore
4	OISD 141 – Design and construction requirements for cross country hydrocarbon pipelines
5	OISD 117 – Fire Protection Facilities for Petroleum Depots and terminals
	<b>International Standards</b>
1	API 581: Risk Based Inspection, Recommended practice
2	GE Codes: Institution of Gas Engineers and Managers
	<b>Websites</b>
1	<a href="http://www.ukopa.co.uk/publications/">http://www.ukopa.co.uk/publications/</a>
2	<a href="http://www.hse.gov.uk/pipelines/hseandpipelines">http://www.hse.gov.uk/pipelines/hseandpipelines</a>
3	<a href="http://www.nationalgrid.com/uk/Gas/">http://www.nationalgrid.com/uk/Gas/</a>
	<b>Other References</b>
1	Committee for the Prevention of Disasters, Netherlands- Guidelines for Quantitative Risk Assessment CPR 18 E (Purple Book), 2005.
2	Frank P Lee's, Loss Prevention in the Process Industries, 2001
3	Quantitative Risk Assessment study for Town Gas Company for Greater Cairo City, November 2006
4	J R Taylor's, Risk Analysis for Process Plant, Pipelines & Transport.