Design Consideration of Gas Pipelines

A Project Report submitted in partial fulfillment of the requirements for the Degree
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in
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(Academic Session 2003-05)

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CERTIFICATE

This is to certify that the Project Report on ***"Design Consideration of Gas Pipelines"*** submitted to University of Petroleum & Energy Studies, Dehradun, by **Mr. Amit Aggarwal** in partial fulfillment of the requirement for the award of Degree of Master of Technology in Gas Engineering (Academic Session 2003-05) is a bonafide work carried out by him under my supervision and guidance. This work has not been submitted anywhere else for any other degree or diploma.

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Amit Aggrawal

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Executive summery

The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. The transportation system for natural gas consists of a complex network of pipelines, designed to quickly and efficiently transport natural gas from its origin, to areas of high natural gas demand. Transportation of natural gas is closely linked to its storage, as well; should the natural gas being transported not be required at that time, it can be put into storage facilities for when it is needed. There are essentially three major types of pipelines along the transportation route

The transmission of gas to the consumer may be divided into four distinct units

- The gathering system
- The compression station
- The main trunk line
- The distribution line or service line

Pipeline comprises gathering system, mainline and service line provide an economical method of transporting fluids over great distances. After the initial capital investment required for their construction they show low operating costs and unit costs that declines with large volumes of throughput. Many factors must be considered in the design and construction of long-distance or cross-country gas pipelines.

These include the nature and volume of the gas to be transmitted, the length of pipeline, the type of terrain to be crossed, and the maximum elevation of the route.

Construction of pipeline provides an economical means of transporting fluids in large volumes over great distances. They are convenient to fabricate and install, and provide an almost long life span. Because flow is continuous, minimum storage facilities are required at either end (field supply end, and the consumer end), operating costs are very low, and flow is guaranteed under all condition of weather, with good control. There are no spillage or other handling losses, unless the line develops a leak, which can be easily located and fixed for surface lines.

So the design and construction of the pipeline transmission system calls for the services of well trained, fully dedicated, and experienced engineering, and legal staff. Complex engineering studies are needed to decide on the diameter, yield strength, and pumping horsepower required to give the optimum results for any particular pipeline transmission system.

Chapter-1

Overview of Pipelines

Chapter-1 Overview of Pipelines

1.1 Introduction

Pipelines are all part of physical facilities through which crude, oil products, gas, water and slurries moves in transportation. It includes pipe, valves, fittings, flanges regulators, pressure vessels, pulsation dampeners, relief valves and others appurtenances attached to the pipe, compressor unit, metering station, regulators station and fabricated assemblies

Pipelines affect daily lives in most parts of the world. Modem people's lives are based on an environment in which energy plays a (predominant) role. Oil and gas are major participants in the supply of energy, and pipelines are the primary means by which they are transported. It is no coincidence that an extensive pipeline network goes hand-in-hand with a high standard of living and technological progress.

Among other uses, oil and gas are utilized to generate electrical power. Using electricity/oil and gas directly, houses are heated, meals are cooked, and a comfortable living environment is created. Petrochemical processes also use oil and gas to make useful products.

To fulfill the oil and gas demand for power generation, recovery processes, and other uses, pipelines are utilized to transport the supply from their source. These pipelines are mostly buried and operate without disturbing normal pursuits. They carry large volume of natural gas, crude oil, and other products in continuous streams.

Construction procedures for most pipeline systems can be adapted to consider specific environmental conditions and are tailored to cause minimal impact on the environment.

Unattended pumping stations move large volumes of oil and petroleum products under high pressure. Similarly, natural gas transmission systems, supported by compressor stations, deliver large volumes of gas to various consumers.

1.2 Types of pipelines

According to products

- Crude
- Oil products
- Gas
- Water
- Slurries

According to location

Onshore: it covers all inland cross-country pipelines not in offshore areas covered by submarine pipelines

Offshore: it is also called submarine pipelines. It covers all the pipelines in offshore areas beyond the line of ordinary high water.

According to role

- Main line
- Spur line
- Trunk line
- Laterals
- Feeder

We are using pipelines for transportation of oil and gas and its products because of following reasons:

- Pipelines are economical mode of transportation
- Safer
- Environment friendly
- Minimum loss of material in transportation
- Minimal impact on land use pattern.
- No traffic problem
- High reliability
- Least energy requirement
- Minimum hazards

1.3 Gas pipelines

The Gas Authority of India LTD (GAIL) – now called GAIL India LTD a leading public sector enterprise, is the largest gas transmission and marketing company I India. Today GAIL owns over 4000 km of pipeline and has about 95% market share in the Natural Gas business in India. Also, more than half of the total urea production in India is gas-based, out of which GAIL contributes more than 90%, thus making a significant contribution to India's agricultural sector also. The company also completed the world's longest (1200 km) and India's first cross-country LPG pipeline from **Jamnagar to Loni**, Near Delhi. There exists a total of 3331 km of LPG pipelines in the country with a throughput capacity of 8304 MMTPA, work on some of which is still in progress. GAIL is now in the process of doubling the throughput capacity of its main **Hazira–Bijaipur- Jagdishpur** (HBJ) pipeline. Work on the capacity expansion began in 2002 and will eventually raise the capacity of the pipeline from about 1.1 BCF/D to 2.1 BCF/D. AIL also plans a new distribution network in West Bengal and a pipeline which could connect Kolkata with Chennai. India is investing heavily in the infrastructure required to support in-creased use of Natural Gas. This has become even more so with the major development in December 2002 when Reliance announced its discovery of large volumes of Natural

Gas in the Krishna-Godavari basin, offshore from Andhra Pradesh, around India's Southeast coast. New reserves from this find are estimated at about 5 TCF. Cairn Energy also reported finds in late 2002 offshore Andhra Pradesh as well as Gujarat, which contains reserves estimated at nearly 2 TCF. State owned ONGC, which was originally engaged in the gas production from the Bombay-High offshore fields, has further added to gas discoveries on India's East coast as well. Shell has signed a Memorandum of Understanding with the State Government of Uttar Pradesh in Northern India for the development of a Natural Gas distribution infrastructure. In addition, there are regional gas grids of varying sizes in Gujarat (Cambay Basin), Andhra Pradesh (Krishna-Godavari Basin), Assam (Assam-Arakan Basin), Maharashtra (Ex-Uran Terminal) , Rajashthan (Jaisalmer Basin), Tamilnadu (Cauvery Basin), and Tripura (Arakan Basin). Meanwhile, GSPL (Gujarat State Petronet Ltd) is implementing a 1600 km long gas grid in the state of Gujarat. GSPL was incorporated as a special purpose vehicle by the Gujarat State Petroleum Corporation in December 1998, especially to implement the gas grid for the transmission of LNG from import terminals to demand centers across the state.

1.4 Pipeline policy

On September 29, 2003 the GOI announced the draft pipeline gas policy which envisaged the laying of 7,000 km of pipeline network for gas transportation at a cost of around MM US$ 3902.86 in the next 5-6 years. As a part of this policy, GOI pro-poses a National Gas Grid on the pattern of the National Power Grid to manage the distribution effectively. While individuals will be permitted to lay pipelines for distribution purposes, say up to 100 km, but if the length is beyond the prescribed limit the construction would be carried out in accordance with the 'Common Carrier Principle' to avoid duplication and wasteful expenditure.

The main objective of the draft policy, presently undergoing finalization with the GOI, is to put in place a distribution system for carrying gas, the availability of which is likely to improve considerably, it having been struck at several places, as mentioned above, with arrangements for the movement of liquefied Natural Gas (LNG) having been tied up indefinitely. Under the proposed policy, all trunk pipelines covering more than one state or operating at a pressure more than the notified level will be build or managed by a company to be decided by the GOI but, until is notified, by GAIL India Ltd. Seizing the opportunity, GAIL has unveiled a MM US$ 4336.51 plan to build a 7,890 km gas grid, along with a completion schedule. The rationale: gas grids in several countries like Italy, France, Turkey and also in China and Korea have been built by the NOCs, because of issues of safety and security.

The policy envisages appointment of a Regulator under the Petroleum Regulatory Board Bill 2002 for regulating transmission, distribution, and supply and storage systems for Natural Gas/ LNG and to promote development of the sector. The Regulator will ensure access gas pipelines on non discriminatory common carrier principle for all users. And the tariff for the transmission pipelines and distribution pipelines would be approved the Regulator. Pipelines in India have traditionally operated at 100% capacity (since these are captive pipelines of oil companies). However, where pipelines are operated under common carrier principle mooted in the draft pipe-line policy, they may in reality be faced with uncertainty utilization, arising from demand

Demand supply dynamics. Since these are long life projects, high capacity utilization over long periods becomes a pre-requisite for financial viability. Probably the key issue that requires resolution is the demand by the financial institutions that the proposed pipe-line projects enter into long term 'Take or Pay' contracts. According to some, this demand would largely violate the common carrier principle, which at-tempts to ensure equitable access to all users. The key concern is price.

The principles governing the tariff structure should ensure adequate competition among various mode combinations, fair return to investors (i.e., returns commensurate with the risks assumed), equitable access all users and equitable costs consumers. While it is easy to enunciate the broad principles, implementing this could be an extremely complex task, given the peculiarities the situation and the relative lack time available for formulation of policy and implementation.

1.5 Cost consideration

Considering the economies of transportation pipeline has been considered as the most economical mode of transportation for petroleum products and it is for this reason that world over most of the petroleum products are transported through pipelines. It ma not be exaggeration to call these pipelines as arteries of energy. Before starting LPG pipeline product GAIL under took cost optimization study for Kandla- Jamnagar-Loni pipeline result indicated that pipelines are considered the cheapest mode of transportation for LPG for distance more than 200 kms for the shake of comparison results are reproduced as under:

1 roads	**Rs 2.44 / MT/KM**
2 railways	**Rs. 2.03 / MT/KM**
3 pipeline	**Rs 1.38 / MT/KM**

1.6 Transnational pipeline Opportunities

In addition to the pipeline projects being developed within the country as mentioned above, the GOI is trying to strike alliances to import piped gas from gas-rich countries in the vicinity, such as Iran and Turkmenistan in central Asia, Qatar and Oman in West Asia and neighboring Bangladesh. Proposals for gas pipelines from Iran and Bangladesh are under active consideration. The first proposition is to connect Iran's South Pars field with the HBJ pipeline. The second preposition is to connect Bangladesh's Bibiyana gas field in North Eastern Bangladesh with India's Northern Gas markets. Unocal Corporation and its subsidiaries in Bangladesh have submitted a gas export pipeline proposal, known as the Bangladesh Natural Gas Pipeline Project, and the proposal is pending approval from the Bangladesh Parliament.

The recent large gas discovery in Myanmar (OVL and GAIL collectively hold a 30% stake) has opened up a new avenue for importing gas into India. The emergence of this option would have a significant impact on the business dynamics of the proposed transnational pipelines from Iran and Bangladesh. Another crucial factor in this segment should be the progress made by the GOI in its efforts to improve the Geo-political scenario in the region. GOI's pricing policy (under formulation) would play a crucial role in the demand supply scenario of gas, as the user industries have alter-native options to gas.

Once GOI clarifies its stand on gas pricing, LNG policy and the common carrier principle, significant, positive implications for the commercial aspects of the natural gas industry in India should be forthcoming.

Chapter-2

Elements of Pipeline Design

Chapter -2 Elements of Pipeline Design

Many factors have to be considered in the engineering and design of long-distance pipelines, including the nature and volume of fluid to be transported, the length of pipeline. The types of terrain traversed, and the environmental constraints.

To obtain optimum results for a pipeline transmission system, complex economic and engineering studies are necessary to decide on the pipeline diameter, material, compression/ pumping, power requirement, and location of the pipeline route. Major factor influencing pipeline system design are:

- Fluid properties
- Design conditions
- Supply and demand magnitude/locations
- Codes and standards
- Route, topography, and access
- Environmental impact
- Economics
- Hydrological impact
- Seismic and volcanic impacts
- Material
- Construction
- Operation
- Protection
- Long-term Integrity

2.1 Fluid Properties

The properties of fluid to be transported have significant impact on pipeline system design. Fluid properties are either given for the system design or have to be determined by the design engineer. The following properties have to be calculated for gas at a specific pressure and temperature:

- Specific volumes
- Super compressibility factor
- Specific heat

- Joule-Thompson coefficient
- Isentropic temperature change exponent
- Enthalpy
- Entropy
- Viscosity

For liquid (such as oil or water):

- Viscosity
- Density
- Specific heat

2.2 Environment

The environment affects both below- and above-ground pipeline designs. For below-ground pipelines, the following properties have to be determined during system design:

- Ground temperature
- Soil conductivity
- Soil density
- Soil specific heat
- Depth of burial

In most cases only air temperature and air velocity have a significant impact on the design of above-ground facilities. For both below- and above-ground 'pipelines, ground stability influences pipeline design/the pipeline support system. Significant variations in ground elevation particularly affect liquid pipeline design.

2.3 Effects Of Pressure and Temperature

Temperature and pressure influence all fluid properties. A temperature rise is generally beneficial in liquid pipelines as it lowers the viscosity and density, thereby lowering the pressure drop. A temperature rise lowers the transmissibility of gas pipelines due to an increase in pressure drop. This results in a net increase in compressor power requirements for a given flow rate, The value of absolute (dynamic) viscosity for gas increases with an increase in pressure and temperature, Such an increase will result in an increase in frictional loss along the length of the pipeline.

Pipeline temperature also impacts the environment In winter, the cold soil temperature can affect the pipe and the fluid being transported. Cooling of non-insulated liquid pipelines by frozen ground increases liquid viscosity and density, thereby requiring greater pumping power.

Liquids that have a constant shear rate with respect to shear stress at any given temperature are termed Newtonian fluids (e.g., water, crude oil), and the viscosity is a function of temperature only, increasing with decreasing temperatures. Non-Newtonian, fluids such as bitumen have viscosities that are not only a function of temperature, but also of shear rate and, in some cases, lime (i.e., shrinkage).

There are a number of different fluids that can exhibit Non-Newtonian behavior. These include diluents (e.g., starch, water, and quicksand), pseudo plastic fluids (e.g. lime solution) and Bingham plastics.

For Non-Newtonian fluids, the viscosity has to be carefully considered. Since the shear rate changes with different fluid velocities, the viscosity curve of a specific fluid can be determined at a known fluid velocity along the fluid temperature profile of a pipeline.

2.4 Supply/Demand Scenario, Route Selection

Supply and delivery points, *as* well *as* demand buildup, affect the overall pipeline system design. The locations of supply and delivery points determine the pipeline route and the locations of facilities and control points (e.g., river crossings, energy corridors, mountain passes, heavily populated areas). The demand buildup determines the optimum pipeline facilities size, location, and timing requirements.

Following the identification of supply and delivery points, and as a preclude o pipeline design, a preliminary route selection is undertaken. Such a preliminary route selection is generally undertaken *as* follows:

- Identification of supply and delivery points (1 :50000 map).
- Identification of control points on the map.
- Plot of shortest route considering areas of major concern (high peaks, waterlogged, terrain, lakes, etc.).

- Plot of the selected route on aerial photographs and analysis of the selected route using a stereoscope to ascertain vegetation, relative wetness, suitability of terrain, construction access, and terrain slopes, etc.
- Refinement of the selected route to accommodate better terrain, easier crossings etc.

This preliminary route selection is often examined by aerial reconnaissance and on-site visits to ensure the pipeline route and potential facility locations are feasible prior to detailed survey. Determining the pipeline route will influence design and construction in that it affects requirements for line size (Length and diameter), as well as compressor or pumping facilities and their location. Hydraulics, operational aspects, and the requirement for special studies in areas where the pipeline traverses unstable ground in highly wet and corrosive soil are generally established at this stage.

The economically optimum sizes of facilities required for the entire range of possible flow rates are determined by the supply and demand buildup data. This data also influences the timing and location of the facilities and whether additional metering stations.

2.5 Codes and Standards

Pipelines and related facilities expose the operators, and potentially the general public to the inherent risk of high-pressure fluid transmission. As a result, national and international codes and standards have been developed to limit the risk to a reasonable minimum. Such standards are mere guidelines for design and construction of pipeline systems. They are not intended to be substitutes for good engineering practices for safe designs.

Major codes affecting pipeline design are discussed later. Some Federal and other governmental authorities have the right to regulation defining minimum requirements for the pipeline and related facilities. These regulations are legally binding for the design construction and separation of pipeline system facilities, which are under the jurisdiction of the relevant authority.There are also a number of other authorities (e.g., utility boards) who have jurisdiction over specific concerns with regards to pipeline design and construction. These authorities have the right to enforce their own regulations, setting minimum requirements for pipeline facilities within their jurisdiction.

2.6 Environmental and Hydrological Considerations

2.6.1 Environmental

The environmental evaluation of a pipeline route is an integral component of its design and construction. It requires special planning to ensure effective and successful protection and reclamation procedures. Initially, resources in the immediate area of the pipeline route are identified and assessed to determine potential impacts. Although site-specific resources that are usually considered in an evaluation are wildlife, fisheries, water crossings, forest cover and archaeological and palacontological resource A soil and vegetation evaluation is also conducted to determine soil handling and reclamation procedures.

Land use in the immediate area of the pipeline route is also identified and evaluated to ensure that conflicts do not arise with other companies or individuals. Protection procedures are based upon these resource assessments and are then integrated into the design parameters of the pipeline construction and specifications.

Timing for pipeline construction is also taken into consideration in the evaluation of resources, as seasons can effect the selection of the most appropriate mitigative procedures. Construction techniques that are effective during the summer may not be appropriate or effective ill the winter.

Alternatively, dealing with site-specific resource impacts may create conflicting timing constraints with those of proposed construction schedules.Specialized techniques to reclaim the construction right-of-way are implemented following mainline construction. Every attempt is made to match existing species revegetation purposes to ensure successful reclamation of non cultivated lands and to return cultivated lands to their previous agricultural productivity.

During construction of the pipeline, environmental inspection is ongoing to ensure compliance with environmental design and protection procedures, and to maintain consistency with various regulatory approvals. Problems that are identified during the design and construction phase of the project are reviewed internally and may initiate environmental research, which in turn may modify future design criteria.

In selecting a pipeline right-of-way (ROW) that is economical and complies with environmental regulations, an environmental impact assessment is usually undertaken for the purpose of determining/developing environmental quality management guidelines for pipeline construction and operation. These guidelines usually include the following:

1) Compliance

- Legislation compliance
- Environmental guideline compliance
- Environmental coordination, audit and training
- Recommendation by volcanologist / Geotechnical /seismic consultant.

2) Guidelines for soil erosion protection

- Erosion process and types
- Erosion risk assessment
- Erosion protection

3) Guidelines for water quality protection

- Baseline water quality
- Site selection
- Water analysis/quality index
- Impact and mitigation measures

4) Guidelines for archeological heritage protection

- Historical resources
- Archeological studies
- Regulations

5) Environmental protection resources and methods

- ROW preparation and pipe installation.
- ROW width during construction
- Grading
- Rip rap
- Sand plugs
- Temporary cover
- Sediment/silt traps
- Canals/disturbances

- Volcanic areas (if applicable)
- Permanent physical erosion control method
- Soft plugs
- Revegetation /regarding
- Drainage system
- Ditch foam plugs
- Agronomic erosion control
- Revegetation measures schedule
- Procedures and methods
- Revegetation plan

1.6.2 Hydrological

A pipeline may be subject to buoyant forces due to water migration and flooding or water crossings. The design must consider the potential for damage to the pipeline due to flood plains and the need for dredging of water crossings, scouring or channel shifting in order to determine the correct pipeline design and installation technique. The design may need to consider the determination of pipe depth, buoyancy control, pipeline installation, and construction methodology in areas of hydrological concern. Usually facilities are designed such that they will not sustain any unanticipated damage from a I: I 00 year flood, and will fully and continually operate under 1:50 year flood conditions. Hydrological Condition and scouring evaluations should be undertaken for major river crossings with established 1:50 years and 1: 100 year's flood plains.

2.7 Economics

The economics of transporting fluids by pipelines affect almost all design and construction parameters. For any pipeline project, the objective of economic analysis is to determine which of the alternative design and construction solutions offers the best economic. Economic analysis is carried out to determine the optimum choice between size of pipelines (diameter, wall thickness, and material) and compression/pumping power requirements. An economic analysis is also needed for utility purposes, to define tariffs that have to be charged .for the transmission of fluid to achieve a stipulated economic performance of a pipeline system investment.

The economic feasibility of a pipeline project is usually established before any optimization takes place. One criterion that is often used for acceptance or rejection of a project is the expected rate of return on the invested capital.

Once the feasibility is proven optimum choices between line sizes and pumping/ compression requirements are determined. Timing considerations may be optimized and tariffs may be determined (mostly for utility companies).

Estimates have to be made for the overall investment requirement and associated optimum choices between line size and pumping/compression requirements are determined. Timing considerations may be optimized and tariffs may be determined (mostly for utility companies).

Estimates have to be made for the overall investment requirement and associated operating costs of the proposed pipeline system. These are the two principal components of owning and operating a pipeline system. The relevant costs for a pipeline project have to be carefully considered covering all phases from planning to operating and maintaining the pipeline over the course of its life. Elements that influence the cost estimate and therefore the economic analysis are outlined in the following subsections.

2.7.1 Direct Costs

Direct costs cover expenditure directly related to the design, construction, and operation of all pipeline system, including the following:.

- Line pipe
- Compression/pumping facilities
- Meter stations
- Valve and fittings
- Protection facilities (coating plus cathodic protection)
- Scraping/cleaning facilities if any
- Pressure reduction facilities
- Power generation (if applicable)
- Construction costs
- Engineering costs
- Survey costs
- Cost of ancillary facilities

- Legal and land costs (ROW acquisition)
- Docks, wharves
- Leak detection system
- Logistic costs (those associated with material and equipment transportation)
- Operating and maintenance costs (those associated with local taxes, fuel, energy, material, and labor costs)
- Other costs (line fill, working capital required to operate the pipeline, etc.)

2.7.2 Indirect Costs

Indirect costs affect the financing of a pipeline project, and include costs associated with the acquisition of necessary funds to cover the purchase of materials and construction. Indirect costs also cover the interest on money borrowed to finance the pipeline project.

2.7.3 Economic Analysis

Oil and gas producing companies may use an economic analysis to justify a pipeline project over to alternative solutions. Oil can be transported by road or rail. Gas may be fed into an existing pipeline network owned by a utility company. In the latter case, a tariff for self-'ownership is determined and compared to the tariff charged by the utility company for transportation of gas to the delivery point: The system design is influenced by the economic analysis since a number of technical solutions are investigated by varying pipeline size, pumping or compression facilities, and the timing of the facility expansion or addition.

Utility companies are interested in establishing the appropriate tariff to charge a customer for transporting the customer's fluid in the company's lines. For a selected pipeline size, given that the volume of fluid to be transported can have an upward trend (as a result of demand buildup) the tariff generally decreases as the throughput increases. If the pipeline design or operating conditions are changed, the tariff will change. As a result to determine the viability of the pipeline system configuration for all modes of volumetric flows.

When the economic viability of a pipeline project is established, the analysis is usually rerun using the optimal technical configuration and the most refined cost infom1ation available. The following additional cost parameters need to be considered:

- Equity investment as a portion of total investment (loan-equity ratio) . Interest on borrowed capital
- Duration of borrowed capital (i.e., repayment schedule)
- Depreciation rate of facilities investment for book purposes
- Depreciation for tax purposes
- Escalation rate of operation and maintenance cost
- Required rate of return on investment
- Escalation rate on tariff
- Expected life of the pipeline until abandonment

After evaluation of all the above parameters, the factor by which the economic viability of a pipeline system is measured is the rate of return. The higher the rate of return, the more attractive the project is forms an investment point of view. Calculation of investment rate of return based on computing relevant cash streams for each calendar year and discounting accordingly. This type of compression is best suited for computer application due to the repetitive nature of the calculations

2.8 Materials/Construction

For long-distance pipeline systems, the significant cost in terms of capital investment is the cost of the pipe material and installation. Pipeline pressure, grade, installation location, and technique affect the cost and design. Pipe material/grade affects the wall thickness and determines the choice of and limit on the welding/installation technique. For a given design pressure and pipe diameter, the wall thickness decreases with a higher grade material. However, higher grades of steel are usually accompanied by cost premiums and more stringent construction techniques, which translate into higher costs.

2.9 Operation

The design stage should also determine the most stringent conditions the pipeline would operate under and provide for facilities to prevent failure, including line rupture. An example of the latter is sudden valve closure in liquid pipelines where valves are located downstream in a downhill terrain. Such an example is shown in the paper by Kung and Mohitpour (19H6) entitled "Non-Newtonian Liquid Pipeline Hydraulics Design and Simulation Using Micro computers." Sudden valve closure at such a location could cause pipeline pressure to exceed the maximum design pressure set by the pipe strength and wall thickness. Without surge mitigating facilities the pipeline could rupture resulting in environmental and maintenance implication.

Sudden valve closure in liquid pipelines (e.g. crude oil) may create a low pressure situation that in extreme cases can lead to vapor pockets in the line. Since the cal lapsable vapor pockets can damage the pipelines, this condition has to avoid.

2.10 Pipeline protection

2.10.1 External Protection

Buried pipelines are subjected to external corrosion caused by the action and composition of the soils surrounding them. During the design stage, the available types of external coating material and cathode system required to protect the pipeline from external corrosion are evaluated. The coating and cathodic protection are chosen according to economics and ability to protect the pipeline.

External coating is usually a plastic material that is wrapped or extruded onto the pipe or fusion-bonded to the surface. External coatings have to be designed to serve as a corrosion barrier and to resist damage during transportation, handling, and backfilling. Therefore, in some cases corrosion protection coatings are combined with other external coatings, such as insulation, rock shield, or concrete.

2.10.2 Internal Protection

Fluids containing corrosive components such as salt water, hydrogen sulfide (H_2S), or carbon dioxide/monoxide can cause internal corrosion. Many of the internal corrosion problems can be corrected in the design stage. This is done by proper design and selection of materials appropriate for the fluid to be transported. An example is the pipeline transportation of sour gas. The types of corrosion that can occur in sour gas pipelines are:

- Hydrogen-induced corrosion
- Hydrogen-induced cracking
- Sulfide stress cracking (hydrogen embrittlement)
- Pitting corrosion
- General corrosion
- Erosion corrosion

Hydrogen-induced cracking such as blistering has been observed in both low- and high-yield-strength steels under both stressed and non-stressed conditions. Hydrogen blistering and cracking results from the diffusion of atomic hydrogen, produced by the corrosive elements in a wet H_2S environment, into the steel, where it is absorbed in laminations or inclusions in the pipe wall.

The atomic hydrogen changes to non diffusible molecular hydrogen, building up high localized pressures that cause blisters or cracks in the pipe walls. The design will set the stage for the protection of the pipe against such a failure by specifying the limits on the following:

- Quantities of cerium or other rare earth metals to spheroidize manganese sulfides
- Level of sulfur content
- Level of copper content (up to 0.3%) to reduce the hydrogen absorption properties of the steel.

The exact mechanism or sulfide stress cracking or hydrogen embrittlement is not clearly understood; however, it is generally agreed that it is influenced by three factors environmental, metallurgical, and stress-related. Environmental factors include pH, H_2S concentration and temperature. Metallurgical variables include strength or hardness, ductility, composition, heat treatment, and microstructure. The susceptibility of a steel to sulfide stress cracking increases with increasing hardness and stress and also with decreasing pH level of liquids. Sulfides stress cracking is evidenced as a reduction in normal ductility and the embrittlement of steel.

A specification for the line pipe material developed at the design stage ensures that the pipe produced is suitable for the operating temperature that will be encountered and is not susceptible to hydrogen-induced corrosion. Pitting corrosion results from chemical attack at low points where fluids settle and accumulate in the piping system. Sulphate-reducing bacteria may also cause pitting corrosion.

General corrosion results from chemical attack and usually occurs on the upper half of the pipe wall adjacent to low areas where the pipe wall is alternately wet and dry. The use corrosion inhibitor has proven to be the only effective method to mitigate internal corrosion in wet sour gas pipelines. On-stream pigging facilities are generally incorporated into the design of the system to permit the removal of liquid accumulation on a schedule. On-stream pigging also improves the distribution of the corrosion inhibitors and is a valuable aid in the: mitigation of internal corrosion.

Erosion corrosion results from impingement of fluids/chlorides on the pipe surface at high flowing velocities. Piping is generally sized to limit flowing velocities below the critical velocity at which corrosion erosion will begin to occur. Critical velocity is defined as the point at which velocity is a significant factor in the removal of inhibitor films or corrosion products.

2.11 Pipeline Integrity Monitoring

No matter how well pipelines are designed and protected, once in place they are subjected to environmental abuse, external damage, coating disbondment, soil movement/ and third-party damage. The goal of any pipeline integrity program is to prevent structural integrity problems from having a significant effect on public safety, the environment, or business operations by identifying and performing the most effective inspection, monitoring, and repair activities.

2.11.1 Integrity Assessment Methods

There are several techniques available to assess the integrity of the pipeline once it's in place. These are summarized as follows:

- Visual inspection
- Depth of cover survey
- External nondestructive testing (NDT)
- Radiography
- Magnetic particle testing. Dye penetrant inspection
- Ultrasonic inspection
- Cathodic protection monitoring
- Coating disbondment and damage survey
- Hydrostatic testing.
- Geometry in-line inspection (ILI) tools
- Caliper pig
- X. y. z geometry (inertial guidance) tool

- Ultrasonic in-line inspection tools
- Conventional magnetic flux
- High-resolution magnetic flux (3D)

Utilization of high-resolution tools facilitates an accurate prediction of external and internal corrosion areas.

2.11.2 Risk Assessments

Risk assessment is an integrity management tool and its purpose is to identify and quantify the risks associated with pipeline operation, such that remedial action can be performed in a timely manner. This is achieved through the ranking of potential risk to safety, environment, and operations.

Several risk assessment methods are used by the industry. The most common are failure probability methods and ranking systems. The most appropriate method depends upon several factors, including system complexity, availability of historical data, and rigor required by the analysis.

Pipeline integrity and management decisions are made much easier by the risk assessment and prioritization process, which establishes a firm, documented basis for determining expenditures and schedules.

2.12 Pipeline Repairs

Once an integrity assessment method establishes a requirement for pipeline repair, there are several methods that are commonly used by the industry to restore pipeline integrity:

- Local coating repairs
- Coating rehabilitation
- Sleeve repair
- Cutout repairs

Use of each repair system depends on the extent of damage or corrosion problem but repairs are carried out to restore the integrity of the pipeline to assure its intended operational capacity.

Chapter-3

Route Selection

Chapter-3 Route Selection

Before designing the pipeline feasibility studies has to be done. After getting the inputs from the clients feasibility analysis has to be done by the organization. If the proposed pipeline is feasible to lay down then engineering design basis is done.

Inputs from the clients are:

- Locations of the pipeline
- Various consumers of the product
- Flow rate of product

3.1 Route Selection

Route selection process of identifying constraints, avoiding undesirable areas and maintaining the economic feasibility of pipeline. The ideal route of course would a straight line from the origin to the terminal point. The preliminary route selection involves planning the route on available maps in office. Then followed by fieldwork to verify the acceptability of the route. The following factors must be considered prior to selecting the optimal route for the pipeline:

- Cost efficiency
- Pipeline integrity
- Environmental impacts
- Public safety
- Land-use contracts
- Restricted proximity to existing facilities

3.1.1 Key factors for route selection

- Related to rivers, creeks, lakes and swamps
- Unnecessary crossings
- Braided channels
- Areas of erosion potential
- Bedrock
- Natural meander progression
- Related to physiography

- Excessively steep slope
- Side slope
- Rocky slope
- Erosive soils
- Rocky soil
- Sandy soil
- Earthquake location
- Fault location
- Related to environment
- Fish spawning areas
- Historical & archaeological sites
- Merchantable timberland
- Others factors that affect the route selection are
- Road and railway crossings
- Areas of population concentration
- Restricted areas such as national parks
- Forest regeneration sites. Etc.

3.1.2 Map selection

- Obtain the best available topographic maps
- Use scale of 1:5000 if possible
- Well site and pipeline plans are obtained from the appropriate Regulatory Department. Etc.

3.1.3 Plotting restriction

- Major highways and roads
- Townships
- Railways
- Rivers, canals etc.
- Well sites and access roads
- Existing pipelines
- Wildlife and environmental reserves
- Historical reserves
- Forest reserve sites

3.1.4 Establishing a Route

- Draw a line form point A to B.
- Draw alternate route
- Draft preliminary route sketch
- Finding out the minimum length route.

3.1.5 Evaluating the preliminary route

- Note the river or major creeks crossing
- Check the proximity to population concentration and restricted areas
- Take initial environmental consideration into account complete an initial environmental consideration into account
- Complete an initial terrain analysis
- Establish the preliminary length of the route

3.1.6 Refining the preliminary Route

- Evaluate the various consideration/ restrictions for each alternate route or option.
- Redraw or refine the route
- Re-evaluate each route and choose the most optimum solution from a cost perspective.

3.1.7 Obtain existing Arial Photograph

- Obtain suitable photograph from government photo libraries.
- Evaluate river crossing and steep terrain.
- When existing government photos are outdated, the proposed route may be re-flown and re-photographed, if the project is large enough to warrant it.

3.1.8 Flying the preliminary route

- Confirm or reject speculations
- Reconsider any alternate routes
- Adjust the lines as necessary and add any pertinent notes.
- After that finalizing of the route (Office route) is done.

3.2 Alignment Sheet

Alignment sheets provide information about topography and ground profile of the pipeline. These alignment sheets are then forwarded to the contractor providing all the technical details for carrying out pipeline installation.

Alignment sheets consists of several rows in which the following parameters present:

- Intersection points (TP/IP): TP refers to Turning points namely TP-0, TP-1, TP-2 etc. and IP refers to intermediate points namely IP-1, IP-2, IP-3 etc. these intermediate points are used for distinguishing line.
- Deflection angle: This is the angle at which the route is deflected from its original path.
- Distance between IP/TP in meters
- State district and Tehsil
- Planimetry: The complete scaled route with various topographical details, their location and orientation is given. For e.g., road crossings, Nala crossings, rail crossings etc.
- The scale is used as follows:

Horizontally	1:5000
Vertically	1:1000

- Ground profile: It is drawn with the above scale. Datum level is considered to be some meters above mean sea level for easy reference.
- Surface terrain details: The types of terrain's encountered in the path of the line like fields, road, rivers etc.
- Special provision: these are the provisions like concrete coating to counterattack the effect of buoyancy.
- Class/Zone: Different classes are specified such as class-1, class-2 etc. these classes are specified according to the ASME 31.8 for gas pipeline and 31.4 for oil pipeline.
- Design factor: respective design factors of the classes are specified as per ASME 31.8 for gas pipeline and 31.4 for oil pipeline.
- Cumulative design: the row limits of all major facilities are specified.
- Pipeline cover minimum: Pipeline is buried at a depth of 1.0 m except at river/road/rail crossings. The minimum cover of all the facilities is marked by extension lines above the crossings. The minimum cover for the road crossings is 1.2 m and that of rail is 1.7 m.
- Special installations fitting markers: KM is used after every kilometer.

   - ➢ Direction marker is indicated before a pipe undergoes a bend.
   - ➢ Pipeline warning sign is used before any crossings
   - ➢ Arial marker is indicated after every 5 km.

- Pipe wall thickness: the thickness of the pipe varies according to the classes. Different classes will have different design factors with which the thickness also varies. This is done according to specifications as per ASME 31.8 for gas pipeline and 31.4 for oil pipeline.
- Crossings: symbols of various crossings are used to indicate the type of crossing including the method of installation of pipeline across the crossing.
- Coating scheme: the coating scheme is 3-layer side extended polyethylene coating.
- Cathodic protection installation.
- Soil resistivity
- Soil stratification

3.2.1 Legends use in the alignment sheets is:

- Topographical symbols used in the sheets are given
- Pipeline symbols used in the sheets are given
- Soil symbols used in the sheets are given
- General notes.
- Bill of material for drawing
- Reference drawings: the cross section drawing numbers are mentioned which have to be referred for the details of various facilities.
- Bottom most right part consists of the name of the client, project, section, chain age, job number and the drawing number.

3.3 Location Classes for Design And Construction

Location class 1 A class 1 is any 1 – mile section that has 10 or fewer buildings intended for human occupancy. A location class 1 is intended to reflect areas such as wasteland, deserts, mountains, grazing land, farmland and sparsely populated area.

Class (1) division 1 This division is a location class 1 where the design factor of the pipe is greater than 0.72 but equal to or less than 0.80 and has been hydrostatically tested to 1.25 times than the maximum operating pressure.

Class (1) division 2 This division is a location class 1 where the design factor is equal to or less than 0.72 and has been tested to 1.1 times the maximum operating pressure.

Location class 2 A location class 2 is any 1-mile section that has more than 10 but fewer than 46 buildings intended for human occupancy. A location class 2 is intended to reflect areas where the degree of population is intermediate between location class 1 and location class 3 such as fringe areas around cities and towns, industrial areas, ranch or country estates etc.

Location class 3 A location class 3 is any 1-mile section that has 46 or more buildings intended for human occupancy except when a location class 4 prevails. A location class 3 is intended to reflect areas such as suburban housing development, shopping centers, residential areas industrial areas and other populated areas not meeting location class 4 requirements.

Location class 4. A location class 4 includes areas multistory buildings are prevalent where traffic is heavy or dense and where there may be numerous other utilities underground. Multistory means four or ground floor. The depth of basement s or number of basement floors is immaterial.

3.3.1 Crossing Sheet

Crossing sheet provides the information about no. Of crossing takes place across the proposed pipeline route and their location of the class. Information from crossing sheet

Pipeline section
Length in Km
Highest elevation in m
Number of major crossings
Railways crossings
National highway crossings
State highway crossings
Road crossings
Major/Minor River Crossings
Nala/ Stream/ Canal Crossings

3.3.2 Crossing Details

- River crossings: All river crossings shall have a minimum cover of 2.5 m below scour level or as per requirements of local/statutory authorities, whichever is higher. Crossings shall be carried out by open cut or Horizontal Directional Drilling (HDD) method depending upon width, depth, bank slopes, soil type, flow etc.

- Rail crossings: Pipeline at rail crossings shall be provided with casing pipe. The casing pipe shall be two nominal pipe sizes larger than carrier pipe and shall be installed by Boring/Jacking. The rail crossing shall comply with the requirements of API 1102.

- Road crossings: Road crossings shall comply with the requirements of API 1102. All national highways crossing shall be cased crossing. The casing pipe shall be two nominal pipe sizes larger than carrier pipe. The casing pipe shall be installed by Boring/Jacking method. Higher thickness carrier pipes shall be used at crossing.

- Existing pipeline crossing: The specific requirements of Owner/operator of existing pipeline shall generally be followed. The minimum clearance between the lines shall be 300 mm unless specified otherwise.

Chapter-4

Pipeline Mechanical Design

Chapter-4 Pipeline Mechanical Design

This chapter applies specifically to the design of steel pipelines for transmission of gas and liquid petroleum products. It is not intended to be applied to other types of lines, such as low pressure, plastic, or distribution lines.

4.1 Codes and Standards

The design, material selection, and construction of pipeline facilities are governed by codes and standards that prescribe minimum requirements. The purpose of the codes and standards are to ensure that the completed structure will be safe to operate under the conditions to be used. Besides these, other regional, national, or international standards may be used in specific situations. While local regulations may also apply.

Individual companies may elect to develop in-house standards or specifications, which are more stringent than the minimum code requirements. Such standards are generally developed based on past experience and are intended to complement design and operating procedures.

In all cases, familiarity with applicable codes, standards, or specifications is required before the design commences. The following codes and standards form the basis of the pipelines wall thickness calculations.

4.1.1 American Petroleum Institute (API)

API 5L	Specification for Line Pipe

4.1.2 American Society of Mechanical Engineers (ASME)

ASME B 31.8	Gas Transmissions and Distribution Piping System Pipeline for Pressure Piping

4.2 Location Classifications

The most significant factor contributing to the failure of a gas pipeline is damage to the line caused by human activity. Pipeline damage generally occurs during construction of other services. These services may include utilities, sewage systems or wad construction and will increase in frequency with larger populations living in the vicinity of the pipeline. To account for the risk of damage, the designer determines a location classification based predominantly on population concentrations. Canadian and American codes differ marginally in the requirements for determining a specific location classification. Table 4-1 reflects the requirements of the relevant North American codes.

Table 4.1 Location of Classification

	Canadian code	American code	
Location classification	Z662-96 (liquid and gas)	ASME B31.4 (liquid)	ASME B31.8 (gas)
Class 1	Dwelling units≥10	Not applicable	Dwelling units≥10
Class 2	10< Dwelling units<46 buildings or area occupied by more than 20 people	Not applicable	10< Dwelling units<46
Class 3	Dwelling units≥46	Not applicable	Dwelling units≥46
Class 4	Dwelling units≥4 stories	Not applicable	Buildings ≥4 stories Dense traffic or underground facilities

4.3 Pipeline Design Formula

The widely used formula for determining the circumferential and axial stresses in a pressurized thin-walled pipe can be developed quite easily by considering the vertical and horizontal force equilibrium.

A unit tangential force *F* is created in the pipe wall due to the application of an internal pressure, *P*, assumed to act on a unit length of pipe The resultant vertical force due to this pressure is *PD*, so the equilibrating force *F* in the pipe wall must be *PD/2* This force acts on an area of pipe wall, *A*, given by the product of the wall thickness *t* and unit depth of pipe.

This is the hoop stress equation which can be transposed to yield the familiar Barlow equation for the wall thickness of the pipe. A similar consideration of the horizontal equilibrium of forces enables an expression for development of longitudinal stress in the cylinder. The longitudinal force on the pipe wall caused by the internal pressure is approximately $\mathbf{F = P (\pi D^2/4)}$, which is equilibrated by the force in the pipe wall. This force acts on an area approximated by $\boldsymbol{\pi}$**Dt** so the axial stress S_N is

$$S_N = F/A = P\pi D^2 /4\pi Dt = PD/4t$$

A more accurate representation of the axial stress would be found by using the actual area of pipe wall resisting the longitudinal pressure force that is

$$S_N = F4/\pi\,(D^2-d^2) = Pd^2/\,(D^2-d^2)$$

Where *D* and *d* are the outer and inner diameters respectively. This is slightly less conservative than using the thin-wall approximation. In a similar fashion, the bending section modulus Z of a thin-walled cylinder can be approximated as $Z = \pi r^2 l$ where *r* is the mean radius, or in exact terms:

$$Z = \pi/32\,((D^4-d^4)/D.$$

4.3.1 Wall Thickness Calculation

Formulation for pipe wall thickness and grade selection based on pressure and other loads, the wall thickness of gas transmission pipeline varies with the pipe grade, location and design pressure. The design pressure, which is specified by the system designer for any, should not be less than the maximum operating pressure (MOP) of the pipeline at the location where all the forces are considered. The pipe wall thickness and material selected by the designer should provide adequate strength to prevent deformation and collapse by handling stresses, external reaction, thermal expansions and contractions. According to the pipeline codes ANSI-ASME B31.8, the stress design requirement to be considered are limited to normal design conditions for operating pressure, thermal expansion and contraction ranges, temperature differential, and other forces acting on the pipeline. Additional loading include:

- Occasional extreme loads (Earthquake)
- Slope Movements
- Fault Movements
- Seismic-related earth movements
- Loss of support
- Thaw settlements
- Frost heave
- Cylindrical traffic load
- Construction and maintenance deformation
- Mechanical vibrations
- Hydraulic Shock

These loadings require supplemental design criteria (Such as heavier wall thickness or stronger material) to ensure a safe and operational pipeline. This report covers the calculation of pipeline wall thickness as per ASME Code B 31.8, for onshore gas pipelines.

Formula used

The design pressure for steel gas piping systems or the nominal wall thickness for a given piping system or the nominal wall thickness for a given design pressure shall be determined by the formula

$$t = \frac{P\ D}{2SFET}$$

Where,

P	=	design pressure in psi
S	=	specified minimum yield strength in psi
t	=	nominal wall thickness, in mm
D	=	pipe outside diameter, in mm
F	=	design factor
E	=	Longitudinal joint factor
T	=	temperature derating factor.

Design pressure (P)

It is the maximum pressure permitted by this code, as determined by the design procedures applicable to the materials and locations involved.

Nominal wall thickness (t)

It is the wall thickness computed by or used in the design equation. Under this code, pipe may be ordered to this computed wall thickness without adding allowance to compensate for the under thickness tolerance permitted in approved specification.

Specified minimum yield strength (S)

It is expressed in pound per square inch, is the minimum yield strength prescribed by the specification under which pipe is purchased from the manufacturer.

Diameter or Nominal outside diameter (D)

It is the as produced or as-specified outside diameter of the pipe, not to be confused with dimensionless NPS. For example,

NPS 12 pipe has a specified outside diameter of 12.750 in.

NPS 8 pipe has a specified outside diameter of 8.625 in.

Longitudinal Joint Factor (E)

If the type of longitudinal joint can be determined with certainty, the corresponding longitudinal joint factor, E may be used. Other wise, E shall be taken as .60 for NPS4 and smaller, or .80 for pipe larger than NPS4

Table 4.2 Longitudinal Joint Factor for different line pipe

Spec. No.	Pipe class	E factor
ASTM A 53	Seam Less	1.00
	Electric resistance welding	1.00
	Furnace Butt welded: continuous weld	0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric Fusion Arc Welded	0.8
ASTM A 135	Electric resistance welded	1.00
ASTM A 139	Electric Fusion welded	0.8
ASTM A 211	Spiral welded steel pipe	0.8
ASTM A 333	Seamless	1.00
	Electric resistance welding	1.00
ASTM A 381	Double submerged arc welding	1.00
ASTM A 671	Electric fusion welded	
	Classes 13,23,33,43,53	0.80
	Classes 12,22,32,42,52	1.00
ASTM A 672	Electric fusion welded	
	Classes 13,23,33,43,53	0.80
	Classes 12,22,32,42,52	1.00
API 5L	Seamless	1.00
	Electric resistance welding	1.00
	Electric flash welded	1.00
	Submerged arc welded	1.00
	Furnace butt welded	0.60

Temperature De-rating factor (T)

Table 4.3 Temperature De-rating factor

Temperature, °F	Temperature Derating Factor, T
250 or less	1.000
300	0.967
350	0.933
400	0.900
450	0.867

Design factor (F)

Table 4.4 Design Factor

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 next available wall thickness as per API 5L greater than the calculated thickness is then selected.

The minimum acceptable wall thickness is taken as 6.4 mm to prevent damage from handling of pipes during transportation and construction phases. The highest grade selected is API 5L Gr. X-65, PSL-2.

In order to identify the most economical option from the numerous material, wall thickness combinations, the total tonnage for each combination for the given pipeline length is determined. The benefits of reduced tonnage (by the selection of higher grade material) are compared to incremental cost associated with selection of superior metallurgy.

Through the above process the optimum material and wall thickness combination is identified. The wall thickness selected for the proposed pipelines are summarized in Table-4.5

Specified minimum yield strength (S) = 46000 psi

Design pressure (P) = 92 (kg/cm^2

Density =7850 (kg/m^3)

Steel Grade = X46

Table-4.5: Summarized different parameter used in pipeline design

(Dia) (in)	F	E	T	Thickness (mm)	Available thickness (mm)	L (Km)	Weight of steel (Kg)	Weight of steel (MT)
42	0.72	1	1	21.0	22.20	400	228665168913.02	228.67
42	0.6	1	1	25.2	25.40	150	97808929154.93	97.81
42	0.5	1	1	30.2	30.20	50	38585353509.65	38.59
42	0.4	1	1	37.8		12	0.00	0.00

Sample Wall Thickness Calculations

Data for Murawan-Lucknow pipeline is as follows :

Pipeline design pressure (p) = 78.7 Kg/cm2

Corrosion allowance (A) = 0.5 mm

Pipeline outside diameter (D) = 219.1 mm

Approximate pipeline length = 32 Km

Temperature derating factor, T for 250 or less °F is 1.00

It is proposed to use Electric Welded pipes as per API specifications 5L, Product Specification Level-2(PSL-2).

From table 402.4 of ASME B 31.4 E, Weld Joint factor = 1using eg. (1) and(2) above the wall thickness for various grades is calculated as follows :

API 5L Grade X-52

For class-1 design factor = 0.72

$$t = \frac{(78.7 * 14.223)(219.1)}{2(0.72*1*52000} + 0.5$$

= 3.275+.5

= 3.775 mm

The next higher standard thickness available as per API specifications 5L is 6.4 mm

The total tonnage = weight per unit length (from API 5L)*pipeline length

= 33.57 Kg/m*3200 m

= 1074.24 tons

For class 2 design factor = 0.6

$$t = \frac{(78.7*14.223)(219.1)}{2(0.6*1*52000)} + 0.5$$

= 3.93 + 0.5

= 4.43 mm

The next higher standard thickness available as per API specification 5L is 6.4 mm

The total tonnage = weight per unit length (from API 5L)*pipeline length

= 33.57 Kg/m * 32000 m

= 1074.24 tons

For class 3, design factor = 0.5

$$t = \frac{(78.7 * 14.223)(219.1)}{2(0.5*1*52000)} + 0.5$$

= 4.716 + 0.5

= 5.216 mm

The next higher standard thickness available as per API specification 5L is 6.4 mm

The total tonnage = weight/unit length (from API 5L) * pipeline length

= 33.57 Kg/m * 32000 m

= 1074.24 tones

For class 4, design factor = 0.4

$$t = \frac{(78.7 * 14.223)(219.1)}{2(0.4*1*52000)} + 0.5$$

= 5.895 + 0.5

= 6.395 mm

The next higher standard thickness available as per API specification 5L is 6.4 mm

The total tonnage = weight/unit length (from API 5L) * pipeline length

= 33.57 Kg/m * 6000m

= 201.42 tons

4.4 Expansions and Flexibility

Piping has to be designed to have sufficient flexibility to prevent thermal expansion or contraction from causing excessive stresses in the piping material or imposing excessive forces or moments on equipment or supports. In many cases, allowable forces and moments on equipment may be less than those for the connecting piping. If expansion is not absorbed by direct axial compression of the pipe, flexibility should be provided by the use of bends, loops, offsets, and, in rare instances, by mechanical joints or couplings.

In simple teems, a flexibility analysis determines a suitable piping layout so as to minimize pipe stresses. Such an analysis evaluates the range of stresses the piping system will encounter while undergoing cyclic loading. The most common of these ranges is the thermal expansion stress range caused by system start-up and shut-down conditions. Often the stress range encompassed by the consideration of the cold (start-up) and hot (shutdown) conditions will be sufficient to cover other thermal expansion conditions such as standby, or variations in operating envelopes. However, any cyclic condition that could result in a significant stress range, irrespective of whether or not the source is thermal expansion, will require evaluation. Hence, any event that could cause relative displacement between anchor points, such as settlement or seismic disturbance, would fall into this category. After determining that the piping layout has adequate flexibility, the designer is free to use judgment, span tables, or simple formulae to locate suitable positions for intermediate supports to carry weight and other loads. The nature of these supports will be dependent upon the magnitude of the likely pipe displacements at their proposed locations. For example, if these are very small then a rigid support may be used. Springs or gapped supports may be used to accommodate vertical or lateral displacements. The overriding consideration is that the support type must offer minimal restraint to the system as it undergoes cyclic loading, in order that the stress range is not unduly increased.

There are fundamental differences in loading conditions for buried or similarly restrained portions of piping and the above-ground portions not subjected to substantial axial restraint. Therefore, different limits on allowable expansion stresses are necessary. Note that the ASME B31.8 code does not clearly differentiate between restrained or unrestrained lines. Rather, it is the operator's responsibility to define the type of restraint present, determine the loads causing axial stress and limit them appropriately. The assumption is made in both B31.4 and B31.8 that a buried pipeline is restrained and an above-ground pipeline is unconstrained, but this is not always an appropriate assumption.

4.4.1 Restrained Lines

Expansion calculations are necessary for buried lines if significant temperature changes are expected. Thermal expansion of buried lines may cause movement at points where the line terminates, changes direction, or changes size. The hoop stress due to design pressure is determined in accordance with Equation:

$$S = \frac{PD}{2t}$$

For a pressurized pipe, the radial growth of the pipe will induce an opposite longitudinal (Poisson) effect to that caused by thermal effects. This will reduce the compressive stress such that

$$S_L = \nu S_h - E_c \alpha (T_2 - T_1)$$

where

S_L = restrained longitudinal compression stress

ν = Poisson's ratio

E_C = cold modulus of elasticity of steel

a = linear' coefficient of tl1ennal expansion

T_2 = maximum operating temperature

T_1 = ambient temperature at time of restraint

t = wall thickness

and

$$S_h - S_L \leq 0.09\, S \times T$$

where

S = specified minimum yield strength

T = temperature derating factor

Note that this formula does not apply if S_L is positive (i.e. tension).

For those portions of restrained pipelines that are freely spanning or supported above ground, the combined stress is limited by ASME B31.8 in accordance with the following formula

$$S_h - S_L \pm S_B \leq 0.09\ S \times T$$

Where

S_B = absolute resultant value of beam bending stresses caused by dead and live loads acting in and out of plane on the pipe, and is given as follows:

$$S_B = [(0.75 i_i M_i)^2 + (0.75 i_o M_o)^2 + M]^{0.5} / \quad Z$$

Note that M_i, M_o, and M_t are the in plane, out of plane, and tensional moments respectively, acting on the pipe and Z is the section modulus. The terms i_j and i_0 refer to the in and out of plane stress intensification factors that have been identified for various critical piping components, usually by experimental means. They can be found for a variety of components such as elbows, meters, and fabricated tees in Appendix 'E' of ASME B31.8 (1992).

ASME B31.4 does not include a temperature-derating factor, but limits the range of applicable temperatures to under 120°C. It should also be noted that ASME B31.8 does not distinguish between restrained and unrestrained lines.

4.4.2 Unrestrained lines

Expansion calculations for aboveground lines have to account for thermal changes as well as beam bending and the possible elastic instability of the pipe and its supports (due to longitudinal compressive forces). CSA Z662, ASME B31.8, and ASME B31.4 segregate requirements for combining stresses in terms of unrestrained lines. However, the requirements vary slightly between the two codes and will therefore be addressed separately. In both CSA Z662 and B31.8 the stresses due to thermal expansion for those portions of pipeline systems without axial restraints are combined and limited in accordance with the following formulae:

For bending

$$S_b = \frac{iM_b}{Z}$$

Where

S_b = resultant bending stress

I = stress intensification factor

M_b = resultant bending moment

Z = section modulus of pipe

For twisting

$$S_t = M_T / 2Z$$

Where S_t is the torsional stress and M_T is the twisting moment.

The combined thermal expansion stresses can be combined as follows:

$$S_E = \left(S_b^2 + 4S_t^2\right)^{\frac{1}{2}}$$

where

S_E = combined thermal expansion stress.

However, the combined thermal expansion stress is not permitted to exceed 0.72 of the specified minimum yield stress times the temperature derating factor In AS ME B31.4, the bending stresses due to thermal expansion for those potion of pipeline systems without axial restraint have to be combined and limited in accordance with Equation (7 -17) (for temperatures less than 120° C):

$$S_B = \{(i_i M_i)^2 + (i_o M_o)^2\}^{0.5} / z$$

Where

S_B = resultant bending stress

M_i = the in-plane bending moment

i_i = the stress intensification factor for bending in the plane of the member'

M_o = bending moment out of, transverse to, the plane of the member

i_o = stress intensification factor for out-of-plane bending.

The following limiting cases must also be satisfied;

$$0.5\ S_H + S_{B(D)} < 0.54S$$

Where $S_{B(D)}$ = absolute value of beam bending compression stress resulting from dead loads

A further limitation is caused by the addition of live loading so that where

S_L = longitudinal stress $PD/4t$ and $S_L + S_{B(D+l)} < 0.85\ S$

absolute value of longitudinal bending stress from both dead and live loading. Both CSA and ASME codes specify minimum allowable wall thickness for various pipe diameters. The intent is to minimize pipe damage during normal manufacturing, handling, construction and operation.

4.4.3 Anchoring and Support

Reinforced concrete blocks are often used to serve as anchors. However depending on soil conditions. Other types of anchoring, such as steel pile and bracket, may be employed.

All aboveground piping, barrels, and valves must be adequately supported. Supports usually bear on footings, slabs, or piles. The piping must be restrained from lateral movement. The supports must be insulated from the piping to isolate the facility electrically from ground faults.

Stresses and deflections occur in pipelines at the transition from the below-ground (fully restrained) to the above-ground (unrestrained) condition. An analysis of the stresses and deflections in transition areas, resulting from internal pressureltcll1pcrature changes, is necessary to determine anchor block requirements and pipe size. Longitudinal deflections are used to check if an anchor block is required. The forces required to maintain the pipe in a fully restrained condition are then used to size the anchor block.

Case 1 – No Anchor

Consider a length of pipe capped at C, as shown in Figure 4.1. The section up to Point A is fully restrained, while the portion immediately to the right of R is unrestrained. "Between A and B there is a transition from being restrained to unrestrained. Note that fully restrained is taken to mean a condition of zero longitudinal strain as this line is pressurized and heated the pipe will elongate and end B will move to the right an amount ΔL from some point of complete fixity, A, which is at a distance *L,* from B. This distance, *L"* to the point where the line can be considered fixed.

In the unrestrained portion of the pipe, B-C, the longitudinal stress caused by the internal pressure will be half the hoop stress, less that due to the Poisson effect. The strain in the longitudinal direction due to internal pressure is therefore

$$\varepsilon_{PR} = \frac{S_H}{2E} - \nu \frac{S_H}{2E}$$

while the strain caused by any change in temperature ΔT is given by

$$\varepsilon_{TH} = \alpha \Delta T$$

The net longitudinal strain at Point B will therefore be

$$F_S L = A_P(S_{LB} - S_{LA})$$

The transition of stress and strain between Points A and B is assumed to vary as a linear function of length, *L.* as shown in Figure 4-2.

In order to establish the Length L, over which the transition occurs, the longitudinal resistance of the soil must be known. A simplifying assumption is to consider the soil constraint to be constant per unit length so that any tendency to move will be counteracted by a constant and opposite soil force. Wilbur (1983) has recommended a design value for I the resistance of average soils (in SI units):

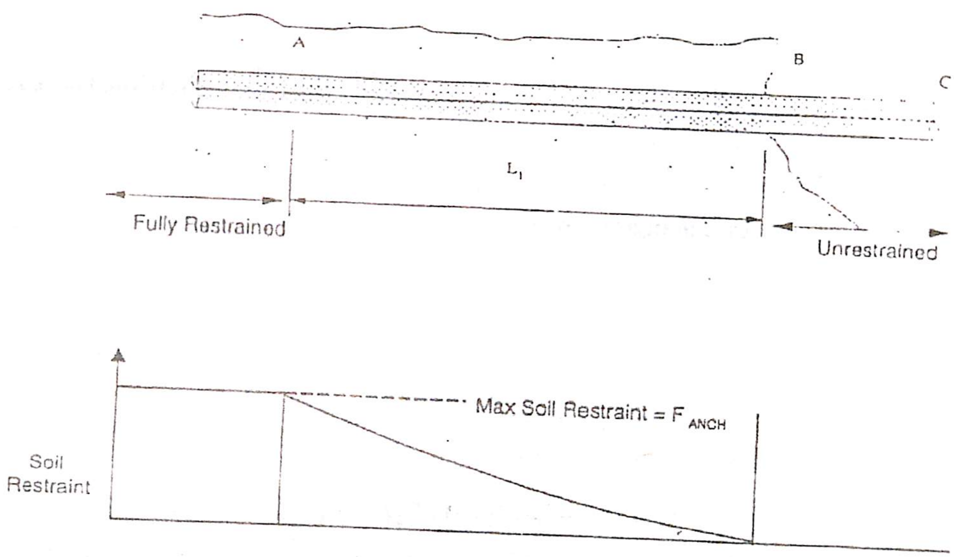

Figure 4.1 Transition from full to unrestrained

where A_p = cross-sectional area of the pipe
L = length of pipe between fully restrained and unrestrained regions.

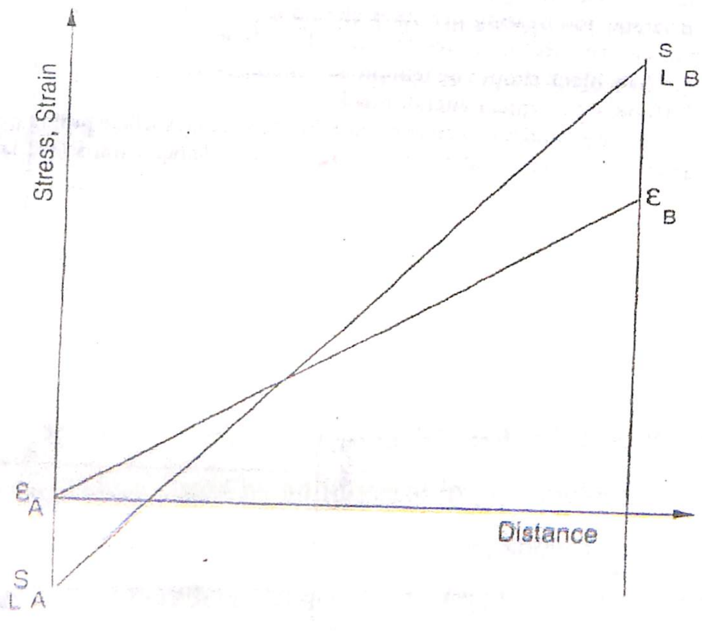

Figure 4.2 Stress and strain between points A and B

$$Fs = 0.0873\ D_0^2$$

Where

Fs = soil resistance/unit length of pipe, kN/m

Do = outside pipe diameter, m.

Between A and B, equilibrium of forces exists and can be described as

$$F = (S_{LB} - S_{LA})A_P$$

or

$$L = AP\ \{ (S_{LB}-S_{LA})/F_S \}$$

The total movement at B will be the average strain between A and B over length L, given by $\delta = E_B/2$ which is exactly half what the movement at B would have been had the soil restraint been zero.

Case II - With Anchor

When an anchor is used to restrict longitudinal deflections, the stress distribution will be that shown in **Figure 4.3**. The transition from fully restrained to unrestrained occurs at the anchor. The resultant force on the anchor is simply the difference in stress on each side multiplied by the cross section area of the pipe. .

The anchor force is thus given by

$$F = (S_{LB} - S_{LA})A_P$$

which can be written for the case of a capped end pipe

In the case of an increase in wall thickness beyond the anchor block, the result is essentially the same. The decrease in stress is compensated by an increase in pipe metal area. In order to minimize the size of the block, upper limits of lateral soil bearing pressures should be considered. Friction between the block and the soil can be used to reduce the size of the block

The block should be reinforced concrete, cast against undisturbed soil. Figures 4.4 and 4.5 depict a typical anchor block.

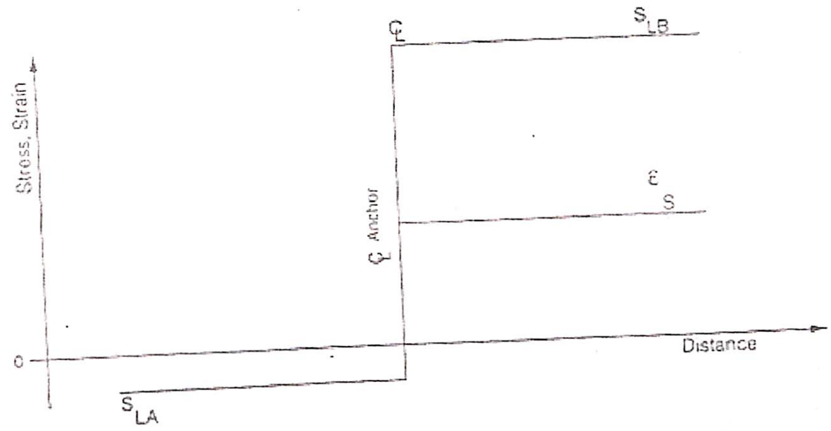

Figure 4.3 Distribution at anchor location

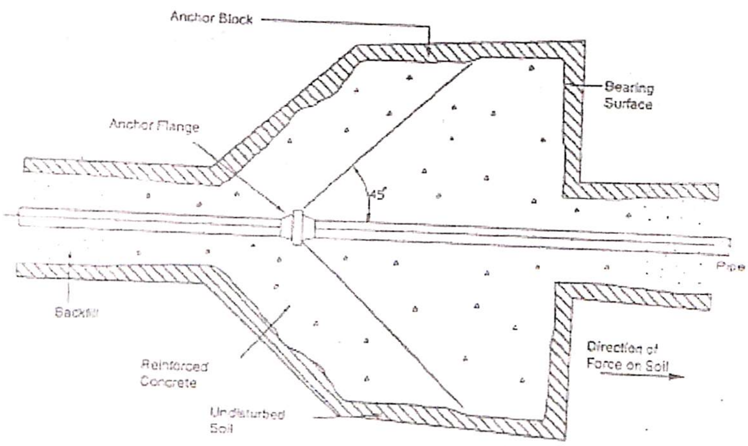

Figure 4.4 Plan view of anchor block

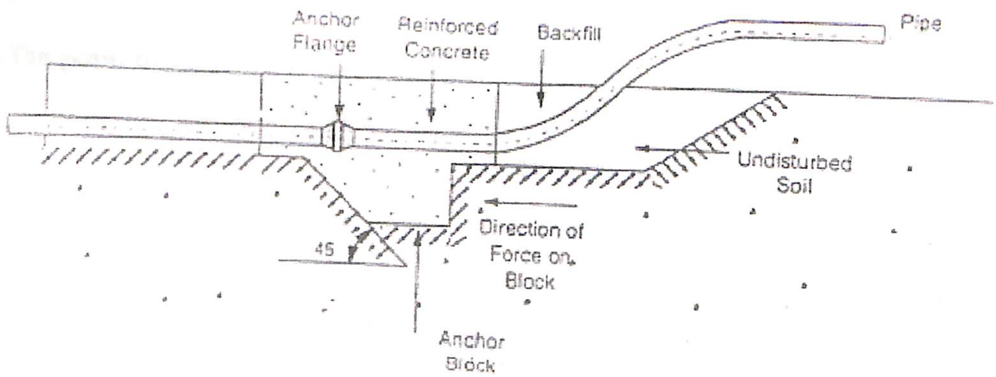

Figure 4.5 Cross-section through anchor block

Care should be taken to ensure that connected surface piping has sufficient flexibility to absorb a degree of lateral anchor movement. Scraper traps (see later), should be installed such that they move with the piping, rather than being rigidly attached to blocks, Instances of traps, together with their support blocks, being displaced a few centimeters are not uncommon.

4.5 Joint design of unequal pipe wall thickness

If the difference between wall thicknesses is equal to or less than 1.0 mm, no transition is required. In such cases the stress concentration generated by such a small discontinuity is not large enough to pose a problem; however, differences greater than 1.0mm have been shown by industry experience to result in failure.

5.5.1 Pipes Operating with High Hoop Stresses

For pipes operating at hoop stresses over 80% of the specified minimum yield strength (SMYS), the following procedures are applicable. First, whenever $(t_1 - t_2) \leq 0.3\ t_2$, the thicker wall pipe is counter bored and tapered with a length of counter bore *(L)* greater than or equal to L_o, but not less than 50 mm, where:

$$L_o = (0.85D)/\sqrt{D/t_2}\ \text{mm}$$

This technique ensures a reduction in the local stress of over *75%* at the weld joint. In the case where $(t_1 - t_2) \leq 0.3\ t_2$, the thicker wall pipe may back bevelled as per Figure 4-11.

Another consideration is a transition occurring at a bend location. The transition welds are not typically located in the immediate region of high bending moments (such as may. be generated by a field over bend or sag bend). III these situations the transition weld is generally located at a distance of not less than X, from the point of high bending moment, where

$$X_0 = (\sqrt[4]{D^2 t})/10$$

4.6 Piping Vibration

The minimum recommended mechanical natural frequency for piping components is 30hertz. In addition, the predicted mechanical natural frequencies should not lie within 20% of primary excitation frequencies.

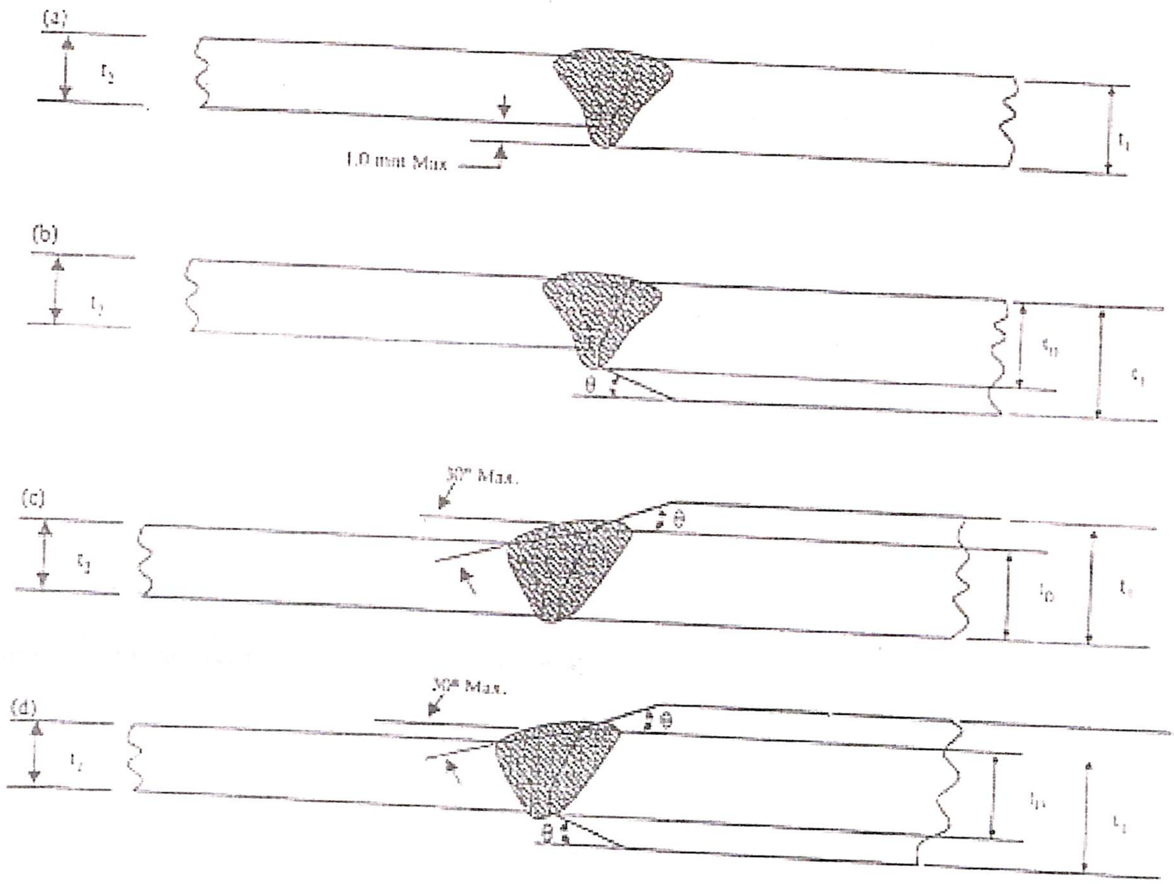

Figure 4.6:Back beveled joint design for piping design to operate at a hoop stress of 60% SMYS or less

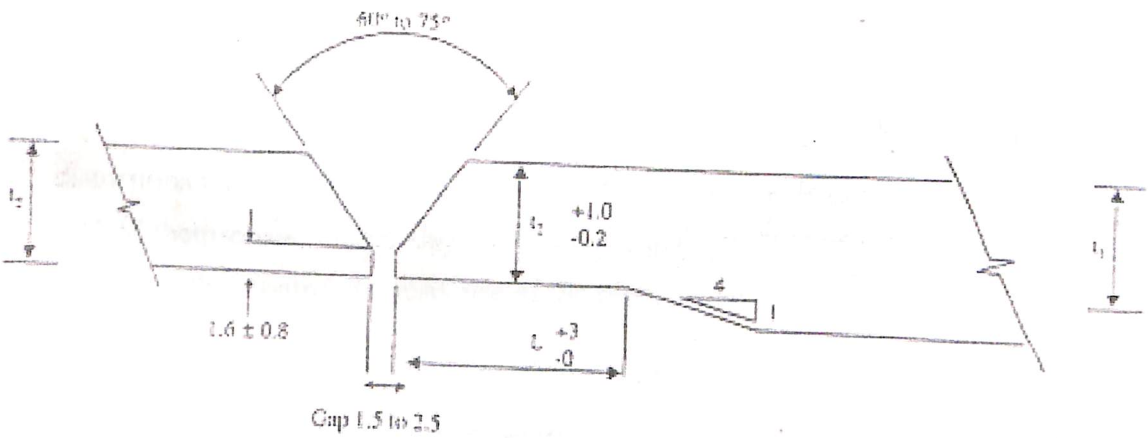

Figure 4.7 Counterbore and taper joint design for transition welds joining pipe of unequal wall thickness. Tolerances in mm.

Typical primary excitation frequencies at reciprocating compressor sites include:

1. First and second harmonics of the reciprocating equipment speed range for piping close to the equipment
2. First harmonic of the rotating equipment runs speed range for piping close to the equipment
3. First harmonic of a reciprocating compressor run speed range for piping exposed to compressor pulsation when only single acting load steps are part of operating conditions. First and second harmonics of reciprocating compressor run speed range when double acting load steps are present.

4.7 Pipe Soil Interaction

In geotechnical design slopes fault movements are important considerations while seismic-related earth movements thaw settlements and frost heave may also bear consideration. All of the foregoing arc imposed deformations with regard to the pipeline and would ordinarily result in a localized nonlinear response, which is not specifically covered in the codes. Rather the designer is required to determine what supplemental design criteria will be needed to provide an adequate response to these imposed deformations. Longitudinal strain has often been chosen as the quantity upon which to establish the governing criteria for the following reasons:

1. The loads ensuing from imposed deformations are self limiting in nature, because they are developed by the constraints of adjacent material or by the self-constraint of the pipeline. That is to say secondary stresses are developed, which satisfy strain displacement compatibility within the pipe or between the pipe and the supporting medium. Local yielding and minor distortions may result from these second my stresses but they will generally not cause failure in and of themselves. Under these conditions, deformations or strains, rather than loads are the quantities that control the response of the pipe.

2. All of the types of ground movement noted above 'will usually be sufficiently large as to cause the pipe to deform into the elastoplastic regime of the material. Here the almost flat stress-strain characteristic of a pipeline steel means that strain is the sensitive quantity when considering the equilibrium state of the pipeline.

3. It is essential to note that it is strain and not stress that causes structural failures. If the longitudinal strain is sufficiently large in compression than local buckling of the pipe wall will result. Conversely, there is also a limit on the magnitude of the tensile longitudinal strain since in combinations with the hoop strain in a pressurized line the material could readily become inelastic. A commonly used criterion for the maximum tensile strain in the longitudinal direction is 0.5%, though in general, this is a conservative value. Usually, the maximum acceptable value of compressive longitudinal strain is that which will bring about the onset of local buckling of the pipe wall, even though there are a number of documented instances where severe corrugation of the pipe has taken place without the initiation of a rupture. The conservatism here is due to the unstable post buckling behavior of cylindrical thin shell structures. Generally the load-carrying capacity of such shells falls off dramatically once local buckling is initiated. However, for a buried pipeline load carrying capacity is not a significant factor, hence a comparatively large amount of deformation can occur before the pipeline will lose its capacity to carry internal pressure.

4.8 Differential Settlement Analysis

A more accurate, though complex means of determining whether the critical "pipe" curvature has been exceeded can be obtained by modeling the pipe as a continul11 of finite elements," supported by a nonlinear soil foundation. In the analysis, the pipe pro tile is permitted to deviate from the ditch bottom profile for two reasons:

1. The soil under the pipe deforms under its weight and the overburden.
2. The pipe will span short depressions in the soil profile.

The key step in the analysis is to represent the pipe soil interaction by a finite-element-model in which the pipe is discredited into a number of one-dimensional beam elements interconnected at their end points (nodes).

Pipe stiffness, transverse loads axial loads, and foundation "spring" stiffness are aggregated at these node points to fom1 a set of algebraic equations, which can easily be solved on a computer, the model is subject to the usual assumptions of beam theory that is: the deflections are small, plane sections remain plane, shear deflections are ignored etc. The interaction of the beam model and the soil is defined at each node point using a load deflection curve, such as that shown in Figure 4-8.In this figure Δ represents the deflection of the pipe and *Q* is the soil reaction, defined as a force per unit length of pipe. In the figure, the soil reaction is zero for deflection than the soil settlement Δ. A deflection Δ larger than Δ will cause an upward reaction *Q* as determined by the curve while the shape of the *Q* - δ curve is the same at all nodes, except for the value of the settlement Δ, it can vary if soil properties change locally. Because of the nonlinear soil response defined by Figure 4-8 an iterative procedure must be used to solve the algebraic equations and so determine the final deflected shape. The calculated deflections will be correct for the model to within the tolerance set for the iteration process; errors in the analysis are introduced only by the approximation of the true pipe soil interaction as a discretized model. This error can be reduced by increasing the number of elements in the model at the expense of increasing solution time.

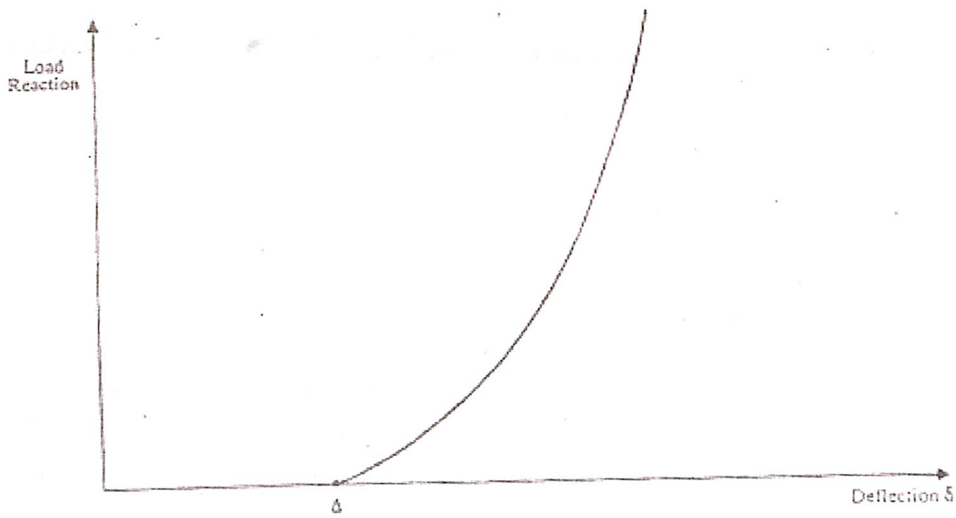

Figure 4.8: Load deflection curve

4.9 Geo technical considerations

There are two further geotechnical considerations that warrant attention: slope stability and seismicity. There is a considerable body of literature on both topics and space limitations here will pem1it a discussion of only the principal issues rather than analysis, The attention of the reader is therefore directed to' the cited references for a full understanding of the issues.

Slope Stability

For those pipelines that are required to pass through hilly or even mountainous areas slope instability can be: a critical design issue. In many instances even gentle slopes exhibit slow soil movements of the order of 10^{-3} – 10^{-2} m/year. When such movements interfere with a pipeline, they can induce unacceptably high strains in the pipe wall over a period of time (I to 5 years). They can in fact trigger failure modes in the pipe as evidenced by statistics collected for pipelines crossing active slopes. Hence there is a need for acceptable design criteria and appropriate monitoring systems when lines go into service. Current techniques for producing ground movements are based on traditional geotechnical analysis (deterministic or probabilistic), and require extensive geotechnical data that is often hard to obtain for large pipeline networks. Hence be identification slide mechanisms and of the controlling parameters of ground movement is a difficult task. Landslides, or slips, occur whenever an unstable mass of material slides' along a specific surface or zone known as the failure surface. Many of the steeper slopes along a pipeline route occur on the approaches to river crossings.

In order to maintain the if integrity of the pipeline and minimize slope disturbances, all such sites have to be investigated and, if necessary, stabilized prior to commissioning the line. The analysis of the slow movement of slopes is invariably based on continuum mechanics and usually consider the following aspects:

1. A limit state for the slope.
2. Continuous deformation in the soil when a state of limit equilibrium is reached.

Where slopes on or adjacent to the right-of-way are considered to be marginally stable, and where a slope failure may affect the integrity of the pipe, or cause unacceptable erosion, some form of slope stabilization becomes necessary. Common methods for stabilizing slopes are based on one or a combination of the following techniques:

- Reduce the loads causing failure
- Increase the internal soil resistance through reduction of the pore-water pressure
- Increase the resisting forces by toe loading
- Increase the resisting forces by structural means

Generally speaking, preventive measures involving gravity drainage earthworks will prove to be the most suitable and cost-effective, though it may be necessary to resort to sheet piling and grading, which are both more expensive.

Reducing loads Causing Failure

Flattening a marginally stable slope by cutting or grading it to a flatter angle is one means of stabilizing to prevent either shallow or deep-seated failure. However, it should not be used in areas of permafrost because the removal of the top layer of ice-rich soil will also remove the insulation it provides. Thus thawing will be greatly accelerated and this could lead to shallow slumping.

Lowering the Ground-Water level

This method is particularly effective in preventing deep-seated failures. It involves lowering the ground-water level in the "driving" or active earth pressure area of a potential or existing slide, thus reducing the hydrostatic loading and increasing the soil shearing resistance. It is relatively inexpensive to achieve where drainage can be accomplished by a gravity system. It is generally used in conjunction with a diversion system for the control of ground water.

4.10 Reduction of Pore-Water Pressures

4.10.1 Improving Surface Drainage

The improvement of surface drainage by reducing the flow of water on or near the surface of slopes increases the soil-shearing resistance by reducing the pore-water- pressures as well as the load-causing failure. The method referred to in lowering the Ground-Water Level is applicable to improvement of surface drainage. In addition, the use of shallow trench drains down the right-of-way slope will control down slope drainage by channeling the flow in. a gravel-tilled trench. These methods are most effective in stabilizing slopes susceptible to shallow-type failure.

4.10.2 Internal Drainage

Internal drains such as horizontal bored drains, and vertical sand drains are often used to reduce excess pore-water pressure and thereby increase the soil shearing resistance. It is important to know the pore pressure regime in the soil since it is the variation in this regime that ultimately causes deformation. For instance: negative pressures in the pore fluid (suctions) produce an increase in the soil's shear strength.

4.10.3 Revegetation

Revegetation is a favored method for slope erosion control, but normally it becomes fully effective several years after construction.

4.10.4 Toe loading

The equilibrium of a stable slope can be upset by the addition of new overloads at the top of a slope or else by erosion at the toe. Both of these effects will alter the value of the applied shear stress. In cases where a slope is deemed to be marginally stable, and particularly where there is evidence of active erosion at the toe, toe loading or earth buttresses may be used to provide stabilization. Compacted earth buttresses placed on a slope, or berms placed on the lower portion of a potential slide area and beyond the toe, should consist of free draining material so as to encourage drainage from the slope. This method applies equally well to both shallow and deep-seated types of failure. When earth fills are used to stabilize slopes at river crossings, they have to be suitably armored to provide protection against erosive action from river flows.

4.11 Structural Methods

Stabilization of a potential or existing slide area may be accomplished by structural methods such as the use of retaining walls, earth anchors, vertical piles, or sheeting. Since these methods require that resistance to mass movement be obtained from below the slide area, it must be determined where a potential or existing failure plane is located. This will usually require detailed field investigation in order to determine the ground conditions so that the extent and type of slope stabilization can be determined.

Grading of soil or rock slopes is occasionally undertaken to increase soil strength or to decrease compressibility or permeability. However, it is generally quite costly and only justified when the more convential simpler procedure described previously are unsuccessful.

4.11.1 Seismic Effects

Pipelines in seismic regions are vulnerable to earthquake loads, which could & significant damage. Most earthquakes have their origin in tectonics that is the energy causing the motion is produced from the tearing and grinding of the trilateral associated with a slippage movement within an active fault system. A consideration of the geology along the pipeline route is therefore pertinent to an assessment of potential earthquake activity. It would be appropriate, for example, to consider that the maximum magnitude of earthquake' would occur either on an existing fault system or relatively close to it, where supplementary faulting might develop. However, as one moves away from such a region it is reasonable to ass lime that somewhat smaller magnitudes of earthquake are likely to be developed than along the main fault system. Associated with the magnitude is the local intensity felt at the pipeline, of an earthquake centered deep in the earth beneath the pipeline, or some distance away horizontally but at the same focal depth. In general, large earthquakes occur at focal depths of 70 to 80 km or greater, while those smaller in magnitude have a depth of focus of approximately 50 km.

The effect of earthquakes on the pipeline is multifaceted. The shaking from the earthquake induces additional stress into the pipe and additional forces into the anchors in the above-ground structures. In addition, the earthquake Waves traveling through the ground impose bending, tension, and compression stresses in buried pipe. Shaking of the ground can cause liquefaction or compaction of some granular materials. The ground accelerations during an earthquake also add to the gravity and ground-water seepage forces, which contribute to slope failures.

The shaking of the ground also causes dynamic movements in the above-ground pipe and supports, Shaking perpendicular to the pipe causes the pipe to sway back and forth thereby inducing bending stresses in the pipe between anchor supports. In addition, the longitudinal shaking of the pipe induces additional forces on the anchors. The stresses and forces become greater as the slope along the pipeline becomes greater.

The traveling seismic wave will induce stresses within the buried pipeline as it moves with the ground. The pipe though is sufficiently flexible in bending to accommodate the large radius of curvature that the ground movements will produce thus the induced bending stresses will be quite small.

At the surface of the soil, compress ional waves are of negligible amplitude however the surface waves can have appreciable amplitudes. These waves will produce strains within the pipeline when their direction of propagation is at an angle to the pipeline. The maximum effect in the longitudinal direction of the pipe occurs when the wave is propagating at an angle of 45 to it, with shearing motion occurring in a direction at right angles to the propagation direction. Under these conditions the longitudinal strain in the pipe is approximately given by

$$E_L = \frac{\text{maximum ground velocity}}{2 \text{ x wave propagation 'velocity}}$$

For a pipe velocity of say 3 ft/s, and a wave velocity of 2,500 ft/s the longitudinal strain in the pipe will be 0.0006, which corresponds to a longitudinal stress of 1800 psi. In reality the pipe will not move entirely in sympathy with the soil, that is the soil in all likelihood, will move faster than the pipe, and hence the longitudinal stress calculated above will be conservative. Nevertheless, it must be included in addition to other effects that cause stresses in. the pipe in order to ensure its structural adequacy, A reasonable criteria for permissible deformation to avoid rupture is to limit strain to 2% at any section except at stress concentrations where it could double.

Seismic liquefaction: This occurs most commonly in fine-grained loose granular materials that are saturated. In this situation, the grains of soil are loosely stacked and all of the void spaces are filled with water. Upon occurrence of a seismic event, shaking causes the grains of soil to lose contact in an attempt to density. During that period of time when the water is 'attempting to drain out so as to allow the densification of the soil grains, the soil mass takes on the characteristics of a dense viscous liquid. When the soil at the base of a slope liquefies the slope will become unstable, and in places where this has the potential to occur, the pipeline should either be rerouted if possible, or the soil suitably stabilized to reduce the risk of slumping.

With above-ground piping the dynamic motion is applied to the base of the anchor blocks and supports and hence their flexibility and freedom to rotate or tilt must be considered. The ground motion .can be expressed either as a time history that enables maximum accelerations and velocities to be determined or as response spectra. This infom1ation, in either form, can be used as the forcing function in a dynamic analysis of a finite-element representation of the above-ground pipe work. Finally, consideration must also be given, for both buried and above-ground pipelines, to the relative motion at faults crossing the pipeline. It is not uncommon to have vertical or horizontal displacements of several feet where faulting occurs. These of themselves will not cause the pipeline to rupture if it has been designed to accommodate such movements. Relative movement of 4 to 5 feet can be sustained without failure by a properly supported aboveground pipeline, although one or two supports may lose contact with the pipe. With buried pipelines such displacements might cause severe distortions or misalignment but not necessarily rupture or collapse.

4.12 Valve Assemblies

Block Valves

Block valve assemblies are used to isolate sections of mainline or long laterals when isolation is required in the event of a line break or if maintenance in a section of the line is necessary.

Required Components

The following are the main components required for a block valve assembly:

- A gate or ball valves the size of the mainline to allow passage of pigs.
- Two blow downs (gas only), either remote from or directly connected to the mainline, interconnected for equalizing the pressure on both sides of the block valve.
- A riser on each side of the block provide a power supply for a hydraulic/ pneumatic operator, or for taking fluid samples, connecting pressure gauges or performing flow tests.

Side Valves

The side valve assembly is required to isolate a lateral from the mainline in situations where a line break may occur or when maintenance of the lateral may be necessary.

Required Component

A side valve assembly consists of the following components:

- A gate or ball valves the size of the lateral.
- A check valve and bypass line (for receipt laterals)
- A blow down with appropriate valving (gas only)
- A flange and insulation set to separate the lateral electrically from the mainline.
- Test leads from the mainline and the lateral

Note that the purpose of a check valve in the assembly is to prevent reverse flow. It will also prevent flow from the mainline into the in flowing lateral when the pressure in the lateral is less than that in the mainline. Check valves are not required on sales laterals. These assemblies are located on the lateral immediately adjacent to the mainline.

Compressor Station Tie-Ins Purpose

The main purpose of compressor station tie-ins is to direct the flow either through the compressor station (by opening the side valves and closing-the block valve) or past the station (by closing the side valve and opening the block valve). These valves allow the station to be isolated (in an emergency or for maintenance) without stopping the flow of fluids.

Required Components

The main components required for side valves and a block valve for a compressor station is:

- A mainline block valve
- A suction and a discharge valve (ball or gate)
- Power operators. Normally tied into the station automation

Valve Operators

Operators are chosen according to case of operation and economics. Typical operator configurations include:

- Direct hand wheel or wrench-operated valves for NPS 4 valves and smaller
- Hand wheel gear -operated for NPS 6 to NPS 12 valves
- Power operation for all NPS 16 valves and larger, and for smaller valves in meter and compressor stations that are designed for remote or automatically controlled operation.

Possible modes of operation include:

- Pneumatic controls with a choice of high pressure, low pressure or rate of pressure drop line break controls
- Remote electronic signal operation, generally used:
    1. To shut-in a meter station when sour gas is detected.
    2. When a meter station is remotely operated by a central gas control facility.

Valve Selection for Pipeline Application

Mainline isolation valves fulfill three basic functions: sectionalizing, diverting and segregating or dividing, up the pipeline into smaller segment that can be isolated is required to minimize and contain the environmental effects of a line rupture where pipelines are interconnect, valves are required to divert product flow to meet production needs. Finally, valves provide the means to segregate or isolated individual process equipment such as scraper traps and, on a broader level, entire plants for safety, maintenance, or operating reasons. Mainline valves must be of a through-conduit or through-bore design to accommodate the scrapers. Gate and ball valves are generally utilized for fluid transmission pipeline applications.

There is no single valve and actuator combination that is correct for every pipeline or every application. Variables that must be considered and specifically evaluated for each valve installation include the following:

- Operating characteristics
- Function
- Location
- Fluid service
- Materials options
- Space available
- Maintenance
- Repair capability
- Delivery schedule
- Costs

Operating Characteristics

The majority of regular slab-gate and ball valves are specified with soft seats that are capable of providing a bubble-tight shutoff. Their temperature limit is generally around 130"C. Both types of valves have two seats and are considered to be "double block and bleed" by the loose "definition that their tightness can be verified by opening the vent between the seats. Metal-seated valves are also available for use in abrasive/high temperature applications.

In a ball valve, the ball is mounted on fixed trunnions and the seats are free to move. At very low pressures, the spring force provides the seal and as line pressure increases it forces the seat against the ball proportionally. In most designs, if the upstream seat leaks, the 'downstream seat is pushed back by line pressure and fluid leaks past the valve. III a few designs, line pressure is also made to act on the downstream seat, thus providing a dual seating capability. However, a body relief valve must be provided to protect against over pressuring.

In the gate valve, seats, as well as the gate are free to move. Both seats can seal at the same time because the upstream seat seals against the gate and the gate seals against the downstream seal. If the upstream seat leaks, there is a possibility that the downstream seat I may hold. Also, because line pressure acts on the entire exposed gate area, the sealing load is much higher than when compared to a ball valve.

Function and Location

Most pipeline valves are remotely located and therefore are either manually operated or fluid powered. Generally, the geared hand wheel is the most cost-effective. Valves that are infrequently operated and those that do not need to be operated immediately or at high speed are in this category. The use of a gate valve is also recommended in low usage situations in order to utilize cheaper assets for large valves; in situations where high-speed operation is essential, high gear ratios are required. In these cases, a two-speed gearbox and portable driver such as a small gasoline engine are utilized for this purpose.

Fluid Service and Materials Options

There is no evidence to show that either type of valve has an advantage in any particular fluid service. Either type should perform well in gas or liquid applications. Both gate and ball valves are available in various materials to suit the service conditions. For relatively non corrosive applications, a carbon steel body with a nickel-plated trim are used. For medium corrosive services, stainless steels or alloy trims in the full solid form or as overlays are generally specified.

Space Availability

Due to its greater height, the gate valve is at a distinct disadvantage in locations where above-ground space is limited or in buried applications where construction costs are at a premium. In above-ground applications, the gate valve will require more elaborate access platforms. If the valve is to be buried, the longer length of the gate valve below the" bottom of the pipe means that additional excavation is needed in the immediate area of the valve.

Maintenance

A major problem encountered with ball vales is spring and behind-the-seat body corrosion. Its primary cause is the lack of proper draining during the initial phases of operation or subsequent to hydro testing. This usually results in sluggish operation of the valve. In some cases corrosion has caused the valve to simply "freeze."

The gate valve is usually prone to operational problems due to an accumulation of particulates in the cavity. This occurs if the valve is not properly seated in the fully open or fully closed position for long periods of time. The debris will tend to solidify and thus prevent the gate from closing fully. Serious damage may result if the operator overrides the actuator limit switches or exerts excessive force on the hand wheel regular draining is required to remove debris if such occurrences are frequent. Although not always successful, the best results can be obtained by flushing the cavity through two drain ports located 180 degrees apart.

A problem experienced in sandy environments is seizing between the stem nut and the stem due to entrapment of wind-borne matter when the stein is exposed. Stems must be adequately protected and cleaned on a regular basis to prevent this occurrence. Actuator maintenance checklists should address the following:

- Verification of adequate hydraulic fluid levels
- Lubrication
- Pneumatic supply
- Absence of leaks
- Corrosion of electrical tem1inations and contacts
- Mechanical linkage problems

Delivery and Costs

Given the infrequent rate of failure of a ball valve the extra expense of a split body is' rarely justified. Little difference is expected in delivery times between the gate and ball valves. Valve costs are also similar. Actuator cost also on forms a small percentage of the valve cost.

4.13 Scraper Traps

Scraper commonly referred to as pigs, are used in the daily operation and construction of pipelines. They are used for a variety of reasons :

- To clean a pipeline, thereby increasing the line's efficiency.
- To gauge or survey any objectionable restrictions or pipe deformations such as dents and buckles.
- To remove water after hydrostatic testing of newly constructed pipelines,
- To separate product batches.

To inspect the pipeline internally, to detect any loss-of-metal defects (caused by Internal or external corrosion). Pig traps should be designed and installed to meet the requirements of the intended usage's, such as cleaning or inspection. The relevant design codes must be followed to ensure overall compatibility and safety. The manufacturer should be consulted for any dimensional and configurational requirements for the trap.

There is currently no formula for determining the maximum length of a pig run or the location of an intermediate pig launch and receipt upon the quality of the pig, the quality of, the pig velocity. till' I)ig design. The interior line conditions (rough, semi rough, smooth) and the medium in which the pig is running. However, there is some general guideline (Table 4-6)

Till recommended spacing between traps is not necessarily the maximum distance that a pig may travel in a single run. This will vary considerably from pig to pig, and from pipeline to pipeline.

TABLE 4-6. Guidelines for choosing pig trap locations (Ref ASME/ANSI B31.8, 1993)

Pipeline Category	Recommended Spacing (Km)
Newly constructed gas line	100-200
Newly constructed product line	200-300
Newly constructed oil lines	300-500

4.13.1 Major Components Of Scraper Trap Assembly

- Pig barrel and end closure
- Isolation valve
- Kickoff valve
- Bypass valve
- Mainline isolation valve (an mainline bypass).
- Blow down stack and valve (far gas service. only).
- Pig barrel drain valve (mainly far liquids)
- Pipe bends leading to the assembly
- Anchors and supports

Pig Barrel And End Closure

A pig launch (Figure-4-9) should be at least 1 .5 times as long as the longest pig

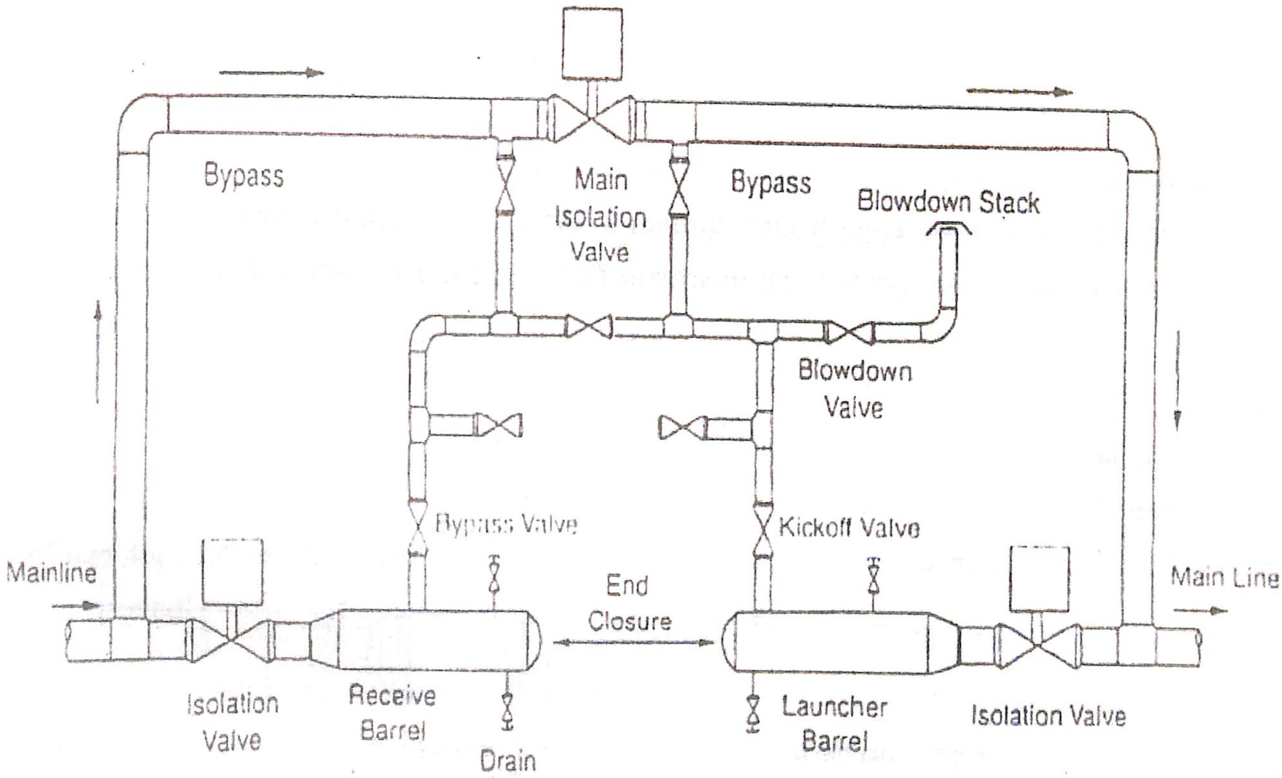

Figure 4.9:Scraper launcher/ Receiver

(Cleaning or pig inspection). An exception to this rule would be far products lines where it is necessary to launch two or more pigs in succession to separate buffer batches (batching pig).

The launch barrel diameter should be one to two NPS sizes larger than the line pipe. The launch barrel must be equipped with connections (usually flanged) far the kickoff line and, if drainage is required, drain valves. The kick off connection should be located on the side of the trap close to the closure end. The drain outlets should be located on the bottom of the barrel, also close to the end closure

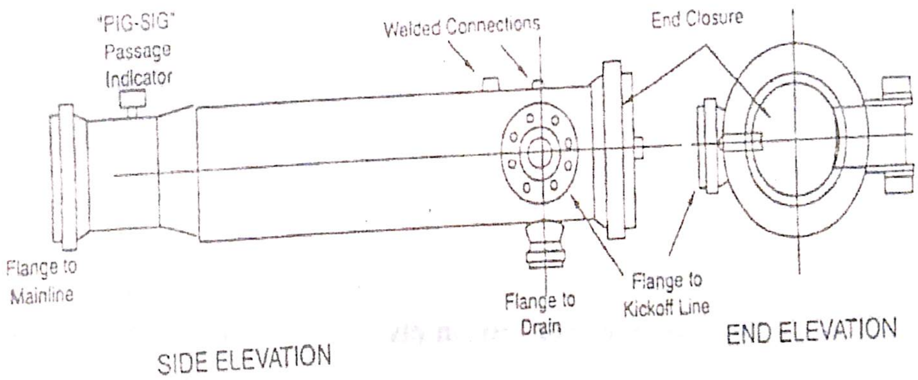

Figure 4.10:Typical Pig Launcher

For gas lines, a blow down stack and valve are required. Welded connections for "gauging, purging, and blow down should be included on the barrel and located on the top, close to the end closure.A pig signal should be installed downstream from the launcher to indicate the passage of the pig into the main line. Most operating companies prefer the use of seamless pipe for the scraper barrel. Low temperature materials must be used. Welds must be thermal stress relieved for low ambient temperature operation. The pig receipt barrel should be at least 2.5 times as long as the longest pig. Consideration must be given to the possibility of running long inspection pigs or, for Product lines a series of pigs for batching. When cleaning pigs are considered, attention must be given to the amount of debris expected.

The receipt barrel must be equipped with flanged connections for a bypass line and drainage outlets. The bypass connection should be located near the mainline connection. The drain outlets should be located near the end closure. The barrel diameter should be one to two NPS larger than the line pipe. Welded connections should be provided for gauging, purging, and blow down. Seamless material is recommended. Low temperature materials and thermal stress-relief welds are required for low ambient temperature applications.

The receipt barrel should also contain a connection for a pig passage indicator. This connection should be located just upstream of the reducer (Figure 4-11).

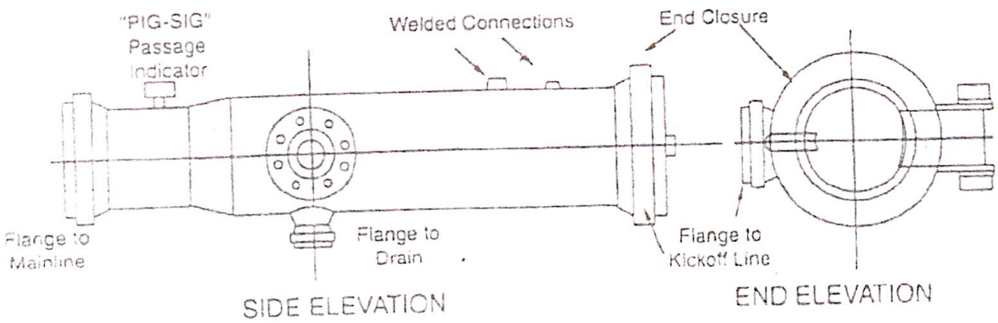

Figure 4-11: typical pig receiver

A quick open end closure will facilitate easy access. Quick open closures should come equipped with a safety pressure-locking device to prevent access while the barrel is under pressure. .

Isolation Valve

A valve is required to isolate the scraper barrel from the main pipeline. The isolation valve should be a double block and bleed valve. This will ensure a bubble-tight seal to effectively isolate the trap from the mainline prior to opening the end closure. The valve must be a full bore, through-conduit type to ensure pig passage. The valve trim and body should be designed for the intended service and ambient temperature conditions.

Depending on the size of the valve, the valve operator can be manually operated or equipped with a power operator. The requirement for automated valve operation will depend on the operating and control requirements. An insulated flange set is usually installed on the mainline side of the valve to electrically separate the mainline from the scraper barrel and valve (Cathodic protection).

Kickoff Valve

The kickoff valve is used to launch the pig. The valve should be between 1/4 and 1/2 of the line size. Depending on the valve size, it can be either a bevel-geared or vertical-stem type. Nom1ally, this valve is '1 1anually controlled to launch the pig slowly into the mainline.

The valve should have double block and bleed features. A reduced port valve is adequate. The valve body and trim must be compatible with the intended service and ambient temperature conditions.

Bypass Valve and Line

The bypass valve is identical to the kickoff valve with the exception that it is connected to the receipt barrel at a point near the reducer or valve end of the barrel. This location allows the pig to pass the isolation valve and then decrease the flow behind the pig to reduce its speed once it enters the trap.

Mainline Isolation Valve

In an emergency situation, the mainline isolation valve is used to isolate the upstream section of the mainline from the downstream section.

Blow down Stack and Valve

A blow down assembly is required for gas services only. The stack and the valve should be designed for low temperature construction.

Drain Valve

Even though drain valves are mainly required for liquid pipelines, they are common in gas services as well. The valve sin is usually NPS 2, although NPS 4 valves arc found on larger diameter barrels. The materials and design must be compatible with the design and operation conditions set out for the barrel. Drain valves are located at the bottom of the barrel, and are usually piped to a tank or include connections for attachment to tanker trucks.

Pipe Bends leading to the Pig Trap Assembly

The radius of the bend leading to the trap must meet the pig traverse requirements set out by the pig manufacture .For normal scraper and batch pigs, a minimum radius equal to three times the pipe outside diameter is usually adequate. However, for electronic instrument pigs, a much longer bend radius may be required.

4.14 General launching Procedures

4.14.1 Launching Procedures - Gas

The following procedure applies to gas kickoff service and the launching assembly shown in **Figure 4-12**.

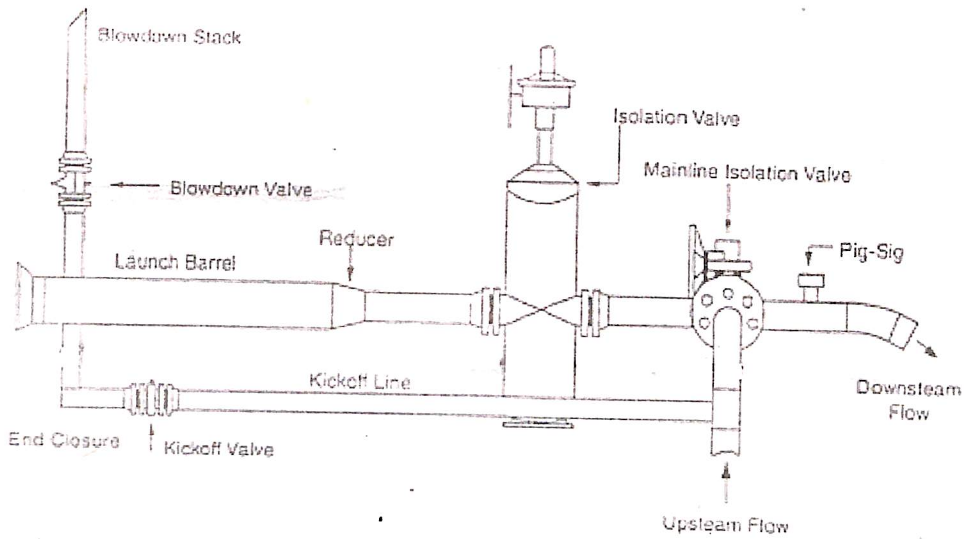

Figure 4- 12 :Typical gas line launching trap

1. The isolation valve and the kickoff valve must be closed.
2. Open the blow down valve to vent pressure from the launcher. (WARNING: Do not attempt to open the end closure until the launcher is completely blown down to atmospheric pressure.)
3. Open the end closure and insert the pig until the front cup reaches the reducer and form a tight fit against the reducer.
4. Close the end closure.
5. Open the kickoff valve slightly to purge air from launcher.
6. Close the blow down valve and slowly bring the launcher up to line pressure.
7. Close the kickoff valve. (CAUTION: Pig damage can occur if the kickoff valve is not closed when the isolation valve is opened .The pig may try to leave the launcher before the isolation valve is fully opened.)
8. Open the isolation valve.
9. Open the kickoff valve. [NOTE: If the pig does not leave the Launcher immediately. slowly close the mainline isolation valve (partially) until the pig does leave the launcher.
10. Open the mainline isolation valve.
11. Close the kickoff and isolation valve

4.14.2 Launching Procedure - Liquid

The following procedure applies to the liquid service launching shown in **Figure 4-13.**

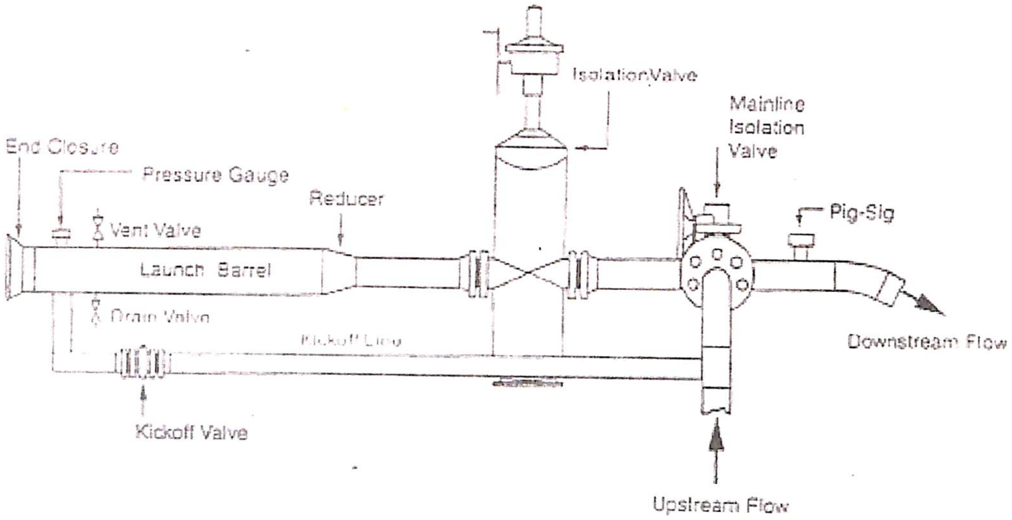

Figure 4-13:Typical Liquid line launching trap

1. The isolation valve and the kickoff valve must be closed.
2. Open the drain valve and the vent valve to allow liquid to drain from the launcher.

(WARNING: Do not attempt to open the end closure until the launcher is empty and at atmospheric pressure.)

3. Open the end closure and insert the pig until the rear cup passes the kickoff line connection and the front cup of the pig fits tight against the reducer.
4. Close the end closure and drain valve. .
5. Open the kickoff valve slightly to purge air from the launcher.
6. Close the vent valve and slowly bring the launcher to line pressure.
7. Close the kickoff valve.
8. Open the isolation valve.
9. Open the kickoff valve.
10. Slowly close the mainline isolation valve (partially) until the flow through the kick off line forces the pig into the mainline.
11. Open the mainline isolation valve.
12. Close the isolation valve and the kickoff valve

4.14.3 General Procedures for Pig Receipt

Receiving pigs are also different for liquid versus gas lines

Receiving Procedures - Gas

The following procedure applies to the receiver shown in Figure 4-14

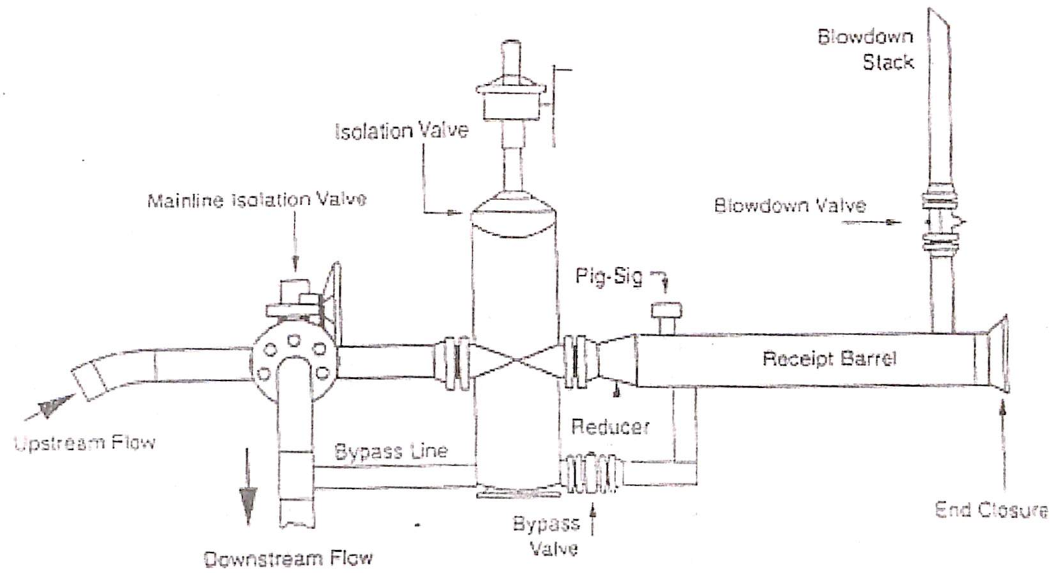

Figure 4.14: Typical pig receiver for gas lines

1. The blow down valve-and end closure must be closed.
2. Before the pig arrives, open the bypass valve and then open the pig trap valve.

(NOTE: If the pig does not enter the trap, slowly close the station suction valve until the pig is forced into the trap.)

3. Once the pig is in the trap, open the station suction -valve.
4. Close the pig trap valve and bypass valve.
5. Open the blow down valve to vent pressure from the receiver. (WARNING: Do not attempt to open end closure until receiver is completely blown down to atmospheric pressure.)
6. Open end closure and remove pig(s). (CAUTION: Some internal pipeline Residues may smolder and ignites when exempted to the atmosphere. These residues should be buried or put in pit where burning can be controlled.)
7. Close end closure.
8. Open bypass valve slightly to purge air from the barrel.

9. Close blow down valve and slowly bring receiver up to line pressure.
10. Close bypass valve. (The bypass valve and trap valve l1lay be opened at this time to be ready for the next pig.)

4.14.4 Receiving Procedures - liquid

The following procedures apply to Figure 4.15:

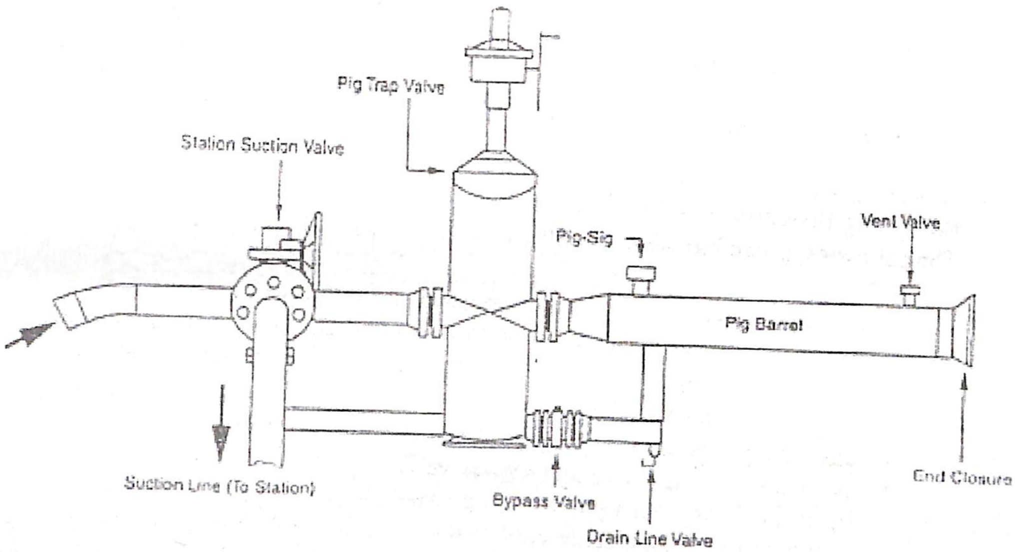

Figure 4.15: Typical pig receiver for liquid lines

1. Close the drain and vent valves and the end closure. Ensure the trap has been purged with air and filled with line fill.
2. Open the bypass valve before the pig arrives, and then open the bypass valve, and then the pig trap valve. (NOTE: If the pig does not enter the trap, slowly close the station suction valve until the pig is forced into the trap:)
3. Once the pig is in the trap, open the station suction valve.
4. Close pig trap valve and, bypass valve.
4. Open the drain valve and vent valve to allow liquid to drain from the and receiver.(WARNING: Do not attempt to open the end closure until receiver is empty at atmospheric pressure.)
6. Open the end closure and remove pig(s).
7. Close the end closure.

8. Close the drain line valve.
9. Open the bypass valve slightly to purge air from receiver.
10. Close the vent valve and slowly bring receiver to line pressure.
11. Close the bypass valve. (The bypass valve and trap valve may be opened at this time to be ready to receive the next pig.)

4.14.5 Valves and Operators

As mentioned earlier, valves can be either gate or ball type. However, where it is necessary to open and close valves where there are high differential pressures across the valves, a ball type valve should be used. Valves must be lubricated regularly to ensure quality performance. Lubrication every. Six months is common practice but the frequency may be adjusted based on local operating experience. The selection of valve operators is based on ease and convenience of operations and, economics. For manual valve operation, common practice is to operate valves of NPS 4 and small via direct hand wheel and it operate NPS 6 and larger by means of hand wheel

Piping

The choice of the steel grade and wall thickness of the pipe and barrel is based on many, considerations, such as:

- Availability of material
- Design pressure and combined stress requirement.
- Adequate ring stiffness
- Design operating and ambient temperature
- Code requirements
- Economics

Coating

Valve assemblies, valves, and piping must be properly primed and painted to meet operating and ambient temperature conditions. Gaps between mating flanges should be taped to prevent entry of any foreign materials and moisture.

4.15 Crossing

When pipelines are required to cross other facilities, structures, or watercourses it is usually necessary to produce individual designs, including drawings . It also necessary to obtain individual approval for such crossings from either the owner company of the facility being crossed or from the appropriate regulatory authority having jurisdiction. Usually these required for the crossing of roads ,railways ,other pipelines , buried and overhead utilities (electrical ,telephone)rivers, and water course..

4.15.1 Roads

Information required for approval to cross roads includes:

- Geometry and location of crossing
- Minimum depth of cover to ditch bottom and to road surface
- Construction methods (bored, punched, or open-cut)
- Pipeline specifications (size, wall thickness, operating pressure, class location, etc)
- Cross –sectional profile
- Warning signs

4.15.2 Railroads

Information required for approval to cross railroads includes:

- Geometry and location of crossing.
- Casing details if crossing is cased
- Construction method
- Cross-sectional details
- Minimum depth of cover to ditch bottom and to the rails.
- Pipeline specifications
- Warning signs

4.15.3 Pipeline and Utility Crossings

Information required for approval to cross other pipelines and utilities includes:

- Geometry and location of crossing

- Relative position and clearance between the two .
- Pipeline specification
- Cathodic protection (test leads)

4.15.4 River Crossings

Information required for approval to cross-rivers includes:

- Geometry and location of crossings.
- Scour considerations
- Depth of burial
- Sag bends location.
- Environmental considerations
- Timing of construction
- Bank stabilization methods
- Buoyancy control methods
- Construction techniques
- Pipeline specifications
- Warning signs

4.15.5 Design of Uncased Crossings of Highways

The following describes a method for designing uncased pipeline crossings of high without compromising the structural integrity of the pipeline. Pipeline codes (specifically CSA ,2662-96) usually permit uncased crossings of highways, provided that the pipeline is installed at a great enough(usually a minimum of 1.2 metres) and that a thicker wall pipe is used within right of-way.

4.15.6 Historical Background

During the past two decades, the state-of-the-art of pipeline design, bas: significantly. 'The design of buried pipelines under vehicular crossings is rather that it also involves soil-structure interaction. Casing of pipeline crossings under railroads was a common practice in the past Technological improvement manufacturing process, construction, and the protection of pipelines have reduced the need for casing. The current practice is to utilize uncased crossings whenever possible.On the basis of studies sponsored by the American Society of Civil Engineers, and the independent research conducted by M.G. Spangler, a design procedure was developed and introduced in a paper presented on June 3, 1964, at the annual conference of the American Water Works Association. The Spangler method, often referred to as the "Iowa Formula," has become the most widely accepted procedure for the design of uncased pipeline vehicular crossings.

4.15.7 Design Procedures

The design of an uncased pipeline crossing must be adequate to provide the following:

1. Sufficient support for the soil, the road surface, and the live loads onr the pipe.
2. Sufficient rigidity so that excessive flattening of the pipe does not occur.
3. Sufficient strength so that combinations of internal and external forces do not cause failure of the pipe.

The adopted basic theories are commonly those credited to Marston and Spangler. Marston's equation has been proven to be conservative. (All design equations are provided at the end of this section.) The analysis of pipeline crossings can be broken down into two main categories: the determination of forces acting on the pipe and determination of the stress and deformations in the pipe section due to the combinations of the forces acting on the pipe. These are detailed below.

4.15.8 Determination of Forces Acting on the Pipe

In this category, the forces include the pipe's internal pressure and the external pressure acting on the pipe due to the weight of the soil above it, as well a5 the wheel loads.

(a) Internal Pressure

The internal pressure is normally known for an operating pipeline or can be calculated using the expression given in the codes for design pressure. Included in this expression is a design factor known as the class location factor which limits the internal stress level on the basis of population density adjacent to a pipeline. .

(b) Soil Load

To calculate the soil load, Marston's theory can be used. Included in Marston's formula is a design parameter called the load coefficient, C_d. It is a function of the ratio of the height of the backfill or earth above the pipe to the width of the ditch or diameter of the bored hole. It is also a function of the internal friction of the soil backfill and the coefficient of friction between the backfill and the sides of the ditch. Marston recognizes five different classes of soil in the development of his original formula. The generally accepted factor used today in design involving highway subsoil material is the soil class, which Marston labelled "ordinary maximum for clay (thoroughly wet}.

(c) Wheel Loads

Vehicle wheel loads are considered as concentrated loads applied at the roadway surface and the load on the buried" pipe, including impact loading, is calculated using the Boussinesq Point Load Formula. An influence coefficient, CT, is included in this formula. Which represents the fractional part of the wheel load that is transmitted through the soil to the buried pipe, and is based on Hall's integration of the Boussinesq equation. This influence coefficient is dependent upon the length and width of the section of pipe under consideration, its depth below the roadway surface, and the position of the point of application of the wheel load with respect to the area in plan of the pipe section. The area on which the load is calculated is a projection of the pipe section on a horizontal plane through the lop or the pipe.Impact factor for vehicles operating on unpaved roads or those paved with a flexible-type surface range from 1.5 to 2.0; for rigid pavements it is taken to be 1.0.

4.15.9 Determination of Stresses and Deformations

A buried pipe under a road crossing is subjected to the hoop stress caused by internal pressure and circumferential bending stress due to the external static and dynamic loads. The bending stresses are assumed to be algebraically additive to the tensile hoop stress due to internal pressure. Also, flexible pipes are characterized by their ability to deform extensively without rupture of the pipe wall. They could fail by excessive deflection rather than by rupture. Therefore, design procedures are also directed toward predicting the pipe deflection under load. These stresses are as follows

(a) Hoop Stress (S„)

The hoop stress in the pipe is computed using Barlow's Formula (**Sh**), which establishes a relationship between the, tensile strength, the internal pressure, and the nominal dimensions of a pipe

(B) Circumferential Bending Stress (S_h)

Stresses in the pipe caused by external loads can be computed using Spangler's Formula. Included in this formula are bending and deflection parameters, K_1 and K_2, which are dependent upon the distribution of load over the top half of the pipe and the resultant. Distribution of the bottom reaction. The load distribution over the top half of the pipe may be considered as uniform. The bottom reaction however depends largely upon the extent to which the pipe settles into and is supported by the soil at the bottom of the trench or bored hole. For bored installations, the bottom reaction may be considered to occur over an arc of 90°. For an open trench installation, the bottom reaction is generally assumed to occur over an arc of 30°.

(C) Deformation

Pipe deflections may be calculated by using the Iowa Formula and ignoring the support of the soil. The pipe. Therefore, acts as an elastic ring having no effective lateral soil support and the deflection is controlled entirely by the elastic resistance to bending of the pipe wall.

5.15.10 Depth of Cover

To protect the pipe from general surface activity (e.g. farming, traffic), minimum cover is typically specified. Normal standards are 0.8 m of cover from the top of the pipeline to Ground surface for pipeline right of way, 2.0 m under railroad crossings with 1.0 m minimum at the ditch low point, 1.4 m in the ditch of the highway crossings, and 1.1 m in the ditch of local road crossings. At installation and assemblies, o.9 m cover is normal. Depth of cover may be reduced in bedrock areas or may be increased in highly unstable soil areas.

4.15.11 Aerial Marking

Aerial markings are usually installed every 10 KM along a pipeline. Though their identification numbers they provide location on the pipeline system to assist in aerial survey/reconnaissance .

4.15.12 Warning Signs

Warning signs are required at all road (including trails, survey, and seismic lines in undeveloped country), railroad, and watercourse crossings. They are there to warn the public to the installation, and should be laid out as follows:

- There is to be one on each side of a crossing.
- They are not to be placed within the right-of-way of a road or railroad, and are to Be a maximum of 0.3 m to outside the fence line.
- They are to face the crossing,
- There are to be no obstructions in front of them (e.g. brush) and they are to be maintained in a legible condition.

Warning signs should say "WARNING PIPELINE" or "DANGER HIGH PRESSURE PIPELINE" with the company name and phone number. Sizes and other details for such signs are usually established by local regulatory authorities.

Chapter-5

Manufacturing Process of line pipe

5.1 UOE Process

Submerged Arc Welded pipes are manufactured by "U-O-E': (U-ing_ O-ing, Expanding) process which is considered to be the most suitable process for manufacture of line pipes used by the Oil & Gas Sector.

Pre-Forming Inspection Of Plates

To detect any steel defect, the steel plate is examined on an on-line ultrasonic machine for lamination and other irregularities before being passed through an Edge Planer where it achieves the required width.

Forming Plate Into Circular Shape

The edge-planed plate is fed through the crimping press, a 'U' press and '0' press in sequence to form a circular shape.

Continuous Tack Welding

After having achieved a rounded form, the next sequential process is Continuous Tack Welding; in this process the gap is welded, continuously along the full length of pipe from outside. Unlike other commonly used tack-welding operations, in Continuous Tack Welding process, the seam of the pipe is completely welded thereby eliminating causes of weld defects, including burn-through and weld-cracks in subsequent welding. Inside and outside welding Continuous Tack Welding is followed by Inner Longitudinal Seams welding and Outer Longitudinal Seam Welding under Submerged Arc to avoid any atmospheric contamination. Guide rolls along the length of the seam and ongoing monitor scanning to avoid any possible defect control the welding heads. The configuration of consumables used is compatible to achieve desired quality result on the weld portion.

Mechanical Expansion

The final dimensions of pipe are obtained by mechanically expanding the pipe. This corrects any deformation such as out-of-roundness or bending that might have occurred during the process As pipes are expanded from inside, uniform diameters are obtained to facilitate field welding. Simultaneously, residual stress is reduced by expansion. A mechanical expander is used for greater accuracy.

5.2 J.C.O Process

To meet the growing demand of potential export market competitively, it was felt necessary to set up a part based longitudinal SAW Pipes manufacturing facility at port of Mundra, which is one of the most efficient private ports on the western coast of India. The state-of-art equipment to manufacture Large Diameter longitudinally Welded SAW Pipes, adopting the J-C-O Process, with all testing & balancing equipment imported from Australia. This modern facility manufactures longitudinally Submerged Arc Welded Pipes in sizes ranging between 18" Outer Diameter to 42" Outer Diameter and Wall Thickness upto 1.5". The plant has an installed capacity of 250,000 MT per annum. The submerged Arc welded pipes are manufactured by J-C-O (J-ing, C-ing, O-ing and Expanding) process.

Hot Pulled Induction Bends

The front end of the straight pipe is clamped in the forward carriage. The tail end is clamped in the feeding carriage. With the aid of the clamp device for the front pipe end which slides along the bending arm it is possible to set desired bending radius. The chain driven feeding carriage pushes the pipe through the induction coil where it is heated in a narrow annul zone to bending temperature. The bending takes place only in the heated narrow annular zone, which shifts continuously over the length of the bend as the bending process advances.

The heating temperature is continuously monitored & controlled with the aid of an optical pyrometer depending upon the material of the pipe and its wall thickness. Immediately after the bending process quenching follows.

Connector Casing

The weld-on Connector casing pipes are used for onshore and offshore exploration and exploitation. Pipes are inspected for drift test before fitting the connector. This is done with the help of clamps. The alignment is checked with the help of telescope and target. It is confirmed that cross wire in the telescope is within the inner most circle of target. After preheating, root welding is performed using GMAW process followed by automatic submerged are welding from outside. During the process current, voltage, speed wire, flux grade, preheating temperature, inter pass temperature are controlled and monitored. Radiography of the circumferential weld joint is performed. Thread protection, Coating and marking are done after inspection.

Helical Seam Saw Pipes

Helical (Spirally) Welded pipes are mode from strip in coil form. After the strip is uncoiled, it proceeds to a trimmer and then to forming rolls to shape it into spiral form. The Spiral Seam is Submerged Arc Welded automatically and continuously first on the bottom of the rotating pipe from inside, then on the top from outside. The welded pipe is cut to specified lengths by Oxy-Acetylene flame- These pipes find application in sewage lines, transportation of water, crude refined petroleum products and gas under low pressure conditions.

5.3 Manufacturing Specifications / Quality Controls

Hydrostatic Testing

To meet the technical specification and API standards and guarantee satisfactory performance in the field, the pipes *are* hydro tested at nominated pressure after mechanical expansion. Testing can be carried out up *to* a maximum pressure of 4200 psi.

Other Tests

All pipes at various stages are subjected *to* a series of stringent non-destructive tests; Ultrasonic Testing and Radiographic examination ensures the quality of weld. Intermediate Ultrasonic Testing, Magnetic Particle Inspection and visual inspection further testify the regularity of quality pattern.

Nondestructive testing Charpy V Notch testing, Drop Weight Tear Testing (own) is available in-house and is carried out as per requirements. Special testing facilities for pipes to be used *for* sour service application *are* available in-house. Hydrogen Induced Crocking (HIC), Sulfide Stress Corrosion Cracking (SSCC)) and Four Point Bend test ore the primary tests undertaken for checking the resistance of pipes *to* corrosive environment. The pipe is beveled, ready for field welding.

Final Inspection

A final, meticulous physical inspection is performed, followed by third party inspection (if required).

End Protection

Metallic bevel end protectors protect the bevel ends of the pipe.

Handling and Storage of Pipes

Special consideration and attention is given to the handling and storage of pipes. Bore/Coated pipes are either directly loaded on the trailers, which have suitable drainage and lashing facilities, or stocked in the coating yard premises. Height of stocks and relevant number of pipe tiers are decided after taking into consideration the recommended practices of API SLW (RP 5LW) concerning static allowable load. Handling operation is normally carried out by forklift, self-propelled or mobile crone. Coated pipes ore handled with rubber/teflon padded hooks to prevent damage to pipe and coating. Also, all handling equipment and practices are designed to ovoid excessive stress on the pipe. Similar safety precautions are used for marine transport to ovoid damage to coating of pipes and pipes themselves.

5.4 Anti Corrosion Coatings

Three Layer Polyethylene (3LPE/PP)

The Polyethylene coating process consists mainly of Shot Blasting, Induction Heating, Application of Epoxy, Adhesive and Polyethylene layers, Quenching and Holiday Detection of pipes. The Bare pipe is taken from the stacking areas by forklift and stacked on the incoming rack. After pre-heating, the pipe enters the Shot Blasting cabinet where it is cleaned to SA 2- 1/2 Grade surface finish. From the rack, the pipe is then placed on the main coating line conveyor. The dust formed during the Shot Blasting operation is removed in Air Blow and Vacuum Cleaning section. The pipe is then conveyed through induction heating system where temperature in the range of 180°C – 210°C is maintained. The Epoxy primer is applied with the help of a spray gun by electrostatic method. An appropriate reclaim system is provided to remove the excess powder. When exiting through the spray booth, the pipe is coated with a layer of Adhesive followed by various layers of Polyethylene in a number of wraps to build up the total specified thickness. An extruder does the Polyethylene application.

The pipe enters the quenching tunnel where the coating is rapidly cooled down by water to avoid damage and oxidation. The pipe is unloaded on to a rack by a hydraulically operated Unloading arm. A set of brushing machines clean the pipe ends when still on the rack. The pipe is then loaded on to a longitudinal conveyor for being subjected to porosity and holiday detection. The pipe is then moved on to the final rack where it is marked and finally: accepted

Fusion Bond Epoxy (FBE)

Pipe cleaning system consists of a support rack, pipe rotation unit, incoming conveyor, two shot blasters, outgoing conveyor and pipe tilting bridge. The coating system consists of Line Feeding conveyor dust remover Brushing machine, Induction furnace with refrigeration unit, Optical pyrometer to measure the pipe temperature application unit, Quenching conveyor, Holiday detector and inspection rack. Pipes are preheated at pipe rotation unit to evaporate the moisture if humidity is more t 90% or pipe temperature is less than dew point + 3°c and then cleaned by using G25 or G18 Grit & shots S330 or equivalent grade to SA 2 '/2 surface finish. Roughness of pipe shall not be less than 40 microns

Shot Blasted pipes are transferred on line feeding conveyor and pass through the dust-removal machine. Chromate solution is applied at surface pre-treatment section, if required then pipe is heated to minimum 80°c. Fusion bond Epoxy is applied on heated pipe in Epoxy application unit, the pipe is cooled to 6O°c - 7O°c and then transferred to end cleaning station for cutback cleaning by brushes. Every coated pipe is passed through Holiday Detector. Post a quality assurance check; the coated pipe is transferred on the inspection rack.

Coal Tar Enamel (CTE)

The Coating Facility and the Hot Induction Bend manufacturing facilities and adopt the some process of manufacturing and testing, facility has additional CTE/Bitumen and Weight Concrete Coating facility. In CTE Coating, Bare pipes are removed from the stockpile & loaded on incoming pipe racks. The pipe is then rolled on to the incoming blaster conveyor. The pipe on conveyor travels through the pre-heating zone & blaster with a screw motion. As the cleaned pipe comes out of the blasting chamber, its surface is checked for cleanliness & surface finish. Cleaned pipe after shot blasting is coated with a thin coat of synthetic primer.

Enamel from stockpile is cut into small pieces and then fed into the kettles. As the kettle is being charged, it is lighted and temperature slowly increased. The temperature is increased to bring the enamel to its application temperature. Hot enamel flows out of each kettle to enamel coating weir. The enamel coating weir distributes the flowing enamel into a long thin curtain of material that runs on the pipe.

The enamel conveyors move & rotate the pipe through the coating area with a screw motion. The flow of hot enamel running out of the weir is usually divided into two streams. The first stream flows directly on the primed pipe. The second stream flows on the pipe after it has received its fiberglass wrap. The final thickness of the enamel coating can be adjusted by varying the amount of enamel that is discharged-from the coating weir. As soon as the outer wrap is applied, the pipe is flooded with water to quench hot enamel. The enamel-coated pipe is inspected for any holiday in the coating.

Procedure: The CTE/PE coated pipes approved by client's inspector are delivered to the concrete coating plant's incoming rack. Every pipe coming from the incoming rack is then discharged to the buggies. If CTE/PE coated pipes previously stored in stocking yard are brought to concrete coating plant, each pipe is tested for holiday prior to concrete coating. CTE/PE repairs, if any, are carried out immediately by the repairing group present through out the concrete coating operations.

After positioning pipes on buggies, the CTE coated pipes are transported to the impinging unit. Pipe surface is cleaned before coating. Wire mesh used for concrete coating reinforcement confirms to the requirements of ASTM 185 with its wire conforming to ASTM 482 or equivalent standards.

Concrete Weight Coating (CWC)

Materials used conform to the following requirements:

- Cement: ASTMC 150
- Water: BS 3148
- Aggregate: ASTMC 33 (Iron Ore & Grits)

Concrete applied by the impinging unit is prepared by the following procedure: A pay loader brings the material from the stocking point & unloads into the material feed hoppers for grit & iron. Cement is stored in silos. Through separate conveying belts, each material is transported to the weigh-batching unit, which is equipped with mechanical scales for weighing of materials. Calibration of batching plants is done once a week.

The batched raw materials are fed to the primary mixer & then to the impinging unit mixer through conveyor, where concrete mix is finally checked visually for consistency & proper water proportion before being sent to the impinging throwing belt.

It is ensured that concrete is impinged upon the pipes with a maximum 30 min from the time of mixing of water. Bevel protectors are installed in all pipes after concrete applications, if desired by the client.

In case fresh concrete needs to be applied after on interruption, surface of the previously placed concrete is cleaned & mode wet to obtain a good bond between fresh & previously placed material.

Weight coated pipes are handled only after 4 days of curing. All concrete coated pipes are cured at least for 4 to 7 days from the date of application of coating to ensure prescribed compressive strength

Chapter-6

Conclusion

Chapter-6 **Conclusion**

This report gives the brief information about the design for the gas pipeline system and what are the parameters considered while designing the system. It also covers the aspect such as manufacturing of the line pipes used, also the work done prior & in construction phase and also the various utilities installed along with the pipeline system to support the network

The purpose of this report is to review and evaluate the problems involved in the design, and operation of a pipeline. Since pipeline technology is depends on many technical discipline, a comprehensive review of the literature would be much too long, and has accordingly been omitted.

On the other hand it is highly important for the engineer to be aware of all relevant aspects of the technology. His principle danger is a partial or incomplete understanding of the questions involved, since he would then be liable to ignore certain elements of the problem and arrive at wrong decisions.

Accordingly, the objective of this book will have been attained if, without solving the actual problems, it gives the reader an awareness of most of the aspects of pipeline installation, so that he can expert advice or consult the professional literature.

Moreover hands on experience with the help of my guides also give me opportunities to hand me practical skills.

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