DESIGN OF LEAK DETECTION SYSTEM FOR LPG PIPELINE

A Project Report Submitted in Partial Fulfillment of the

Requirement For the Degree of

MASTER OF TECHNOLOGY
IN
PIPELINE ENGINEERING

By

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Dehradun

May, 2010

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A thesis submitted in partial fulfilment of the requirements for the Degree of

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CERTIFICATE

This is to certify that the work contained in this thesis titled "DESIGN OF LEAK DETECTION SYSTEM FOR LPG PIPELINE" has been carried out by Abhishar Gautam under my supervision and has not been submitted elsewhere for a degree.

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Nomenclature

LPG =liquefied petroleum gas

Q=Flow rate, (MMTPA)

D=Pipe internal diameter, (m)

Pkm=Frictional pressure drop (KPa)

Sg = specific gravity

P_{ELEV} = pressure loss due to elevation.(KPa)

H= difference in the altitudes of two places.(m)

G=specific gravity of the LPG

h=Head loss due to valve or fittings.(m)

K=Head loss coefficient for the valve or fitting, dimensionless

V=Velocity of liquid through valve or fitting (m/sec)

g=Acceleration due to gravity (m/sec^2)

GPM=gallons per day

bbl= billion barrels

Abstract

LPG is liquefied petroleum gas which is a mixture of propane (C_3H_8) and butane (C_4H_{10}) and other components in some amount. The LPG is a lighter fuel and odour-less too, difficult store and transport.

When LPG is being transported to through pipeline it is done under high amount of pressure and being pumped (i.e liquid state) from one place to another place, to ensure no credible loss to the social and environment concern.

In the design of the leak detection, we may use simple theories of pressure difference and quantity difference between two points of the pipe-segment.

The design is based on the pressure profile variation of the LPG inside the pipeline after considering the losses that takes place during the transmission viz.

a. Pressure loss due to liquid properties (using an empirical relation to find)

b. Pressure loss due to the elevation

c. Minor pressure loss due to fittings etc.

The above mentioned pressure loss are solely responsible for the drop in pressure any other certainty of pressure drop in the section would lead to the leak only, LPG being lighter will make the pressure to drop abruptly too.

Hence when the pressure of the system falls below the allowed one and the quantity received at the receiving terminal of the system.

A program in C++ language is made in order to make the calculation for the same purpose and the data is being calculated on the given conditions of system.

The assumptions are being taken in order to make the calculation which are fair enough to support the calculation.

This work aims at making a general system for detection of leak in the LPG pipeline system and facilitate the user to see the online status of the pipeline at the different length (at one kilometer distance), so the operator judges the drop manually too.

Chapter 1

1.Introduction

There are very few now who are not familiar with Liquid Petroleum Gas because most of the houses now-a-days use LPG cylinders for cooking purposes and of late it is also being used as the fuel for vehicles but very few know about it in details.. LPG is obtained as a by-product when refining crude oil or natural gas and is primarily composed of propane and butane with smaller amounts of propylene and butylenes. These belong to the category of hydrocarbons and Liquid Petroleum Gas has three or four carbon atoms and apart from these hydrocarbons there are negligible amounts of other hydrocarbons as well, which are present. Ethane-thiol is combined in LPG for its characteristic smell so that leaks can be detected easily. Though these are the standard components of Liquid Petroleum Gas, the percentage of each component differs from season to season. In summers the percentage of butane is more than propane and winters the percentage of propane is more than butane. Due to its composition, which is rich in hydrocarbons, LPG evaporates at normal pressure and temperature of atmosphere; therefore it is canned under pressure. LPG can be moved in cans and pipelines and utilized in places far from the place of production, which makes LPG quite popular. The temperature at which Liquid Petroleum Gas gets converted into the liquid form is called Vapor Pressure. To allow Thermal Expansion of LPG the cans are not filled with LPG to the brim, approximately 12% to 18% is kept empty so that even if the volume of LPG increases it does not exert much pressure on the walls of the can..

1.1 USES

LPG is used as a fuel in vehicles, for cooking and also as coolant of late so that the usage of Chlorofluorocarbons can be avoided which causes Ozone layer depletion Hydrocarbons as coolants in air conditioners at home or in vehicles are a good option since they are more energy efficient and need less pressure but there is always the risk of fire since LPG is highly flammable. So it has to be used only when the risks of fire has been taken care of by decreasing the chances of leakage and accidents. LPG as a coolant is also very cheap and does not have the Greenhouse effect as well.

1.2 LPG applications

INDUSTRIES	APPLICATIONS
Agriculture	grain drying/ weed killing/preservation of fruits/tobacco curing/tea drying
Automobile	Heat treatment and paint baking
Ceramics	Biscuit and gloss firing of porcelain and stoneware
Chemicals and drugs	Heating and drying
Electrical	Bulb and tube light manufacturing /filament manufacturing/battery manufacturing
Food	Baking /boiling/frying/drying
Glass	Melting/holding/feeding/working/fire polishing
metallurgical	Annealing billet/heating/descaling/stress relieving//moulds/cupola/ etc
Metal working	Steel working/hole piercing/welding of non-ferrous metals
Packaging	Metal box soldering
Transport	Automotive fuel
miscelleneous	aerosols propellant and other wider applications

LPG stands for liquefied petroleum gas which is being used as a domestic Fuel in many parts of world especially in developing countries, moreover LPG being considered as a clean fuel for automobiles too.

The main constituent of LPG are propane(C_3H_8) and butane(C_4H_{10}) and some other traces of hydrocarbons like iso-propane etc, being a mixture of lighter hydrocarbon it is difficult to handle the LPG at normal conditions.

LPG is considered as clean and normal fuel which is odour less and taste- less in nature, having a boiling point around -40^{0}c at normal pressure condition such as atmospheric level.

LPG almost caters around 37 % of the domestic needs of India and this would grow with the future demand of the domestic users such as living in the western part of the country in 2012.

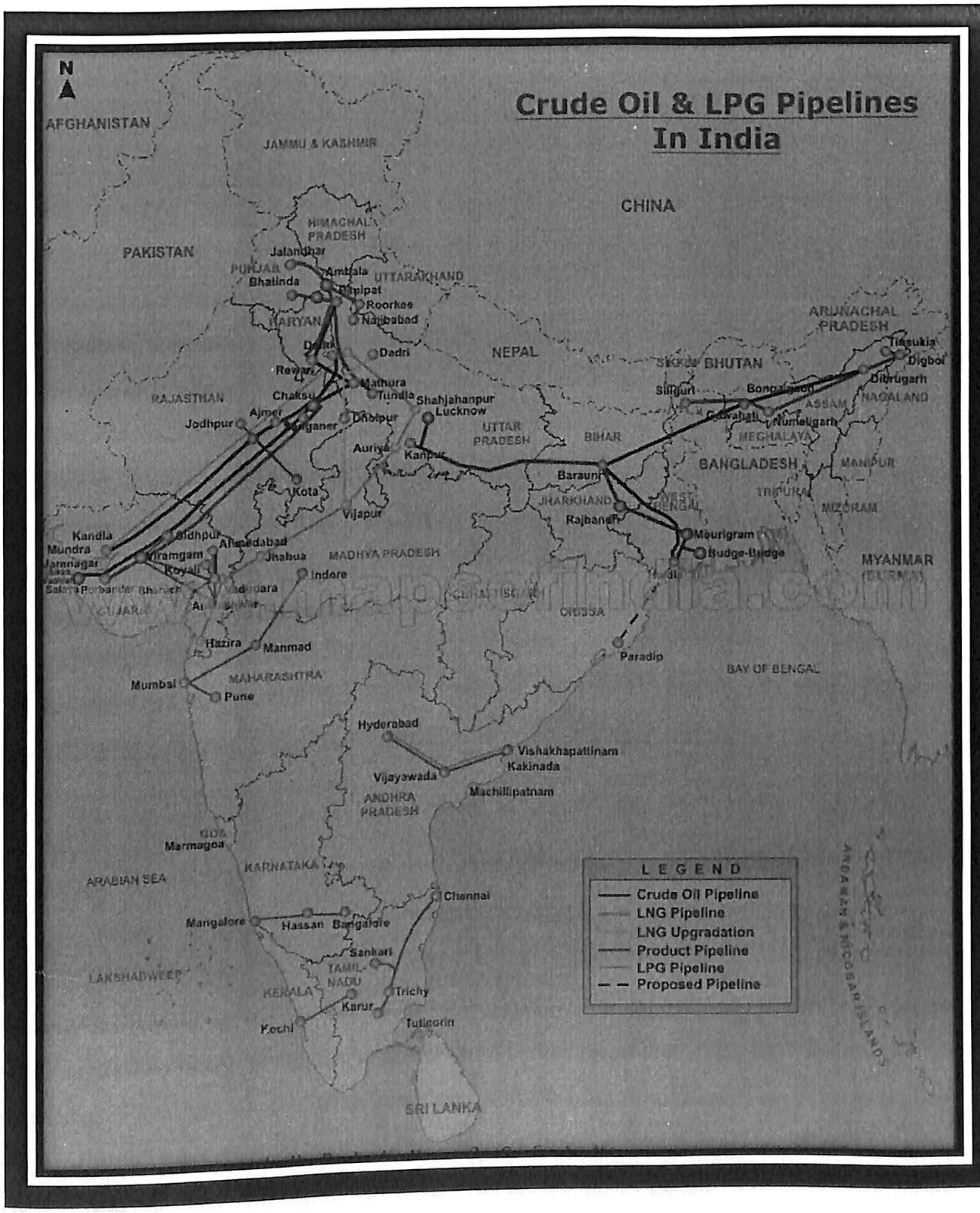
1.3 LPG demands in future

Liquefied petroleum gas (LPG) is used for domestic fuel in India, where the demand is mainly concentrated in the northern, central, and western regions. Locally, LPG is produced by GAIL India, Oil India Limited, Oil and Natural Gas Corporation (ONGC), and India Oil Corporation (IOCL) from natural gas and oil refineries. At present, demand for LPG is higher than local supply, and the deficit is projected to increase further, especially in the northern region in areas close to Delhi. The deficit is filled by imports from the Gulf States.

The hydrocarbon sector in India is critical to infrastructure development. An efficient hydrocarbon sector was expected to play a major role in the success of India's overall economic development and the overall reform program initiated in India in early1990s.At appraisal, country operational strategy for India was to support efforts of the Government designed to achieve higher sustainable economic growth, promote employment, and reduce poverty. To achieve the intended economic growth, ADB's focus was primarily on (i) improving the supply side efficiency of the economy, especially by reducing bottlenecks in the hydrocarbon sector; and (ii) placing greater emphasis on improving policy, institutional, and regulatory frame-works, to enhance the efficiency of public sector operations and encourage private investment Thus, since the demand for LPG in the northern region is projected to grow to 2.6 MMTPA by 2006/07 and 3.5MMTPA by 2011/12.

Despite considerable LPG use in urban areas, demand remained un served in the lower income groups in urban areas, due to their relatively poor access to LPG. In addition to unmet demand in urban areas, use of LPG in rural areas, particularly in northern India, was insignificant due to availability and supply constraints. In view of this, a idea is formulated the Project to promote LPG use in rural areas and increase the access of low income groups in urban areas to LPG. The Project was also designed to improve the environment by replacing the existing LPG road and rail transport mode with a pipeline transport mode and substituting, in rural households, LPG for non commercial and polluting fuels, such as wood, dung cake, and crop residues. The Government has also been actively promoting the use of LPG in rural areas, through its ninth and tenth plans .In 1997, only 27% of rural households were using LPG, and the Government planned to increase the level of LPG use by 1% each year to reach 10% of rural households by 2006/07. This was to result in a total LPG coverage of 37% of all Indian households. As a part of the Project, tapping points were to exist along the route of the pipeline, to encourage the use of LPG in rural areas.

1.4 LPG Pipeline network of India



In recent years pipelines has emerged as an extremely efficient and economic mode of fluid transportation and distribution system. Various industries in the pipeline transportation sub - sector use transmission pipeline to transport materials such as crude oil, natural gas and refined petroleum products. Pipeline system can be broadly divided into three types.

1. Main transmission system
2. Regional transmission system
3. Distribution system /grid

The pipeline infrastructure constitutes fundamental part of a nation's economy. In most countries gas transport and distribution system consist of a large set of highly integrated pipeline network operating over a wide range of pressures. UK has one of the largest pipeline distribution network in the world with many houses and businesses supplied from an extensive national grid primarily, run by a state owned entity named British Gas (BG).

City gas distribution in India is poised for a big leap with the extension of the project to thirty cities in different states by 2009 besides Mumbai and Delhi. Two hundred more cities are likely to be on the city gas distribution map in due course.

GAIL was the first company in India to pioneer city gas distribution project. In addition to marketing Natural Gas through Trunk and Regional Transmission systems, GAIL has formed joint venture companies to supply gas to households, commercial users and the transport sector. Within the short span of 10 years, GAIL has expanded its CNG business from 1 company (Mahanagar Gas Ltd.) in India to 8 in India and 4 abroad.

Gas supplied by GAIL to retail gas distributors serves more than 3,00,000 automobiles as Compressed Natural Gas (CNG) and over 3,30,000 households as Piped Natural Gas (PNG) in the cities of New Delhi, Mumbai, Vadodara, Vijaywada, Hyderabad, Kanpur, Agra, Lucknow. Gail's **Project Blue Sky** is gearing up to execute city gas projects in others cities in India including Pune, Kota, Indore, Gwalior, Ujjain and cities in Kerala and Karnataka through Joint Ventures. They have signed a Memorandum of

Understanding with Infosys Technologies to develop City Gas Distribution Software, leveraging the IT Expertise of Infosys and the domain expertise of GAIL.

1.5 Advantages of Pipelines

For the transport of large quantities of fluid (liquid or gas), a pipeline is undisputedly the most favoured mode of transportation. Even for solids, there are many instances that favor the pipeline over other modes of transportation. The advantages of pipelines are:

1.5.1 Economical in many circumstances. Factors that favour pipelines include large throughput, rugged terrain and hostile environment (such as transportation through swamps). Under ordinary conditions, pipelines can transport fluids (liquids or gases) at a fraction of the cost of transportation by truck or train.Solid transport by pipeline is far more complex and costly than fluid transport. Still, in many cases, pipelines are used to transport solids because the cost is lower than for other modes of transportation, such as trucks.

1.5.2. Low energy consumption. The energy intensiveness of large pipelines is much lower than that of trucks, and is even lower than that of rail. The energy intensiveness is defined as the energy consumed in transporting unit weight of cargo over unit distance, in units such as **Btu per ton mile**. compares the energy intensiveness of pipelines to those for other modes of transport.

1.5.3. Friendly to environment.

This is due mainly to the fact that most pipelines are underground. They do not pose most of the environmental problems associated with trucks and trains, such as air pollution, noise, traffic jams on highways and at rail crossings, and killing animals that strayed on highways and railroads. Oil pipelines may pollute land and rivers when a leak or rupture develops. However, far more spills would occur if trucks and trains transported the same oil.

1.5.4 Safety and reliability: The pipeline are considered to be the most safer means of transfer of fluid under pressure and rest method are threat in some ways or the other to the environment or people of the place. Reliable and continuous means of transport is often guaranteed from pipeline.

1.6 Threats to Pipeline as LPG carrier:

With the increase of the demands and continuity, a need of a continuous supply system is needed for the purpose of the meeting the demands and its constraints, pipeline is always been considered to be the most reliable continuous source for the transportation of the LPG, a further more advantage of the pipeline is to serve the swinging demands too, the capacity of the pipeline can be increased or decreased depending upon the condition of service required.

The LPG pipeline in India mainly contain world's longest LPG pipeline was commissioned by GAIL to facilitate transportation of imported LPG and LPG production from the indigenous units at Jamnagar to the northern region. In addition to it IOCL, India has laid its first cross-country LPG pipeline with an initial capacity of 700,000MT, which is 277 km long starting from the Panipat to Jalandhar with a terminal facility at Nabha.

With these two landmark pipeline India is growing in the pipeline network for the LPG as the demand is touching a toll of over 3.5 MMTPA for the users of the GAIL, India by the year of 2011-12.

With the growing network of the pipeline a need to increase the integrity of pipeline must be increase and makes it fail-proof system in all respect.LPG being an explosive fuel can cause threat to the society and environment if something bad takes place

1.6.1Risk involved with bulk LPG pipeline transportation

LPG is transport in Liquid form under high pressure conditions. When released in air due to leak possesses the following risk:

1.6.2 Highly flammable

The LPG is a mixture of lighter fuel like propane and butane which are highly flammable in nature and having boiling point well below zero degree Celsius when released in normal temperature and temperature condition. Propane being more violent then the butane and cause danger too.

1.6.3 Settles and flows around

The LPG has a property of being settles and make a spill pool and tend to flow around, all over the surface of the pipe.

1.6.4 High liquid to vapor ratio

Being liquefiable LPG has high liquid to vapor ratio and hence difficult to handle.

1.6.5 High increase in pressure due to rise in temperature

The temperature rise of LPG can increase the pressure of the system hence dangerous to transport under variant conditions presented due to various factors.

1.6.6 Vaporizes suddenly, lowers temperature which may cause frost burn

Being Lighter in nature LPG vaporizes suddenly cause cooling of the pipe surface and produce the frost burn or change in the pipe material micro-structure sometimes brittle cracks can be developed.

1.6.7 Lower viscosity and poor lubrication

The LPG has lower viscosity and poor lubricant in nature hence a need of internal lubricant and corrosion allowance has to be given or provided to the pipeline.

1.6.8 Risk of vapor cloud explosion

The LPG has a highly mixture formation capacity for good temperature ranges present, hence this has to be avoided for the point of removing the explosion chances.

1.6.9 Risk of the BLEVE (VAPOURS FORMED FROM FLASHING LIQUIDS)

The LPG handling have a problem of flashing out from the high pressure to the atmosphere with the formation of vapour or gets out from the superheated form and cause the explosion conditions emerged from the unconfined vapour cloud explosions.

The above mentioned eight problem that can be existed separately or together can exist if LPG leaks out from the pipeline space, being an highly inflammable fluid the LPG is a great danger to the things around it.

Hence there is a need to detect out the leak in a LPG pipeline within less time and accuracy so many system philosophy has been developed till date. And many more improvements are still on in this area.

These method covers manual surveys to the satellites one but the accuracy of the system is the overall question which is needed to be answered to the operator of the line.

1.7 Pipeline leak phenomena

When the leak occurs measured downstream pressure of the pipeline will fall down but the pressure at the point of leak predicted to rise. it is not difficult to understand that line is depressurizing as the mass leave through the hole. on the other hand the equation predict the pressure based on predicted mass flow reduces too. As the mass leaves through the hole a real time loss of pressure at the downstream takes place.

1.8 Methods of leak detection

There are various kind of method available for the purpose of the detection of leak and mainly employed methods are:

1.8.1 Biological methods

Experienced and profesional personnel or trained dogs can detect and locate a leak by visual inspection, odour or sound.

A traditional leak detection method is to use experienced personnel who walk along a pipeline, looking for unusual patterns near the pipeline, smelling substances which could be released from the pipeline or listening to noises generated by product escaping from a pipeline hole. The results of such leak detection methods depend on individuals' experience and whether a leak develops before or after the inspection.An additional leak detection method is to use trained dogs which are sensitive to the smell of substances released from a leak.

1.8.2 Hardware-based methods

Different hardware devices or equipments are used to assist the detection and localisation of a leak. Typical devices used include acoustic sensors and gas detectors, negative pressure detectors and infrared thermo-graph. The hardware-based methods can be divided into four types according to the principles on which the devices are designed:

• **Visual devices**

Some leaks can be detected through the identification of temperature changes in the immediate surroundings. Infrared thermograph was used to detect hot water leaks as the surrounding temperature increases after a leak develops (Weil 1993). This method can be used from moving vehicles, helicopters or portable systems and is able to cover several miles or hundreds of miles of pipeline per day

The recent development of advanced wide area temperature sensors makes the temperature profile technique more practical. Temperature sensors such as multi-sensor electrical cable and optical timed main reflectometry using fibre optic cables are used to detect changes of temperature in the neighbourhood of a leak (**Turner** 1991). Ground penetrating radar (GPR) uses a radar transmitter and receiver to accurately pinpoint buried pipeline leaks without digging. The leaking substances can be 'seen' at the source by the radar via the changes in the surrounding soil's electrical parameters. A 'colour-graphic' data format then displays the leak (**Graf** 1990, **Hennigar** 1993).

• **Acoustic devices**

When a leak occurs, noise will be generated as the fluid escapes from the pipeline. The wave of the noise propagates with a speed determined by the physical properties of the fluid in the pipeline. The acoustic detectors detect these waves and consequently the leaks (Hough 1988, Klein 1993, Kurmer1993, Turner 1991).Due to the limitation of the detection range, it is usually necessary to install many sensors along theline. These sensors detect acoustic signals in the pipeline and discriminate leak sounds from other sounds generated by normal operational changes.

• **Sampling devices**

If the product inside a pipeline is highly volatile, a vapour monitoring system can be used to detect thelevel of hydrocarbon vapour in the pipeline surroundings. This is usually done through gas sampling (**Sperl** 1991).The sampling can be done by carrying the device along a pipeline or using a sensor tube buried in parallel to the pipeline. The response time of the detection system is usually from several hours today (remotely operated vehicle) with swimming and sea bed crawling capacity. Pipeline leaks result in hydrocarbon anomalies in surrounding sediments and sea water. which can then be detected by the hydrocarbon detector.

- **Negative pressure**

When a leak occurs a rarefaction wave is produced in the pipeline contents. The wave propagates both upstream and downstream from the leak site. The wave travels with speed equal to the speed of sound in the pipeline contents. Pressure transducers can be used to measure pressure gradient with respect to time (**Turner** 1991). Usually two sensors are used for each pipeline segment to help discriminate between noise and externally caused pressure drops.

1.8.3 Software-based methods

Various computer software packages are used to detect leaks in a pipeline. The complexity and reliability of these packages vary significantly. Examples of these methods are flow/pressure change detection and mass/volume balance, dynamic model-based system and Pressure Point Analysis.

- **Flow or pressure change**

This technique relies on the assumption that a high rate of change of flow or pressure at the inlet or outlet indicates the occurrence of a leak. If the flow or pressure rate of change is higher than a predefined figure within a specific time period, then a leak alarm is generated (**Mears**1993).

- **Mass or volume balance**

If the difference between an upstream and down stream flow measurement changes by more than an established tolerance, a leak alarm will be generated. This method allows the detection of a leak which does not necessarily generate a high rate of change in pressure or flow. The methods can be based on flow difference only which would generate a simple mass or volume balance scheme or on flow difference compensated by pressure/temperature changes and inventory fluctuations in a pipeline (**Liou**1993, **Parry** 1992).

• **Dynamic model based system**

In its various forms this technique attempts to mathematically model with the various mathematical or emperical equations of fluid flow within a pipeline. Leaks are detected based on discrepancies between calculated and measured values (**Griebenow1988, Hamande** 1995, **Lio.u** 1994, **Mears** 1993).

The equations used to model the fluid flow are:

- **Conservation of mass**
- **Conservation of momentum**
- **Conservation of energy**

So these above mentioned methods are broadly employed in the detection of the leak in a pipeline based on the requirement of the operator.

However the software application of locating the leak place is highly preferred, its easy and reliable to use with the SCADA system available in various form of the new breed system which are latest and upgraded to work with.

Leak detection now days done with the IPS (inline pig survey) in which intelligent pigs are used to draw results from running pipeline operation, they work online too i.e they provide the data on continuous or discrete way in addition to the survey it can also elaborate the possibility of leak in future too. The only disadvantage this carries is that it is very costly it can cause cost to the company if the frequency is high in use. Hence for the optimization purpose this technique is applied once in five years of operation of the line.

In newer approach the mixed system of leak detection are being used such as hardware cum software methods are developed this brings the cost of system to be optimized reduce to a level, and many more research are being done in that area.

1.9 Future of leak detection

The future of leak detection methodology is full of advance technologies and mainly these are based on faster retrieval system which are beyond expectation at this moment of operations

1.9.1 Leak detection by using infra-red optical imaging

Infrared imaging now allows workers to see volatile organic compounds that are invisible to the human eye with any kind aid other than the infrared. The first yet to be released commercial camera to record these images now makes clear the presence of often odorless and lighter-than-air compounds that may be toxic, flammable or strictly regulated. By looking for the right wavelength of infrared "heat" the camera sees what people cannot see with the naked eyes

Using infrared imaging technique to spot leaks, damaged pipes, breached seals or valves and other emissions makes business sense and common sense for the operate of the pipeline . The results are powerful, correct, immidiate and yield bottom-line results for the user in operation.

The benefits with the infrared technology to the oil and gas sector

Many industrial gases and chemical compounds are invisible to the naked eye. Yet companies transport, measure and transform. They use a range of tools to monitor, identify and contain these assets from the loading dock, throughout the refinery and chemical processing plant and back to the pipes and cross country pipeline.

1.9.2 Gas solid state leak sensors

This is the biggest area where the research is yet to be put forward by scientists, and the research fellows. The solid state devices are used in wider application and robust in use the basic type of solid state sensors contain the following categories

Semiconductor gas sensors:

The semiconductor gas sensors, also known as chemo-resistive gas sensors, are typically based on metal oxides and recent advancement in this area shows the application of nanotechnology and gas sensing layers to be employed to the sensors. The sensor probes are low cost and power consumption trends. These are adding excitement in the area of detecting device and creating interest into the mind of people

Gas optical sensors

The optical gas sensors play an important role in sensing field for the measurements of chemical and biological quantities. First optical chemical sensors were based on the measurement of changes in absorption spectrum. At present a large variety of optical methods are used in chemical sensors and biosensors including ellipsometry, spectroscopy (luminescence, phosphorescence, fluorescence, Raman), interferometry (white light interferometry, modal inter-ferometer in optical waveguide structures), spectroscopy of guided modes in optical waveguide structures (grating coupler, resonant mirror), and a surface plasma on resonance (SPR). In these sensors a desired quantity is determined by measuring the refractive index, absorbance and fluorescence properties of the analyte molecules or a chemo-optical transducer element. This type of gas sensors are not treated in detailed in this contribution. This is not due to any judgement of the their relative importance but simply for practical reasons.

Electrochemical gas sensors

Chemical species reacting at an electronic conductor/ionic conductor interface exchange electric charges, then resulting in an electric signal. Electrochemical gas sensors employ an electrochemical cell consisting of a casing that contains a collection of chemical reactants in contact with the surroundings through two terminals of identical composition. For gas sensors, the top of the casing has a membrane which can be permeated by the gas sample. Oxidization takes place at the anode and reduction occurs at the cathode. A current is created as the positive ions flow to the cathode and the negative ions flow to the anode., which are electrochemically reducible, are sensed at the cathode while electrochemically oxidizable gases such as carbon monoxide, nitrogen dioxide, and hydrogen sulfide are sensed at the anode

CHAPTER 2

2. LITRATURE REVIEW

There lots of research work going on this area of leak detection, there is a need of reliable, Lesser false alarm generation and optimized for the cost benefit purpose.

With the increasing pipeline network all over the world and increasing safety standard there must be an alarming rise in pipeline research area for the detection of leaks over the period of pipeline operations and emphasis on getting a details from the same station for the entire pipeline.

There are a variety of methods that can detect LPG pipe line leaks, ranging from manual inspection using trained dogs to advanced satellite based hyper spectral imaging (Carlson,1993; Scott and Barrufet, 2003). The various methods can be classified into non-optical and optical methods. The primary non-optical methods include acoustic monitoring (Hough, 1988; Klein, 1993); gas sampling (Sperl, 1991), soil monitoring (Tracer Research Corporation, 2003), flow monitoring (Turner, 1991; Bose and Olson, 1993), and software based dynamic modelling (Griebenow and Mears, 1988; Liou and Tain, 1994).

Acoustic monitoring techniques typically utilize acoustic emission sensors to detect leaks based on changes in the background noise pattern. The advantages of the system include detection of the location of the leaks as well as non-interference with the operation of the pipelines. In addition, they are easily ported to various sizes of pipes. However, a large number of acoustic sensors is required to monitor an extended range of pipelines. The technology is also unable to detect small leaks that do not produce acoustic emissions at levels substantially higher than the background noise. Attempts to detect small leaks can result in many false alarms.

Gas sampling methods typically use a flame ionization detector housed in a hand held or vehicle mounted probe to detect propane and butane. The primary advantage of gas sampling methods is that they are very sensitive to very small concentrations of gases. Therefore, even very tiny leaks can be detected using gas sampling methods. The technique is also immune to false alarms. The disadvantages of the technology are that detection is very slow and limited to the local area from which the gas is drawn into the probe for analysis. Therefore the cost of monitoring long pipelines using gas sampling methods is very high.

In soil monitoring methods, the pipeline is first inoculated with a small amount of tracer chemical. This tracer chemical will seep out of the pipe in the event of a leak. This is detected by dragging an instrument along the surface above the pipeline. The advantages of the method include very low false alarms, and high sensitivity. However, the method is very expensive for monitoring since trace chemicals have to be continuously added to the natural gas. In addition, it cannot be used for detecting leaks from pipelines that are exposed Flow monitoring devices measure the rate of change of pressure or the mass flow at different sections of the pipeline. If the rate of change of pressure or the mass flow at two locations in the pipe differs significantly, it could indicate a potential leak. The major advantages of the system include the low cost of the system as well as non-interference with the operation of the pipeline. The two disadvantages of the system include the inability to pinpoint the leak location, and the high rate of false alarms.

Software based dynamic modelling monitors various flow parameters at different locations along the pipeline. These flow parameters are then included in a model to determine the presence of natural gas leaks in the pipeline. The major advantages of the system include its ability to monitor continuously, and non-interference with pipeline operations. However, dynamic modelling methods have a high rate of false alarms and are expensive for monitoring large network of pipes.

The research is still on the leak detection of LPG pipeline because of its new to the prespective of the transfer of LPG from one installation to the other, recently in India, IOCL, India has laid a LPG pipeline using software and hardware combination and an application of SCADA to ensure a safest operation.

Inspite of the all effort putted into this field of leak detection there are still a need for the development of more reliable system based on less manual effort and online system is required and over all efforts are put to reduce false alarm generation.

In the latest of all research the development an ANN based leak detection with a programming strand as an interface language is used and it is in testing phase till now, once it is done it will be the highly reliable and safest system of development.
The paper published in 2009 by Assistant Professor Timur Chris, Ph.D., Dipl.Eng. "Andrei Saguna" University, Constanta, Romania has explained various type of system and feature that are needed in a future detection system and has mentioned more software based techniques to be employed for the work of detection rather following the same old method of doing the survey.
The need for the leak detection in LPG pipeline is to increase the pipeline integrity of the overall operations. The better system will be a need for the purpose of the future demands in India as we are the growing part in the LPG pipeline areas we have the world biggest LPG pipeline laid by the GAIL. India but still we are growing with the network of LPG. Moreover some other Navratna's are planning to lay LPG pipeline in India in near future to cater the need of different places present all over the country

CHAPTER 3

3.1Theoretical Development

The leak in a pipeline exists when there is sudden change in pressure and the quantity with the time, with the actual required pressure and quantity respectively.

As we move along with the pipe length the pressure of the line starts to decrease in value on the account of the fluid properties based on pipe material factors, elevation difference and due to fittings present on the pipeline sections, there are other minor losses which are present but are not taken into account due to their low magnitude against these pressure losses. The loss of quantity is not permissible in greater extent of value as because the loss of quantity will bring the profits down for the operator on the basis of quantity loss reimbursement for the consumers. The leak in a pipeline is the only reason for the loss of quantity and the downfall of the pressure during the operations hence worth much more importance than anything else.

To detect a leak in a pipeline we can simply apply two condition all together on the basis of the pressure and quantity variation along the length of the pipeline and a close monitoring system would do the purpose for the operator to get into the situation of the leak.

The basic philosophy in detecting the leak is to get the set data of pressure variation in close loop of reading say about at every one kilometre of pipeline this is done in accordance to follow the drop of pressure due to sudden impact of something, to increase the clearity of the picture of the situation we need to take a look at the quantity variation with the time, if it falls below the prescribed flow rate, and relating the results with the pressure loss too we can conclude that the pressure variation is on the account of the quantity variation i.e falling of the mass flow rate in the pipe-segment hence possibility of leak is confirmed.

the variation of the pressure and quantity can be understood easily with the help of the two graphs relation

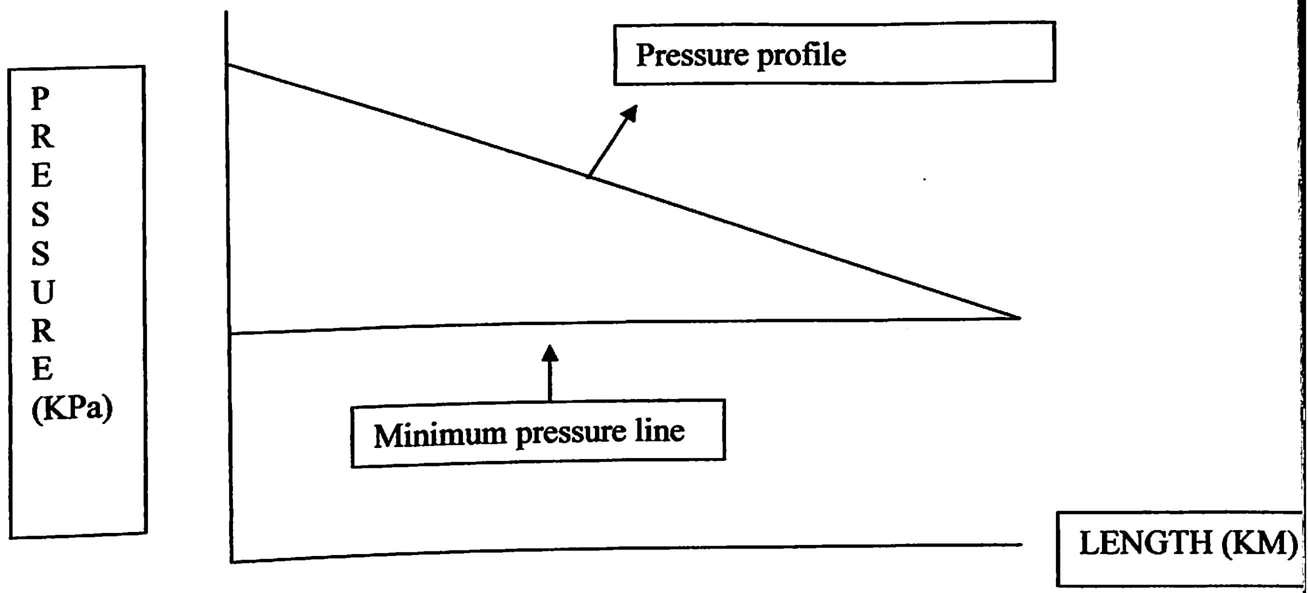


Figure1.0: Ideal pressure profile

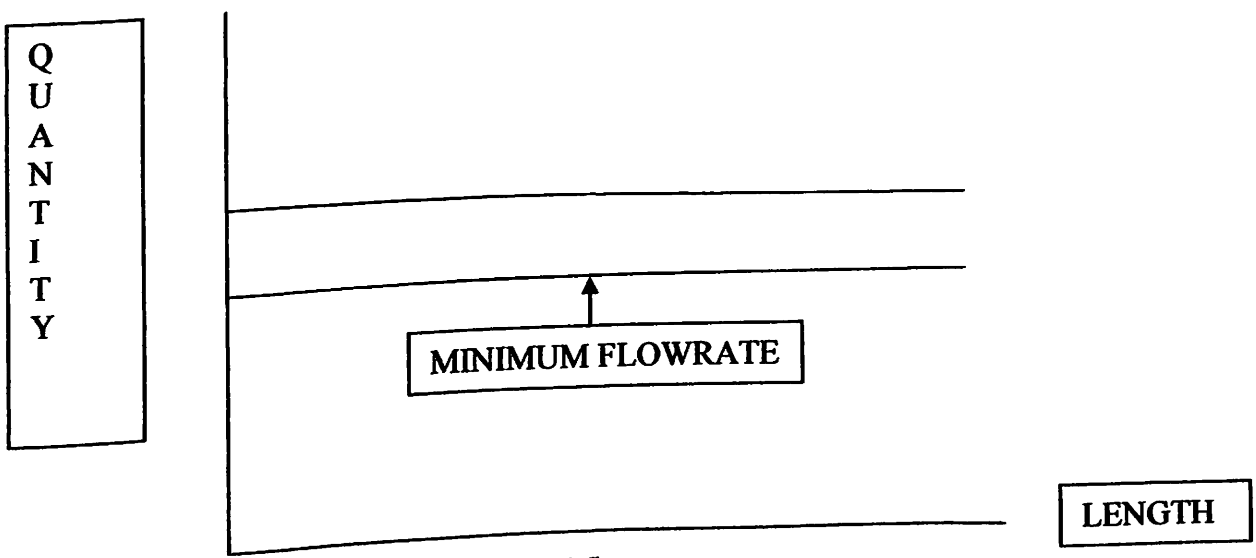


Figure 2.0:ideal flow rate

The curves presented above are the ideal curves which are predominantly used to define the ideal situation of pipeline operation, now we will take a look into the situation that can persist if a leak takes place during the operations.

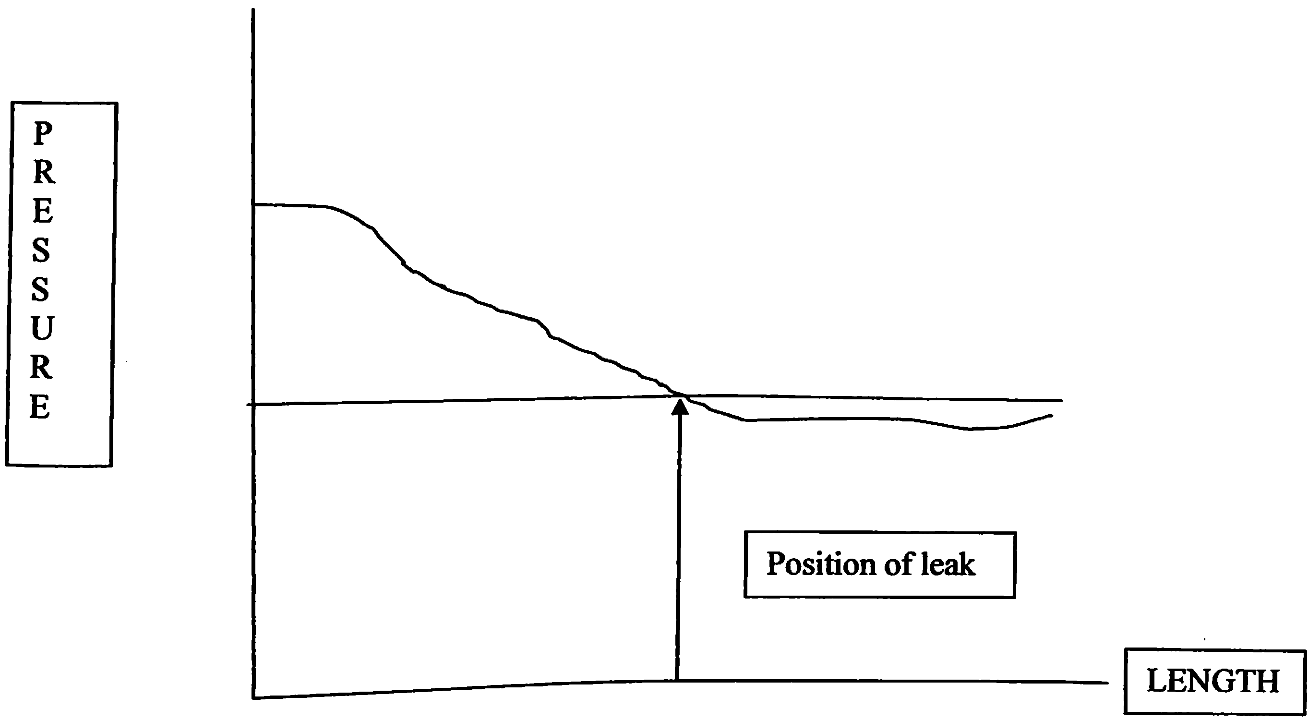


Figure3.0:leak pressure profile

FigurE.4.0: leak quantity profile

3.2 pressure drop calculations:

When the liquid travels through the pipeline there is always pressure drop occurs on the account of the three factors which are as following

3.2.1 Pressure Drop due to Friction

Fluids, in which pressure loss is one of the best technique to detect out leak in a particular section. There is no such standard formula or expression available for the detection of leak but an empirical relation can be establish or used to detect out the leak in a given pipe leg in this condition, we use equation like **Hazen-Williams Equation,** the Hazen-Williams equation is commonly used in the design of There are various method available for leak detection for pipeline distribution lines and in the calculation of frictional pressure drop in refined petroleum products such as gasoline and diesel. This method involves the use of the Hazen-Williams C-factor instead of pipe roughness or liquid viscosity. The pressure drop calculation using the Hazen-Williams equation takes into account flow rate, pipe diameter, and specific gravity as follows

$$h = \frac{4.73 \times L \times \left(\frac{Q}{C}\right)^{1.852}}{D^{4.87}} \qquad (3.1)$$

where,

h=Head loss due to friction, ft

L=Pipe length, ft

D=Pipe internal diameter, ft

Q=Flow rate, ft3/s

C=Hazen-Williams coefficient or C-factor, dimensionless

In customary pipeline units, the Hazen-Williams equation can be rewritten as follows in English units:

Where,

Q=Flow rate, bbl/day

D=Pipe internal diameter, in.

Pm=Frictional pressure drop, psi/mile

Sg=Liquid specific gravity

C=Hazen-Williams C-factor

Q=Flow rate, bbl/day

D=Pipe internal diameter, in.

Pm=Frictional pressure drop, psi/mile

Sg=Liquid specific gravity

C=Hazen-Williams C-factor

C=Hazen-Williams C-factor Another form of Hazen-Williams equation, when the flow rate is in gal/min and head loss is measured in feet of liquid per thousand feet of pipe, is as follows:

$$GPM = 6.7547 \times 10^{-3} \times C \times D^{2.63} \times (HL)^{0.54} \quad (3.2)$$

where

GPM=Flow rate, gal/min

HL=Friction loss, ft of liquid per 1000 ft of pipe

Other symbols are as in Equation (3.36).

In SI units, the Hazen-Williams equation is as follows:

$$Q = 9.0379 \times 10^{-8} \times C \times D^{2.63} \left(\frac{P_{KM}}{S_g}\right)^{0.54} \quad (3.3)$$

Where,

Q=Flow rate, m3/hr

D=Pipe internal diameter, mm

Pkm=Frictional pressure drop, kPa/km

Sg =Liquid specific gravity

Historically, many empirical formulas have been used to calculate frictional pressure drop in pipelines. The Hazen-Williams equation has been widely used in the analysis of pipeline carrying products because of its simple form and ease of use. A review of the Hazen-Williams equation shows that the pressure drop due to friction depends on the liquid specific gravity, pipe diameter, and the Hazen-Williams coefficient or C-factor.

Now if a leak takes place then the pressure drop must be greater than the difference in upstream and downstream plus the drop occurred.

3.2.2Pressure drop due to elevation difference

Due to the difference between altitudes of the places or two point, the loss of pressure or head takes place , this can be calculated on the basis of given formula and that is,

$$P_{ELEV} = 10.197 \times \left(\frac{H}{G}\right) \tag{3.3}$$

Where,

P_{ELEV} = pressure loss due to elevation.

H= difference in the altitudes of two places.

G=specific gravity of the LPG, (Depending upon the composition of the propane mixture we can calculate the density of the LPG)

Pressure loss due to valves and fitting:

In most long-distance pipelines, such as trunk lines, the pressure drop due to friction in the straight lengths of pipe forms the significant proportion of the total frictional pressure drop. Valves and fittings contribute very little to the total pressure drop in the entire pipeline. Hence, in such cases, pressure losses through valves, fittings, and other restrictions are generally classified as *"minor losses"*. Minor losses include energy losses resulting from rapid changes in the direction or magnitude of liquid velocity in the pipeline. Thus pipe enlargements, contractions, bends, and restrictions such as check valves and gate valves are included in minor losses.

Accordingly, the pressure drop through valves and fittings is generally expressed in terms of the liquid kinetic energy ($\frac{v^2}{2g}$) multiplied by a head loss coefficient K.

.For a straight pipe, the head loss h is ($\frac{v^2}{2g}$) multiplied by the factor ($\frac{fl}{D}$.) Thus, the head loss coefficient for a straight pipe is. ($\frac{fl}{D}$.).

Therefore, the pressure drop in a valve or fitting is calculated as follows:

$$h = K\left(\frac{V^2}{2g}\right) \tag{3.4}$$

where,

h=Head loss due to valve or fitting, (m)

K=Head loss coefficient for the valve or fitting, dimensionless

V=Velocity of liquid through valve or fitting, ft/s (m/sec)

g=Acceleration due to gravity, (m/sec^2)

The head loss coefficient K is, for a given flow geometry, considered practically constant at high Reynolds number. K increases with pipe roughness and with lower Reynolds numbers. In general the value of K is determined mainly by the flow geometry or by the shape of the pressure loss device.

The total pressure loss due to this is taken as.

$$P = 1.1 \times density \times acceleration\ due\ to\ gravity \ldots\ldots\ldots\ldots (3.5)$$

The allowance for pressure drop is taken as 10 % hence a factor of 1.1 has been taken for the calculation. (In LIQUID STATE the density of LPG can be calculated as "MASS flow rate/volumetric flow rate")

Hence at this stage the total pressure loss due to these three major factors is,

$$P = P_{km} + P_{ELEV} + P_M \qquad (3.6)$$

On calculating the whole pressure drop due to these factors now we can calculate the received on the terminal

3.3 PHILOSOPHY FOR LEAK TO TAKE PLACE:

If a pipeline segment went under leaking condition then there will be a fall in pressure and the flow-rate for the liquefied petroleum gas (LPG) and if the fall in the both quantity is above permissible limits as set earlier, there is a condition of leak exists.

Condition 1: if the pressure difference in the pipe-segment falls below the prescribed limit.

$$\Delta P = P_1 - P_2 \qquad (3.7)$$

Condition 2 : if the quantity obtained is differing from the quantity must be received by an decided limit

$$\Delta Q = Q_1 - Q_2 \qquad (3.8)$$

If the above two condition gets satisfied then the possibility of leak is confirmed and alarm will be generated

3.3 Hardware Requirement

The system requires some hardware for the proper functioning of the system, the system would be requiring some analog or digital devices like,

1. Pressure gauge
2. Flow meter
3. Transducer etc.

Which are suitable to the pipeline operation that has to be put together in order to gather and monitor the data in order to detect leak inside the line within few units of time. The instrumentation becomes a issue of prime importance for the purpose of the accuracy and integrity of the system, more accurate devices means precise results and good results for the longer operations of work.

CHAPTER 4

4.1 RESULTS AND DISCUSSION

The design code generated is being tested under various condition of data set and one of the following is presented here

THROUGPUT(MMTPA)	2.5
LENGTH	190
PERCENTAGE OF PROPANE (%)	60
UPSTREAM PRESSURE(MPa)	1.4
DOWNSTREAM PRESSURE (MPa)	0.7
UPSTREAM QUANTITY FLOW(Kg/Hr)	300
DOWNSTREAM QUANTITY FLOW(Kg/Hr)	298
ELEVATION DIFFERENCE (M)	25
DIAMETER OF THE PIPELINE(M)	.4572

Table 1.0:input data required to calculate the various pressure drop

This data has been established to find out the possibility of leak in the section with a permissible range of pressure drop and quantity loss, a programming standard of finding the loss of quantity and pressure drop

The code developed is helpful in getting the permissible pressure drop per km of the section of the pipe, and also provide regular pressure measurement of the section too.

The results obtained were of close approximation and the variation comes on the account of assumption made in the calculation.

The output for the above value of the various input for the calculation purpose has been done found like this:

Pressure drop per km (KPa)	**11.459249**

Velocity of the fluid (m/sec)	**0.6**
Overall pressure drop (MPa)	**0.776822**
Quantity loss(kg/hr)	**2**

Table2.0:output of the code for the given set of data

Finally according to the calculation there is pressure drop in the section accompanied with the quantity loss hence a leak is there.

4.2ALGORITHM

1. Enter the values of flow-rate (Q) in MMTPA

(a)Enter the value of diameter (D) of the pipeline in meter.

(b)Take the value of C (William-Hazen coefficient).

(c)Enter the value of the length of section.

(d)Enter the value of the co-efficient of discharge.

(e)Enter the value of the up-stream and downstream pressure (MPA) and quantity (Kg/hr) desired.

(f)Enter the value of the elevation difference in metres.

(g) Enter the specific gravity of the LPG.

2.Calculate the pressure loss due to fluid properties P_{km} using Hazen equation.

$$Q = 9.0379 \times 10^{-8} \times C \times D^{2.63} \left(\frac{P_{KM}}{S_g}\right)^{0.54}$$

3.Calculate the pressure loss calculation based on elevation difference

$$.P_{ELEV} = 10.197 \times \left(\frac{H}{G}\right)$$

4.Calculation of the pressure loss on the basis of the minor losses

$$h = K\left(\frac{V^2}{2g}\right)$$

P_M =1.1h*density*acceleration due to gravity

5.Add all the pressure loss together.

6. Calculate pressure received at the terminal point i.e

4.3FLOW CHART

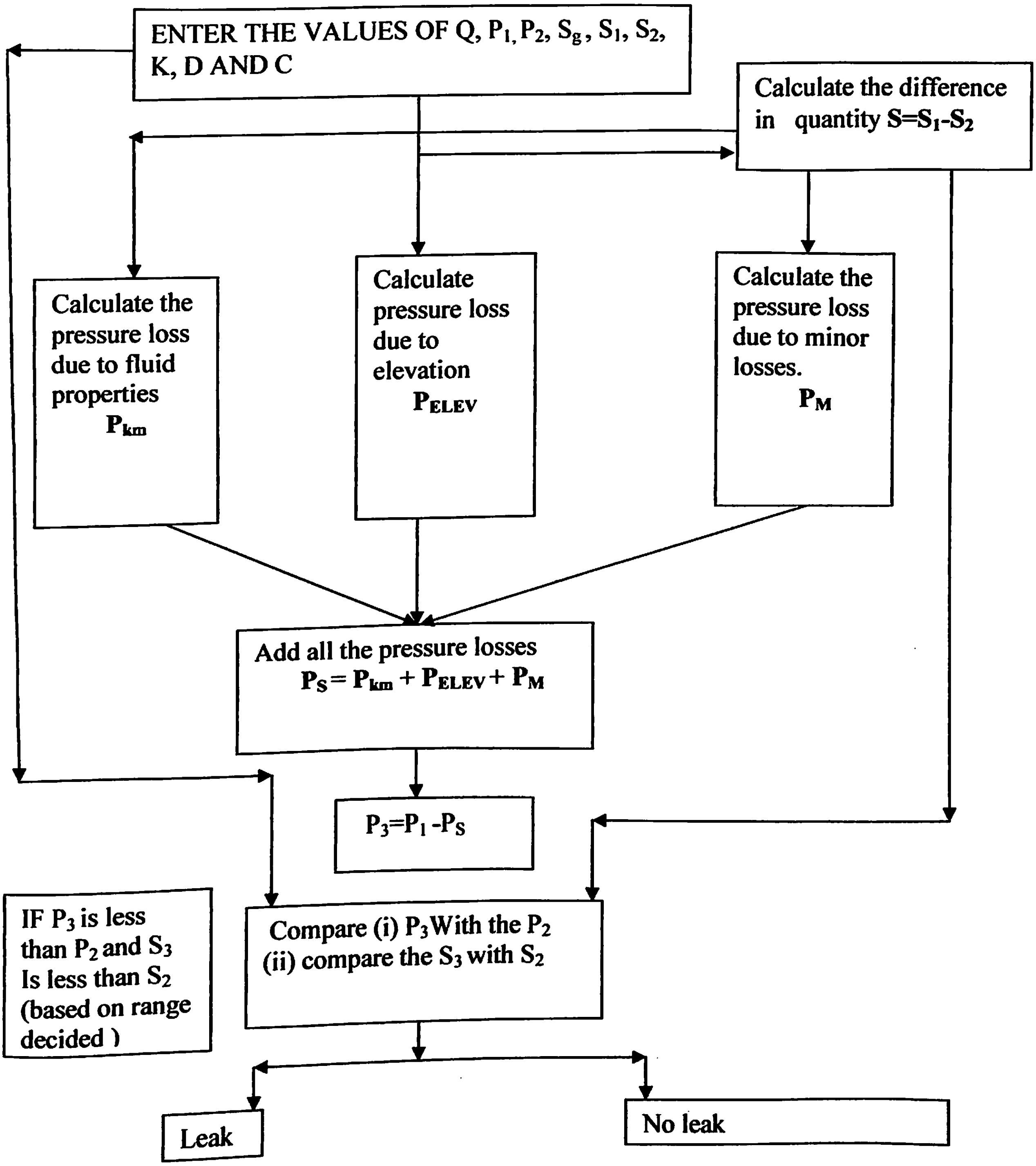


Figure 3.0:flow chart

CHAPTER 5

Chapter5

5.1Conclusion

The code developed on the basis of the above given formula has been successfully developed and has been crossed checked with the help of the available data for the cross checking of the code. The pressure drop are coming in accordance of with the prescribed limits and results are close to the original available data however some modification in the assumption made lead to approximation of the result.

The code is also beneficial in terms of finding out the feasibility of the section of pipeline for the LPG transportation, it do calculate drops in pressure and consider all kind of losses which can majorly affect the operation of the line. It does take pressure drop due to fluid properties, elevation difference and minor losses which holds concern for the designer to think about.

The code developed is user friendly and allow user to modify the inputs and keep tracking the subsequent change in the output, the code is compatible and can be used upto any range of pressure and temperature for LPG.

5.2Recommendations

The code is solving the purpose however there are certain more features that can be added in order to make it more useful for the operations

1. To make this software more user friendly include more metric system like m.k.s, c.g,s etc and provide wider application
2. Include more practical features like random number generation to the whole programme
3. Use this software as back hand programme for some sophisticated designing software like PIPE-SIM, PDMS etc
4. Try to evolve with your understanding and work

References:

1. **Liquid Pipeline Hydraulics** by E.Shashi Menon published in the year 2004 by MARCEL DEKKER, Inc, NEW YORK BASEL.

2. **Pipeline Engineering** by Henry Liu published in the year 2003 in the year 2003 by LEWIS PUBLISHERS.

3. **Designing a cost effective and reliable leak detection system** by Dr.Jun Zhang, REL instrumentation limited, Manchester, U.K.

4.**Pipeline leak detection techniques** paper by Assist.prof.Timur Chris Ph.D, dipl engineering.published in 2007.

5.**Pipeline leak detection study** prepared by Bechtel Limited for the health and safety executives.

6.**General websites**

www.google .com

www.gail.com

www.ndt.net

www.buzzle.com

ANNEXURE 1

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
void main()
{
float h=0.0,d=0.0,q=0.0,c=0.0,cd,p1,p2,q1,q2,l;
float pkm=0,x=0,y=0,k=0,pr=0,v=0,ol=0,pl=0,pkt=0,den=0;
float s,u,sg,p,b;
clrscr();
cout<<"\t ****** PLEASE ENTER THE FOLLOWING DATA *****\n";
cout<<" VOLUMETRIC FLOW RATE (mmtpa) : ";cin>>q;q=133.33*q;//from
mmtpa to m3/hr
cout<<"\n LENGTH OF SECTION (km) : ";cin>>l;
cout<<"\n DIAMETER OF PIPE (m) : ";cin>>d;
cout<<"\n ELEVATION DIFFERENCE : ";cin>>h;
cout<<"\n COEFFICIENT OF DISCHARGE : ";cin>>cd;
cout<<"\n ENTER THE PERCENTAGE OF PROPANE: "; cin>>p ;
//cout<<"\n ENTER THE PERCENTAGE OF BUTANE: ";cin>>b;
cout<<"\n NO. FOR TYPE OF MATERIAL (1.SMOOTH METAL::2.CAST
IRON::3.IRON): ";cin>>c;
sg=((p*0.493)+((100-p)*0.693))*.01;
if(c==1)
c=135.0;
if(c==2)
```

```
c=100.0;
if(c==3)
c=70.0;
float d1=d*1000;
y=(9.0375*c*pow(d1,2.63));
x=q*pow (10,8);
k=pow ((x/y),1.85581);
pkm=k/sg;cout<<"\n PRESSURE DROP PER KM: "<< pkm<<endl;      //pressure
drop per km
pkt=pkm*l*1000;
pr=(10.197*h)/0.5855;     //elevation pressure drop
v=(0.0471335*(q/133.33))/pow(d,2); //velocity
cout<<"\n VELOCITY: "<<v<<endl;
ol=(cd*v*v)/(2*9.8);      //other losses
cout<<"\n UPSTREAM PRESSURE : ";cin>>p1;
cout<<"\n DOWNSTREAM PRESSURE :  ";cin>>p2;
cout<<"\n UPSTREAM MASS FLOW : ";cin>>q1; den=q1/q; //den is density
cout<<"\n DOWNSTREAM MASS FLOW : ";cin>>q2;
pl=ol*den*9.8*0.001 ;// pressure loss
s=((pkt-pl-pr)*pow(10,-6));
cout<<s;
s=s-p1;
for (int a=1;a<=l;a++ )
{

float z=(((pkm*a)+((h/l)*a)+pl)*0.000001);


p1=p1-z;
cout<<a<<"\t"<<z<<"\t"<<p1<<endl;
```

```
}cout<<"\n"<<"LENGTH\t"<<"LOSSES\t"<<"\tPRESSURE"<<endl;
if(s<=(0.95*p2) && q1<=(0.90*q2))
{
cout<<"\n THERE IS A PRESSURE DROP IN THIS PIPE SECTION  ";
cout<<"\n THE  PRESSURE DROP IS : "<<s;
cout<<"\n THE QUANTITY LOSS IS : "<<(q2-q1);


}
else
{
cout<<"\n THERE IS NO LEAK IN THIS SECTION  ";
cout<<"\n THE  PRESSURE DROP IS : "<<s;
cout<<"\n THE QUANTITY LOSS IS : "<<(q2-q1);
}


getch();
}
```

ANNEXURE 2

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
void main()
{
float h=0.0,d=0.0,q=0.0,c=0.0,cd,p1,p2,q1,q2,l,sec,div,ch[25],elv[25];
float pkm=0,x=0,y=0,k=0,pr=0,v=0,ol=0,pl=0,pkt=0,den=0;
float s,u,sg,p,b;
clrscr();
cout<<"\t ****** PLEASE ENTER THE FOLLOWING DATA *****\n";
cout<<" VOLUMETRIC FLOW RATE (mmtpa) : ";cin>>q;q=133.33*q;//from mmtpa to
m3/hr

cout<<"\n DIAMETER OF PIPE (m) : ";cin>>d;
cout<<"\n ELEVATION DIFFERENCE : ";cin>>h;
cout<<"\n COEFFICIENT OF DISCHARGE : ";cin>>cd;
cout<<"\n ENTER THE PERCENTAGE OF PROPANE: "; cin>>p ;
//cout<<"\n ENTER THE PERCENTAGE OF BUTANE: ";cin>>b;
cout<<"\n NO. FOR TYPE OF MATERIAL (1.SMOOTH METAL::2.CAST
IRON::3.IRON): ";cin>>c;
cout<<"\n LENGTH OF SECTION (km) : ";cin>>l;
cout<<"\n SECTIONS OF CHAINAGE : ";cin>>sec;
cout<<"\n DATA FOR SECTIONS : ";
int i;
for(i=0;i<sec;i++)
{
```

```
cout<<"\n DATA FOR SECTION "<<i+1<<" : ";
cout<<"\n   CHAINAGE : ";cin>>ch[i];
cout<<"\n   ELEVATION : ";cin>>elv[i];
}
sg=((p*0.493)+((100-p)*0.693))*.01;
if(c==1)
c=135.0;
if(c==2)
c=100.0;
if(c==3)
c=70.0;
float d1=d*1000;
y=(9.0375*c*pow(d1,2.63));
x=q*pow(10,8);
k=pow((x/y),1.85581);
pkm=k/sg;
cout<<"\n PRESSURE DROP PER KM: "<< pkm<<endl;        //pressure drop per km

    //elevation pressure drop
v=(0.0471335*(q/133.33))/pow(d,2); //velocity
cout<<"\n VELOCITY: "<<v<<endl;
ol=(cd*v*v)/(2*9.8);      //other losses
cout<<"\n UPSTREAM PRESSURE : ";cin>>p1;
cout<<"\n DOWNSTREAM PRESSURE :  ";cin>>p2;
cout<<"\n UPSTREAM MASS FLOW : ";cin>>q1; den=q1/q; //den is density
cout<<"\n DOWNSTREAM MASS FLOW : ";cin>>q2;
pl=ol*den*9.8*0.001 ;// pressure loss
float len=0;
for (i=0;i<sec;i++)
{
if(i==0)
```

```
{h=elv[i+1]-0;
len=ch[i]-0;}
else
{h=elv[i]-elv[i-1];
len=ch[i]-ch[i-1];}

pkt=pkm*len*1000;
pr=(10.197*h)/0.5855;
s=((pkt-pl-pr)*pow(10,-6));
cout<<s;
cout<<"\n TOTAL DROP TILL CHINAGE "<<i+1<<" IS: "<<s;
s=s-p1;
}
cout<<"\n"<<"LENGTH\t"<<"LOSSES\t"<<"\tPRESSURE"<<endl;
if(s<=(0.95*p2) && q1<=(0.90*q2))
{
cout<<"\n THERE IS A PRESSURE DROP IN THIS PIPE SECTION  ";
cout<<"\n THE  PRESSURE DROP IS : "<<s;
cout<<"\n THE QUANTITY LOSS IS : "<<(q2-q1);


}
else
{
cout<<"\n THERE IS LEAK IN THIS SECTION  ";
cout<<"\n THE  PRESSURE DROP IS : "<<s;
cout<<"\n THE QUANTITY LOSS IS : "<<(q2-q1);
}



getch();
}
```