CONTROL OF MAJOR ACCIDENT HAZARDS ON THE ALGERIAN SECTION OF THE PEDRO DURAN FARELL GAS PIPELINE (GPDF\TRC\SH)

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Abstract: Pipelines transporting hazardous material such as natural gas has being recognised as being major accident potential. This potential threat is increasing with the growing demand on natural gas that instigates the realisation of further gas pipeline systems.

In this context the present paper aims to present an integrated approach that could prevent and control the major hazards which might rise from operating high pressure gas pipelines.

This approach includes firstly, a Safety Management System which has to be melt in the general company management system and has to have effective and compatible interfaces with the different stakeholders' activities. Secondly, it is a risk based approach that is supported by a structured risk assessment process which identifies the potential major hazards and quantifies their eventual consequences as well as their likelihood using deferent risk assessment techniques. Thirdly, this approach sets out and puts in place cost effective prevention and mitigation measures able to ensure the control of eventual major hazards. This approach must be fully implemented under the accountability of the line management and has to be supported by the top management in order to ensure its effectiveness.

Keywords: gas pipeline, major accident hazard, risk analysis, individual risk, Safety Management System.

1. INTRODUCTION

Pipelines must provide a safe method of transporting hydrocarbons, and pipeline operators have to ensure that people, environment and property are fully protected from any risks associated with their pipelines.

The pipeline operators control these risks by complying with the regulatory requirements and national codes, and they perform in general additional activities where there is a perceived need, or where analysis or experience has shown that there is a need. Nevertheless, Regulatory regimes are generally 'prescriptive', and will not be adaptable to differing pipelines with differing needs and associated risks. This presents the dual problems of firstly potentially 'missing' new risks, and secondly creating an inflexible environment for operators to apply new technologies that can both identify and mitigate the key risks.

The UK Piper Alpha Inquiry concluded that a purely prescriptive regime in which all safety and integrity requirements are defined by law has been proved to be inadequate [1]. Accordingly regulatory authorities in Europe, USA, and Canada are moving away from '*prescriptive*' approaches to pipeline design and operation, to *'goal settings'* or *'risk management'* approach as the safest and most cost effective means of maintaining and improving safety levels in pipelines especially preventing and controlling major accident occurrence . This approach put the duty on the pipeline operator to demonstrate the effectiveness of the dispositions, the measures and the arrangements put in place to ensure the safe operating of its asset. To do that, the operator has to produce a very detailed document which demonstrates how he will deal with every single situation which may lead to a major accident. This document has to encompass MAPP (Major Accident Prevention Policy), a SMS (Safety Management System), and Key Risk Control Systems and all the arrangements that have to be implemented to create a risk free environment within which all the company activities should be carried out.

2. MAPP & SMS

Effective management involves agreeing objectives, defining a plan to achieve those objectives, formulating detailed work to implement the plan, checking outcomes against the plan, and then planning and taking appropriate corrective action. Safety management in general and management of major accident hazards in particular, is no exception to this general principle.

One of the central elements of Major Accident Control is the formulation and documentation of an organisation's overall intentions and direction of the organisation related to its safety performance in a Major Accident Prevention Policy. With this policy, the safety objectives, targets and improvement programs are established. These objectives, targets and programs must then be deployed and shared through the whole organisation. In contrast to the Major Accident Prevention Policy, objectives and targets concretise what should actually be improved. Targets are usually fairly specific, measurable and time-framed goals, whereas objectives are goals that are more specific than the stated aims, or say, ambitions in the policy.

The theoretical route for implementing the MAPP outlined above appears relatively straightforward. In practice, however, most organisations find it a real challenge to establish effective objectives and targets.

In relation to the management of health, safety and the environment in general, the SMS is the combination of management arrangements and risk control systems for ensuring satisfactory standards of health and safety and compliance with health, safety and environmental legislation.

2.1. Major Accident Prevention Policy Statement

GPDF as part of the national Oil & Gas Company Sonatrach draws inspiration for their safety heath and environment objectives from the Sonatrach HSE policy. However, this policy is not specific for the case of major accidents, therefore it is very important to establish a MAPP not just for GPDF but it should be set by Sonatrach top management and coming down to the bottom line management.

The following statement is an example of what could be a MAPP.

The GPDF is committed to:

- Achieve a high standard of protection for people and the environment and make available all the necessary resources to fulfil it;

Set the necessary roles and responsibilities of personnel involved in the management of major hazards at all levels in the organisation, including contractors where appropriate, and the provision of training to meet identified training needs;

Provide and maintain the arrangements for systematically identifying major hazards arising from normal and abnormal operation and the assessment of their likelihood and severity and execute remedial actions;

Set and maintain the arrangements and procedures for safe operation, including maintenance of the asset, processes, equipment and temporary stoppages;

Provide and maintain the arrangements for planning modifications to, or the design of new installations;

Provide and maintain the arrangements for identifying foreseeable emergencies by systematic analysis and to prepare, test and review emergency plans to respond to such emergencies;

Make available the arrangements for the ongoing assessment of compliance with the GPDF objectives and the mechanisms for investigation and taking corrective action in the event of failing to achieve the these objectives; and

Set and maintain the arrangements for periodic systematic assessment and upgrading of the MAPP and the effectiveness and suitability of the SMS.

2.2. Safety Management System:

The SMS is one part of the pipeline management system. The SMS may also be integrated within a management system which addresses other matters such as quality and corporate image. It must be recognised that the approach towards developing the MAPP and providing and implementing the SMS will vary from company to company, reflecting the overall management philosophy, system and culture.

The safety management system should cover the part of the general management system which includes the organisational structure, responsibilities, practices, procedures, processes and resources for determining and implementing the MAPP.

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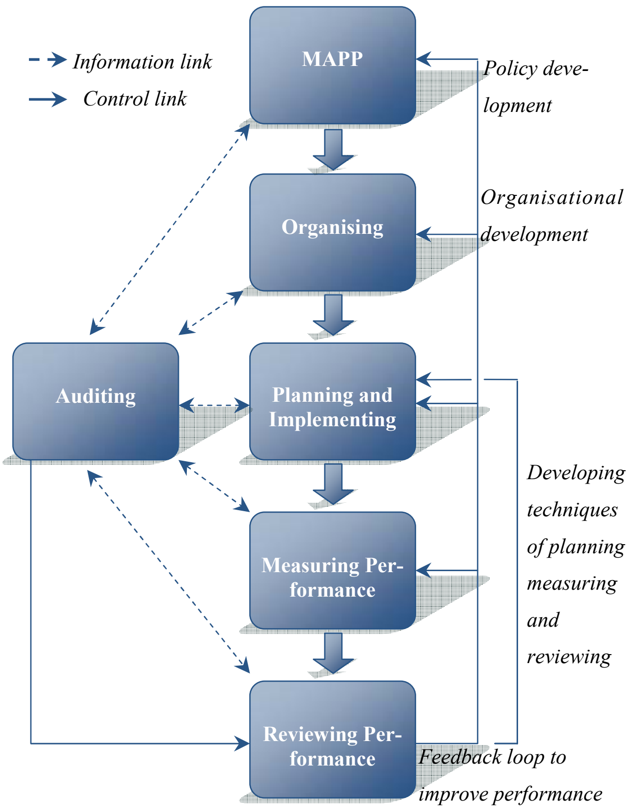
HSE publication HS(G)65 "Successful Health and Safety Management" [2] describes the essential elements for effective management of health and safety. These elements are:

- Policy
- Organising
- Planning and Implementing
- Measuring performance
- Reviewing performance
- Auditing

These elements are inter-linked and are subject to auditing as shown in the HS(G)65 health and safety management system model in fig.1.

a)Policy: It should set out a clear direction for the organisation to follow. It should also reveal the organisation's intention to attain and maintain high standards of health and safety and the commitment to continuous improvement. The policy should establish the health and safety management system and the responsibilities for achieving its objectives.

Organising**:** Organising for health and safety needs both management and employees to be actively involved and committed to the policy. This participation is achieved by ensuring management control, the



effective co-operation of employees and their safety representatives, the establishment of an effective safety communication system, achieving co-ordination of activities and ensuring the competence of the entire personnel.

b)Planning & Implementing: It requires a systematic approach to implement the policy and establish an effective management system to minimise risks. Risk assessment methods should be adopted to establish priorities and objectives for eliminating hazards and reducing risks. If possible, risks should be firstly eliminated by the selection and design of facilities, equipment and processes. If risks cannot be eliminated, they should be minimised through the use of physical controls or, as a last resort, through safe systems of work and the use of personal protective equipment.

c)Measuring Performance: It reveals how effectively the health and safety management system is functioning. This can be done both from an active and a reactive perspective. Active monitoring is intended to measure the achievement of objectives and standards. This involves inspections and checks to ensure standards are being implemented and that the management controls are operating correctly. Reactive monitoring involves the collection and analysis of failures of the health and safety management systems.

Organisations need to learn from accidents, ill-health, property damage and near misses. Information from both active and reactive monitoring can be used to identify causes of failures or substandard performance and to refine the management system to prevent recurrences and to improve performance.

d)Review of Performance: The systematic review of performance should be based on both the data from monitoring and the results of audits of the management system. The review should consider the standard of compliance with the health and safety policy and legislative requirements, the accident and ill-health performance and how well objectives have been met.

e) Auditing: Audits are necessary to make sure that the company organisation, processes and procedures as defined and as actually carried out in practice are consistent with the SMS and that they are effective. Audits need to be carried out by people who are sufficiently independent of the operational management of the unit being audited to ensure the objectivity of their assessment.

The elements discussed above are a mixture of management arrangements, systems which determine how particular risks are to be controlled (risk control systems) and workplace precautions. Fig.2 illustrates the concept adapted to the control of major accident hazards.

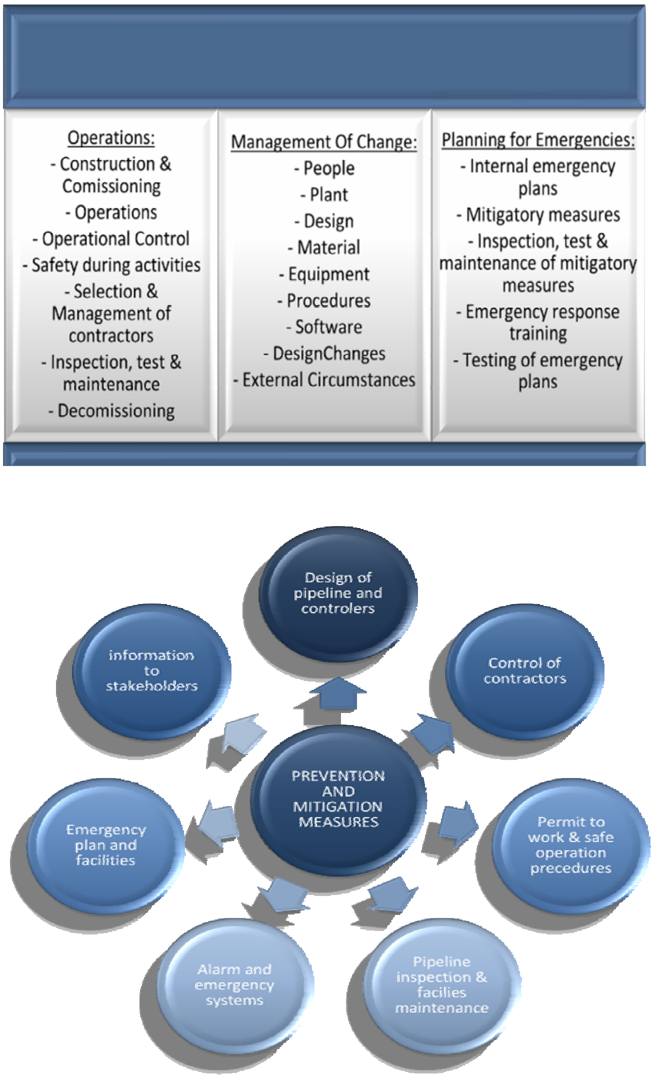
3. RISK ANALYSIS

The purpose of this risk assessment is to identify the hazards, that are related the Pedro Duran Farell Gas Pipeline (GPDF) and have the potential to cause major accidents.

This risk assessment will be limited to the pipeline and will not cover the deferent associated facilities.

GPDF is a 48" and 1,400 kilometres gas line connecting Algeria to Europe through a link under the Strait of Gibraltar.

Fig.2. The Control of Major Accident Hazards Concept.



The pipeline's flow rate is about 11 billion cubic meters of gas per year. It transports natural gas from the National Centre of Gas Dispatching (CNDG) towards Spain and Portugal via Morocco. The Algerian section of this pipeline extends on 530kms and crosses 3 Wilayates (districts) Laghoua, El Bayadh and Naama.

The pipeline pressure varies all along the line, the four scraper trap stations, and the compressor station SC3 which is required to generate enough pressure for gas movement. The 530 km Algerian section has 27 sectionalising valves dividing the pipeline in 28 sections of approximately 18 km. Supervisory Control & Data Acquisition (SCADA) system for electronic monitoring of pipeline is done for the entire stretch of pipeline from the control station.

3.1. Failure Modes & Hazard Identification

Failure of gas pipeline can occur due to a number of different causes such as external interference, corrosion, natural failure, mechanical defects and sabotage as discussed below:

Third Party Interference: Third party damage refers to any accidental damage done to the pipe as a result of activities of personnel not associated with the pipeline [3]. The Pedro Duran Farell Pipeline passes through quite remote rural areas which have a low possibility for major construction operations. However, there are some activities that can incur potential third party damage, and they include the following:

- Vehicles and Trains traffic on the road and truck crossing.
- Farming and tillage activities where mechanical equipments are used in areas where the minimum cover became eroded because of overburden removal as a result of flooding, land erosion or washout from trench due to drainage patterns.
- Excavation activities related to construction activities.

Corrosion: Corrosion is the deterioration of material caused by its environment [4]. Pipeline failure caused by corrosion is by far the most familiar hazard associated to steel pipelines. The Pedro Duran Farell Pipeline is protected against corrosion by means of a high quality anticorrosion coating. In case of damage to the coating, there will also be an impressed current cathodic protection system. However these will not exclude the potential of pipeline corrosion failure which could happen in case of:

- Failure of the cathodic protection system due to inadequate maintenance.
- Above ground pipeline where cathodic protection system is not effective and thus the possibility of corrosion.
- Buried pipe under disbonded coatings, as disbondment causes cathodic protection shielding.

Natural Failures: Natural failures include damage to pipeline caused by land movement, floods, and heavy rains. The GPDF is routed through a sub-arid area where environmental events such as extreme flooding or drought may result in changes in the ground level, and affects the integrity of the pipeline. The pipeline crosses also a number of Oueds, which are streambeds that are dry most of the year except in the event of heavy rains. These Oueds are subject of very rapid change due to water erosion and then can cause pipeline failure.

Mechanical Defects: Mechanical failure encompasses construction, welding and metallurgical defect in the pipeline material. The GPDF pipeline was constructed and tested according to the ASME Code (American Society of Mechanical Engineering) before bringing into service in order to ensure the quality of the pipe's material and welding operations. The defects detected by the different tests were fixed and the pipeline retested to ensure its integrity. Though, all the tests effectuated prior to the pipeline start the affirmation that the pipeline is free from any imperfection is not possible because there must have been defects on the pipeline that could not be detected by the testing procedure. Thereby it is not excluded that mechanical defect may result in the failure of the pipeline especially with the increase of operating pressure entailed by the sustained increase of natural gas demand.

Sabotage or terrorist attack: Sabotage is mainly a direct attack against the pipeline owner. Pipelines are attacked because of their strategic value, their vulnerable locations pipelines are other reasons [3]. In case of GPDF the attack against this pipeline is mainly considered as:

- An indirect attack against the Algerian government since the pipeline belongs to the national Oil & Gas Company Sonatrach.
- A protest for political or social reasons.
- A means to undermine international confidence in the Algerian government's ability to fulfil their natural gas supply contracts.

The ignition of the important quantities of released gas results in a significant threat of damage to people and properties in the immediate vicinity of the pipeline failure mainly from heat radiation is the dominant hazard.

3.2. Consequences Analysis

Leaks from pipeline can result in Jet flow, which on ignition can lead to Jet fire. The levels of incident thermal radiation can affect people and property in the vicinity of an ignited pipeline release. The area of hazard associated with the damage will depend on the mode of pipeline failure, time to ignition environmental and weather conditions at the failure point.

$$Pr = -36.38 + 2.56 \ln (tI)^{4/3} \quad (1)$$

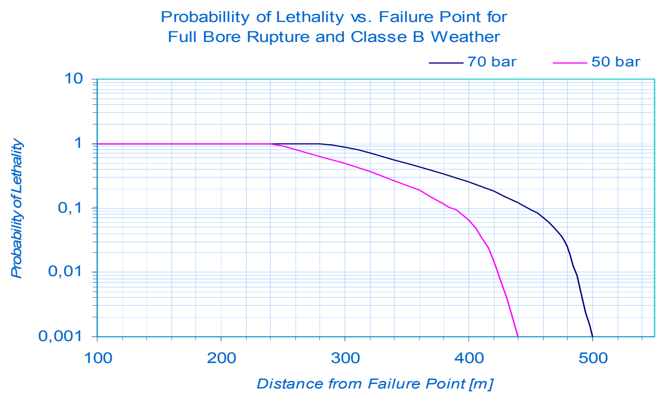
Where:

t: is the time of exposure, seconds

I: is the intensity of exposure (related to distance from flame), kW/m^2

Based on 60 second exposure duration to an unprotected person, probabilities of fatality relating to heat radiation exposure to an exposed person are calculated for the considered scenarios. Fig.3 is an example of the calculations

Fig.3. Probability of Lethality vs. Lateral Distance from Pipeline for full bore rupture in class B weather.



(1) ALOHA 5.4 (Areal Locations Of Hazardous Atmospheres). The CAMEO® Software System Computer-Aided Management of Emergency Operations, U.S. Environmental Protection Agency

3.3. Frequency Assessment

The database of European Pipeline Incident Data Group (EGIG) [6] representing almost 2.77 million kilometre year of pipeline operations was used to determine a failure frequency for this gas pipeline. The failure rate reported by EGIG for on-shore gas pipeline with design pressure greater than 15 bar is 4.44 x 10^{-4} per km per year. The EGIG data base did not provide failure frequencies by hole size.

In contrast The UKOPA data base [7] gives the percentage of leak incidents by hole size over the period 1962 - 2004 and it reveals that:

81 % are pinholes (less than 20 mm).

12 % are medium holes (20 mm to 40 mm).

07 % are large holes (40 mm to more than 110 mm).

The UKOPA shows also that 4 % of high pressure gas transmission pipeline incident in the UK are full bore ruptures. 50 % of pipelines ruptures are caused by external interference [6]. Combining the two data base stated above;

we can estimate that Full Bore Ruptures which represent 4 % of the pipeline incidents according to UKOPA data base have a failure frequency of 1.83 x 10^{-5} failure /km yr.

The Leaks which represent 96 % of the cases have a failure frequency of 4.26 x 10^{-4} failure /km yr.

The failure frequencies discussed above were used in Event trees for quantifying the probability of hazardous incident outcomes. The EGIG data base gives the possibility to evaluate the link between the leak size and the probability of ignition. However, the available data bases do not give information to estimate the delay time between the release onset and the ignition moment. For pipeline rupture scenarios which are mainly caused by external interference such as digging machines, it is assumed that the ignition is most likely to occur and the 0.9 probability is chosen. The ignition probabilities used in the event tees for the other scenarios are mainly driven from the EGIG data base. The assumptions made upon early and late ignitions probabilities will not affect the result as the flash fire resulting from late ignition will lead to a jet fire which is the same out come as in early ignition.

The assumptions concerning the meteorological conditions are made upon the information available on the National Climatologic Atlas.

The probabilities discussed above are illustrated in the following event trees (Fig.4) as well as the consequences scenarios.

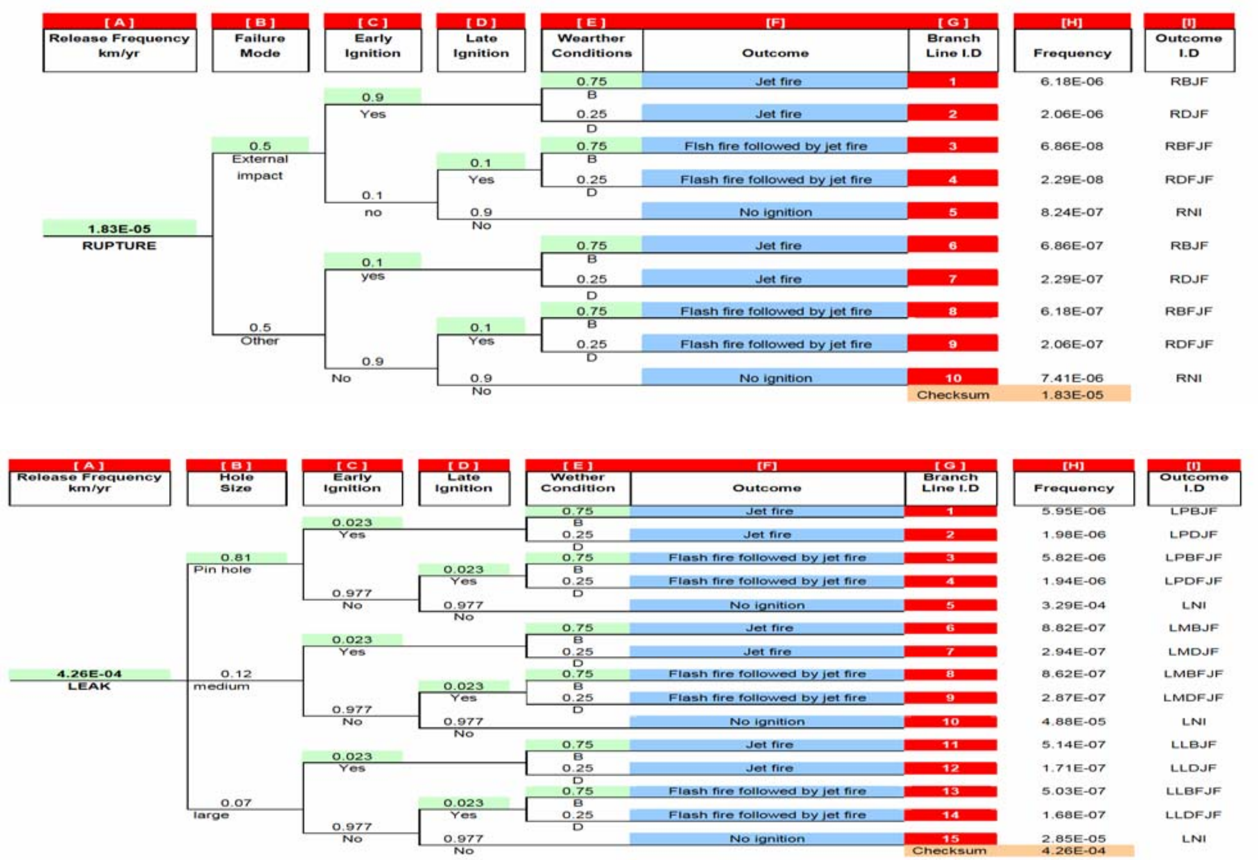


Fig.4. Fault trees for GPDF full bore rupture and leak.

3.4. Risk Assessment

The GPDF Pipeline does not pass into or in vicinity of populated areas, therefore, the present risk assessment will be limited to the estimation of the individual risk of fatality, and will not include evaluation of societal risk.

The consequence of all identified hazardous incidents and their different hazardous distances are combined with the estimated frequencies to assess the risks to the areas surrounding the Pipeline.

The results of this assessment were plotted against the distance from the centreline of the pipeline to develop a set of IR transects.

The IR transect for a pipeline is derived by calculating the individual risk as a function of lateral distance from the pipeline. The IR is a maximum directly above the pipeline, and decreases as we move away from the pipeline until reaching zero. The risk at any given location is a function of:

- The lateral distance from the pipeline (measured at a right angle);
- The risk of a release from the pipeline (measured as the frequency of a release per year per kilometre of pipeline);
- The distance from the release at which an observer at a given location would be affected by the release (called the "range of hazardous effect") [8].

Effective length is used in the risk calculation to estimate the frequency of releases that could affect a given point, since pipeline release frequency is expressed as releases per km per year and so must be multiplied by the effective length to obtain a frequency as releases per year.

The effective length is calculated as follows:

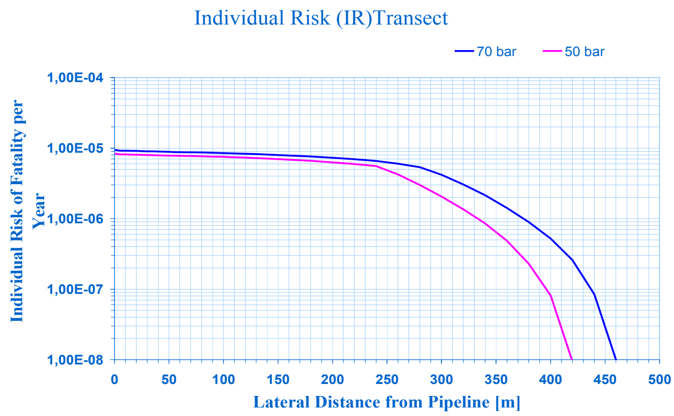
$$L = 2\sqrt{h^2 - a^2} \qquad (2)$$

Where:

h: is the hazardous distance within which a person will be effected by the incident outcomes.

a: is lateral distance from the pipeline.

When pipeline internal pressure is higher the range of hazardous effect is greater because this increases effective length and then, in the event of a release, risk levels near the pipeline increase for a higher pressure since a given location could be affected by a greater length of pipeline.



The actual likelihood of a release does not increase at higher pressure, because the pipeline is designed to contain the higher pressures. Fig.5 illustrates the IR transects for the pipeline at the operating pressures.

The level of IR from the pipeline is acceptable since it is lower than 10^{-5} per year above the pipeline and goes down under 10^{-6} per year starting from 370 m away from the pipeline (see Fig.5). These risk levels are considered as acceptable especially for the GPDF Pipeline which does not cross populated areas, Furthermore the data used in calculating the frequencies of different scenarios are highly conservative for the raison that the European and the UK underground are more congested and their population densities are much higher than the one the GPDF Pipeline crosses.

4. CONCLUSION

On the light of this study the following conclusions could be drawn:

- Major accident prevention have to involve risk assessment process initiated in the design stage and go along side to side with the different activities through the hole life pipeline including construction, commissioning, operation and decommissioning.
- The implementation of the major accident control system should involve all those who their activities has an effect on the pipeline system or could be affected by it in order to be sure, to be sure and to be sure that nothing is left uncontrolled.
- The prevention of major accidents on the pipeline is the responsibility of the pipeline operator but it not limited to him.

- Pipeline major accident prevention must be started and leaded by the pipeline operators and has to be extended to the local authorities, legislators and even the surrounding community; every one has an important role to play in order to ensure effective major accident prevention.

The risk assessment is a very structured tool that has an important role in the decision making process.

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