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# Development Design of Risk Study of Natural Gas Pielines Dissemination and Substainment Upgrade of Safety Enactment

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***Abstract: The study describes the basic features, design, maintenance, and risks of natural gas transportation. The paper begins with a discussion of the natural gas distribution networks, which complete the natural gas transit. Accidents on the distribution gas line might jeopardize urban safety. The primary dangerous implications of a natural gas pipeline breakdown are outlined. Correct design, installation, and maintenance limit the incidence and severity of these accidents: a quick summary of the key technical requirements.***
***Keywords: Release rate, Natural Gas pipeline, Natural gas pipeline design, Risk assessment.***

## I. THE GAS CONTENT DELIVERY SYSTEM

### *A. Major Features and Components*

Transporting natural gas (NG) from a wellhead to a residence or company requires a complicated transportation infrastructure that is safe and dependable.

Pipes, valves, compression stations, pressure control stations, metering stations, pressure vessels, pulsation dampeners, and relief valves vent NG when safety conditions are not maintained.

Fig 1: Compression of NG

There are three main types of NG pipelines: collection, transmission, and dissemination. Transmission pipes transmit NG to pre-processing factories or storage facilities. The distribution system delivers NG to end-users.

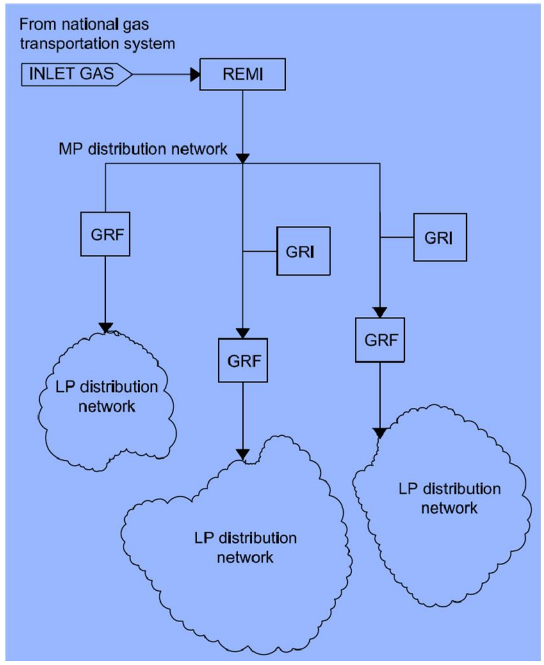


Fig 2: NG dispersal system

Nigeria's gas transmission system includes:

*1)* A first pressure lowering station (REMI): NG from the national transportation system (SNAM) is reduced to 5 barg.
*2)* Medium-pressure pipelines: NG is carried at 0.5-5 barg.
*3)* A second station reduces NG pressure to 40 mbarg (GRF).
*4)* Industrial pressure decreasing stations (GRI).
*5)* GN substation: NG is carried at 18-40 mbarg.
*6)* A component is a piece of equipment.
*7)* Anti-corrosion systems
*8)* System of remote control

Fig 3: Station for reducing the force of pressure.

*B. Analyzed Gas Delivery System Risk*

A system, component, or structure fails when it performs an unanticipated function, such as a leak, rupture, break, or loss of pipe operability (Alzbutas, et al., 2014). A ruptured NG pipeline may endanger persons and property nearby. To assess the risks of NG transport, NG firms must assess the possibility of an unfavorable event occurring (Alzbutas, et al., 2014). The risk analysis tool used to manage industrial safety is mainly aimed at identifying possible hazards and reducing risks (Z.Y.Han et al., 2010). This manner, any leakage hazards may be assessed, and if negative, the system project can be re-defined.

The approach suggested by (Z.Y.Han, et al., 2010). It includes:
*1)* Probability estimation based on the kind of failure evaluated.
*2)* Pipeline accident consequences study, requiring technical examination to quantify accidents.
*3)* Risk evaluation is a mathematical function of the chance of an accident occurring and the resulting consequences.

The second step of risk analysis defines the repercussions of a pipeline failure. An isentropic adiabatic expansion may characterize the leakage dynamic. A pipeline may cause four types of risks to human safety. Contaminated gas diffusion may be disregarded. When NG escapes from a pipe, it is diluted with air at the leaking site, and the resulting vapor/air combination is not flammable. An instantaneous igniting produces a jet fire, a diffusion flame. Instead, if the ignition is delayed by the leaking, two occurrences may occur. Unconfined Vapor Cloud Explosion (UVCE). A fireball arises when a gas leak generates a continuous vapor cloud but does not mix with the air. A UVCE occurs when a gas leak aggressively combines with air, forming a flammable vapor cloud.

The main threat from NG leakage is thermal radiation from a continuous jet flame. It is possible to imagine the jet flame as a succession of point sources of heat emitters. Figure 4 shows the total heat flux received by a ground level damage receptor by condensing the collection of heat emitters into a single point source emitter (Z.Y. Han, et al., 2010).

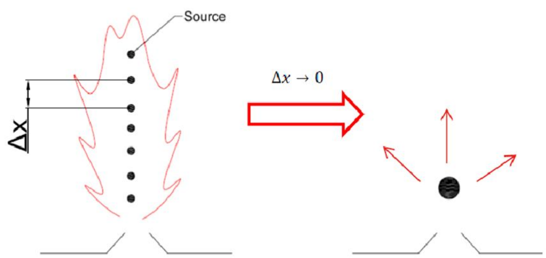


Fig 4: Idealization of jet fire. The flame is a collection of point sources that merge at ground level.

According to Alzbutas et al. (2014), the heat flow I(r) [W/m2] from a point source at a range r [m] is as follows:

$$I(r)=F\square\frac{Q}{4\square r^2} \quad (1)$$

Where:
- F is the radiated heat fraction.
- $\square$ is the Wayne's correlations which can determine atmospheric transmissivity (Wayne, 1991).
- Q is the net combustion release rate, [W].

The heat flux may also be defined as a function of the rupture gas flow (Alzbutas, et al., 2014). If We is the effective gas release rate, then Ki is the heat of combustion [J/kg]:

$$I(r)=F\square\frac{W_e\square K_i}{4\square r^2} \quad (2)$$

There is a peak in the original event, and then a decline. (Crane, 2009) shows that the first peak is:

$$W=\frac{C_d\square d^2}{4}\square p\frac{\square}{a_0} \quad (3)$$

Where:
- $C_d$ is coefficient of discharge gas.
- d is the gas passage's diameter, [m].
- p is the difference in pressure between interior and outside gas, [Pa].

- $\square = k \left(\frac{2}{k+1}\right)^{\frac{k+1}{2(k-1)}}$, and *k* is the gas's specific heat ratio.
- $a_0 = \sqrt{\frac{kRT}{M}}$, is the gas's sound speed, [m/s].
- *T* is gas temperature, [K].
- *M* is molecular weight, [g/mol].
- *R* is the gas constant, [J/K mol].

Due to a change in mass flow, both the flame size and the radiation intensity of a flame change. It is easier to calculate by using We=2 W, where We is the flow reduction coefficient, and it assumes a value of between 0.25% and 0.5%, which is used as an effective gas flow model (for a more conservative procedure).
That's why leakage after a rupture is critical for risk analysis and to ensure that correct requirements are observed during preliminary design or, in the event of a failure, operators can quickly estimate the amount of released gas to assess possible dangers or calculate financial losses before delaying their response for too long.
A non-dimensional model based on mass conservation, momentum, energy, and the equations of state was created to quantify NG leakage (Maloudi, et al., 2014). Relative dimension (the ratio between burst hole diameter and pipe diameter) has been shown to influence release flow among a defined range of strain (from 60 $p_{sig}$ to 1000 $p_{sig}$) in the case where D hole≤0.15D pipe, whereas in the case where $D_{hole}>0.15D_{pipe}$, internal gas pressure influences release flow.

Hole Model:

$$\dot{m}_l^+ = 0.506 D_e^{+2} - 0.002 D_e^+ \quad (4)$$

Full Rupture Model:

$$\dot{m}_l^+ = \exp\left(-0.31 + 0.28 \ln(D_e^+) - 1.02(\ln(D_e^+))^3\right) F_b \quad (5)$$

Where:

- $\dot{m}_l^+$ is the dimensionless flow rate defined as
  $\dot{m}_l^+ = \dot{m}_{leak} / \dot{m}_{gas}$
- $D_e^+$ is the ratio of pipe diameter to hole diameter.
- Fb is coefficient of friction in relation to the diameter of the hole, defined as Fb= Lpipe/Dpipe.

A basic model is also available (Jo, et al., 2002). The model assumes gas leakage is characterized by isentropic expansion. This simplified model is not precise, but the inaccuracy is acceptable for safety applications. The simplified model implies that the danger distance from gas facilities is directly impacted by the release rate; specifically, the danger distance is equal to the square root of the extraction yield.

$$r_{hazard} \propto \sqrt{\dot{m}_{leak}} \quad (6)$$

Thus, the simple model overestimates distance by 3.9% to 20%.

*1) Engineering, Components, Corrosion Control, and Leakage Detection*
The elements that affect pipeline dependability and safety are detailed in (Thomas, 1981). The occurrence of leakage is related to pipe design and operating characteristics is:

$$\square F_{-tot} = \square BaseKFB \quad (7)$$

Where:

- $\square_{F\text{-}tot}$ is the total leakage rate.
- $\square_{Base}$ is the base-line rate of leakage (suggested in the range $[10^{-7};10^{-9}]$ failure per year.
- K is the pipe system's size, kind, and number of fittings.
- F is system age factor.
- "B" is the design learning curve factor.

According to (Lydell, 1999), this association should only be employed if real failure data are unavailable. Technically, ASME B31.8 “Gas transmission and distribution pipe system” outlines the necessary material selection, maintenance procedures, and environmental corrosion management. The piping system design is based on the location class factor, which is allocated to the geographic region where the pipeline will be constructed. The site class may range from 1 to 4: 1 corresponds to sparsely inhabited regions, while 4 covers places with multistory buildings and other subsurface service pipelines.

This factor is critical in pipeline design, determining piping thickness for a given gas inner pressure and steel pipe outer diameter:

$$p=\frac{2St}{D}FET \qquad (8)$$

Where:

- p is the piping pressure design, in psig.
- D is the OD (outer diameter), in.
- t is the thickness of the wall, in.
- S is the material's minimum yield strength, psi.
- F is the place-class-factor (values in table 1).
- E is the long-joint factor.
- T is the derating factor (temp) (values in table 2).

Table 1: place-class-factor values.

| Location class | Design Factor |
|---|---|
| Location Class 1, Division 1 | 0.80 |
| Location Class 1, Division 2 | 0.72 |
| Location Class 2 | 0.60 |
| Location Class 3 | 0.50 |
| Location Class 4 | 0.40 |

The predicted wall thickness should withstand internal gas pressure as well as other loads without harm. As shown in table 1, for the identical design circumstances and exterior diameter, a pipeline placed in Class 1 should be half the thickness of a pipe put in Class 4.

Table 2: derating factor (temp)

| Temperature, [°C] | Derating Factor |
|---|---|
| 120 or less | 1.000 |
| 150 | 0.967 |
| 176 | 0.933 |
| 204 | 0.900 |
| 232 | 0.867 |

There are minimal distances from other subterranean pipes, roadways and trains. In addition, appropriate steps should be taken to safeguard the line, such as increasing wall thickness, building revetments, and placing anchors.

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Because human interaction is the main cause of line rupture, the Code defines the depth of installation as a function of ground type and site class.

External corrosion is a major issue throughout the life of a steel pipeline. This decreases the actual wall thickness. A potential safety issues.

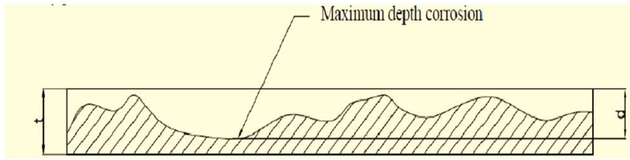


Fig 5: Affected area of corrosion.

Whereas, if new wall thickness cannot yet withstand internal pressure, a repair intervention is necessary. The test first determines the corrosion depth d (inches) and the corrosion length L (inches) along the longitudinal axis, then calculates the non-dimensional factor A:

$$A=\frac{0.893L}{\sqrt{Dt}} \qquad (9)$$

If A is less than or equal to 4.0, the pipe can resist the following pressure (psig):

$$P'=1.1P\frac{\left(1-\frac{2d}{3t}\right)}{1-\frac{2}{3}\left(\frac{d}{\left(A^2+1\right)^{0.5}}\right)} \qquad (10)$$

The maximum allowed operating pressure (MAOP) is the systolic pressure at which a gas network may be operated at the design pressure (the maximum pressure authorized). Any time A is higher than 4.0, then

$$P'=1.1P\left(1-\frac{d}{t}\right) \qquad (11)$$

As long as the MAOP is below P', operators may keep the damaged area in operation and prevent additional corrosion. If MAOP is more than P', the gas pressure in the corroded area should be lowered or a repair intervention performed.

Unless the material can withstand the installation environment, every new pipeline should be externally coated and cathodic protected. The NACE (National Association of Corrosion Engineers) publishes "The Corrosion Data Survey" which contains information regarding material enactment.

However, it is critical to observe the occurrence throughout time. The frequency of inspections is determined by:

- Pipeline issues.
- Method of cathodic corrosion employed.
- Installation environment corrosiveness
- Loss or lapse of protection.
- Inspection and leak investigation experience
- Employee or public safety

Other components may be utilized than steel. One is ductile iron, which is iron with granular spheroidal graphite. Plastic is confined to mains and service areas in normal distribution systems with 100 psi or less pressure.

Plastics have the same wall thickness design as steel:

$$p=2S\frac{t}{D-t}\times 0.32 \qquad (12)$$

When using thermoplastic pipe and tubing, S is the long-term hydrostatic strength obtained in line with the specified specification at design temperature.

Copper, like plastic, can only be utilized at low pressures and with low hydrogen sulfide concentrations.

As stated before, gas leaks may cause human fatalities and economic losses. They are straightforward to prevent using the Code.

1) Surface gas monitoring survey: constant sampling of the atmosphere near the ground. In bad weather, this test is useless.
2) A combustible gas indicator (CGI) or equivalent equipment capable of detecting 0.5 percent gas in air is used to sample the subterranean atmosphere.
3) It employs eye observations to identify aberrant or uncommon occurrences in vegetation.
4) Pressure drop test: evaluates whether an isolated pipeline section leaks.
5) Bubble leakage test: exposed pipe is sprayed with soapy water to check for leaks.
6) In this test, the amount of ultrasonic energy owing to gas leakage is determined. This approach is difficult to employ when an ultrasonic background is present.

The choice of instrument is critical to obtaining accurate findings; nonetheless, instruments should be used in accordance with the manufacturer's instructions.

## II. FUTURE TRENDS AND INDUSTRIAL APPLICATIONS

To reduce the risk of a gas pipeline breakdown, one must first understand its causes. With this knowledge and research effort, it is feasible to identify the steps that must be done in case of a gas accident. In reality, a quick response strategy may save lives and improve network operators and firefighters' response.

As stated in 1.3, it is critical to size and build gas pipelines safely. During service, several phenomena interact, including internal gas pressure, corrosion, earthquakes, and external stresses from third parties. When the interconnections between these phenomena are unknown, operators of gas distribution networks frequently oversize the pipeline. This strategy increases expenses and so extends the investment's payback time. Furthermore, the sustainment program cannot be streamlined, and network operators may plan sustainment services ahead of time to prevent risk, increasing yearly service variable costs. As a result, future study should focus on analyzing interactions between phenomena to better understand sizing relationships.

Finally, a comprehensive monitoring and data collecting system may identify various errors before they occur, providing the user with real-time network information. Using this method, network operators can better determine the severity of an unexpected occurrence. This system is made up of a central operator interface and process instruments positioned along the line.

Many equipment should be placed along pipes to improve network monitoring. However, the acquisition of instruments raises capital costs. From an industrial standpoint, it is critical to do a feasibility assessment that compares the cost increase to the cost decrease owing to fewer failures and the optimization of sustainment plan.

## III. CONCLUSIONS

This document describes the NG transportation and distribution system. The main safety risks, resulting from gas leaks, are reported. As stated in the literature, the main threat to human safety is jet fire. An evaluation of thermal radiation from jet fires is thus presented, and its dependence on leakage flowrate is shown. The mass flow rate may be calculated in three ways, each of which overestimates the leakage compared to the theoretical solution. In one, the danger distance for jet fire is shown to be related to the leakage squared. For the preliminary design of NG dispersion systems, ASME B31.8 specifies material specification, wall thickness calculation, corrosion control and gas leak detection. In particular, a technique for estimating the need for repair interventions when a corrosion defect.

## IV. ACKNOWLEDGEMENT

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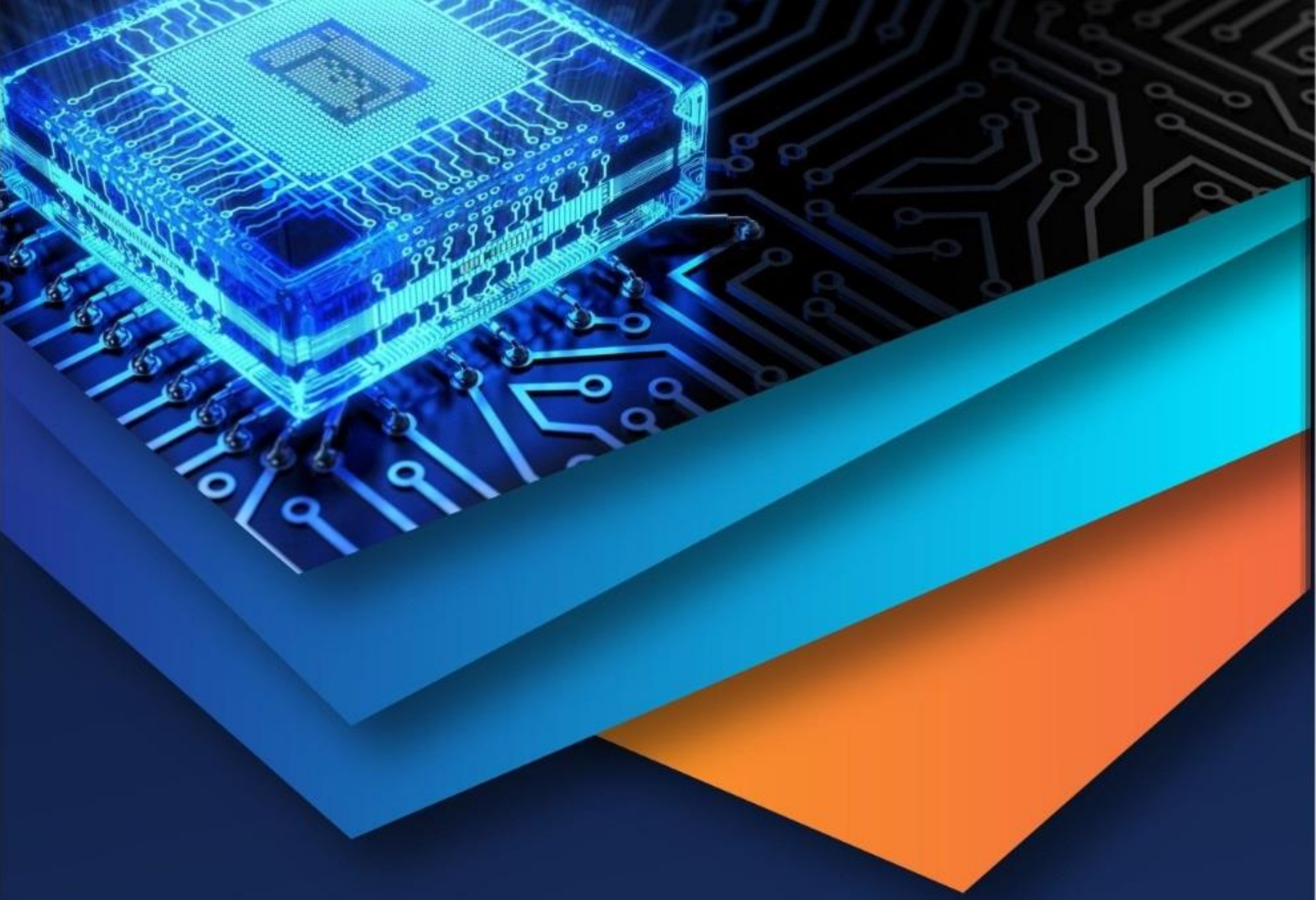

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