EXECUTION OF AN EPC PROJECT

By

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

Master of Technology

(Pipeline Engineering)

By

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ABBREVATIONS

HPCL	:	Hindustan Petroleum Corporation Limited
MMPL	:	Mott MacDonald Private Limited
RT	:	Radiographic Testing
UT	:	Ultra sonic Testing
DPT	:	Die Penetration testing
HDPE	:	High density polyethylene
GPS	:	Global positioning system
PPE	:	Personal Protection Equipment
LDS	:	Leak Detection System
ANST	:	American Society for Non Destructive Testing
API	:	American Petroleum Institute
ASME	:	American Society of Mechanical Engineers
OISD	:	Oil Industry Safety Directorate
SMYS	:	Specified Minimum Yield Strength
ROW/ ROU	:	Right Of Way/ Right Of Use
SMAW	:	Shield Metal Arc Welding
PE	:	Polyethylene
SDH	:	Side Drill Hole
DAC	:	Distance Amplitude Correction
CP	:	Cathodic Protection
HDD	:	Horizontal Directional Drilling

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ABSTRACT

The construction of Mangalore Hassan Mysore Solur LPG Pipeline was commenced in august of 2013 and is under progress which is of 397 km in lengh. For the Fabrication, Laying, Testing, Pre-commissioning and Commissioning assistance of Cross country LPG pipeline for Hindustan Petroleum Corporation Limited M/s ACE Pipeline Contractors Private Limited is assigned as the contractors.

The objective in this project is to prepare observations and recommendations for the organisation for the Pipeline construction activities viz Survey and Grading, Trenching, Stringing, Welding, Non Destruvtive Testing, Destructive Testing, Joint Coating, Installation of Pipeline by Horizontal Directional Drilling, Pre Hydrotesting, Mainline Hydrotesting, Lowering and Backfilling, Commissioning, Planning and Execution as per drawings, Project Management and Cost Administration, Administrative support for project and Health,Safety and Environment that are being carried on along the Haassan-Yediyuru section.

In this above mentioned activities the major objective of the project is

- Performance of Mainline Hydrotesting by calculating the Hydrotest pressure and volume in which this test will play a significant role in the nondestructive evaluation of pipeline, it is important to determine the correct test pressure and then utilize that test pressure judiciously, to get the desired results.
- Design of Horizontal Directional Drilling for installation of Pipeline across a river at 397.24m

CHAPTER 1
INTRODUCTION

HPCL proposes to lay a pipeline from Mangalore Despatch station to Mysore & Bangalore via Hassan for transportation of LPG. The project envisages construction of a main line 295 km & Bangalore line 102km long pipeline which will connect HPCL LPG Despatch station at Mangalore to Receiving station at Mysore, Yediyuru & Solur. The total length of the LPG pipeline will be 397 km. LPG will be supplied from Import Terminal at Mangalore. In between Mangalore & Hassan one Intermediate pumping station is envisaged at Neriya and second future Intermediate pumping station is envisaged at Hassan, In between this entire length of pipe line there some Local & remote Sectionalise valve stations are there.

Pipeline external surface yard coated with 3LPE. The upcoming HPCL [MHMBPL] is being laid in the common ROW of existing Petronet pipeline.

HPCL has appointed Mott MacDonald Pvt. Ltd., as the Project Management Consultant for the said project.

The length of the proposed LPG main pipeline (14"/16/10"/8") is approximately 362 km from Mangalore to Bangalore as detailed below:

Mainline Section	**Size (inch)**	**Length (km)**
Mangalore to IP Station Neriya	14	78.5
IP Station Neriya to IP Hassan	16	86.5
IP Hassan to Intermediate Despatch for Bangalore	10	84.5
Intermediate Despatch for Bangalore to Solur TOP	8	38.34
Solur TOP to Devangundi Bangalore	8	74.51

1.1 Capacity of the main pipeline

The pipeline system has been optimally designed based on initial demand of 1.12 MMTPA (330 m^3/h) and final demand of 1.78 MMTPA (525.56 m^3/h based on 16 hrs/365 days operation)

- Scenario-I : 362.3 km Mangalore to Bangalore
- Scenario-2 : 287.79 km Mangalore to Tap off for Solur
- Minimum Flow Rate : 0.0058 MMTPA (1.71 m',11)
- Operating Flow Rate : 1.12 MMTPA (330.66 m^l/h)
- Operating temperature : 65 deg C
- Minimum temperature : -29 deg C
- Design Flow : 1.78 MMTPA (525.56 m^3/h)
- Design Pressure : 104.113 kg/cm^2
- Main Pipeline Diameter : 14 inch of 78.5 Km, 16 inch of 86.5 Km,10 inch of 84.45 Km and 8 inch of 112.85 Km .
- Spurline Diameter : 10 inch of 106,01 Kms, 8 inch of 8.4 Km and 6 inch of 3.20 Km.
- Thickness : 7.9 mm for 16" pipeline, 6.4 mm for all other diameters pipelines.
- Material of construction for Pipeline : Carbon Steel
- Material Grade of Line Pipe : API 5L Gr.X60 PSL 2

CHAPTER 2

LITERATURE REVIEW

Kenneth W. Lefever presented a paper on **Earthquake fault zone pipeline construction method and arrangement** in which a pipeline is to cross an earthquake fault zone, a trench is dug in the earth substantially wider and deeper than the diameter of the pipeline. The pipeline is installed in the trench in a bed of spherical bodies, which thereafter function during an earthquake to partially absorb compression and shear waves, and to disperse forces acting on the pipeline, whereby the effect of such forces on the pipeline is minimized with the result that rupture does not occur.

W. A. Keene attorneys Pipeline construction considerable difficulty is often encountered in constructing pipelines which are to convey fluids at temperatures appreciably different from the temperature of the earth in which the pipeline is buried. This is particularly true when a pipeline is to be buried in regions of permafrost in order to pump crude oil through pipelines in arctic regions, it is necessary to heat the oil so that the viscosity is sufficiently low to permit the oil to be pumped. While various types of insulating materials are known, the costs of most such materials are usually quite high for extensive pipeline use. In accordance with this invention, a low cost method is provided for constructing pipelines which are adapted to be used in transporting materials at temperatures different from the temperature of the surrounding earth formation.

J.M Race examines **Management of Corrosion of Onshore Pipelines** in which the causes of external and internal corrosion and stress corrosion cracking in onshore gas and hazardous liquid gathering and transmission pipelines. Based on an analysis of the cause of corrosion, it is then shown how risk-based inspection and maintenance strategies are used in the pipeline industry to identify, manage, and control pipeline corrosion.

John F. Kiefner presented a paper on **Role of Hydrostatic Testing in Pipeline Integrity Assessment** in which the economic issues of hydrostatic testing are extremely important and will determine whether or not hydrostatic testing can be used on any given pipeline. For those operators who will be able to use hydrostatic testing, this presentation offers some useful guidelines to help the operator optimize confidence in the test as a means of integrity assurance.

John F. Kiefner and Willard A. Maxey presented a paper on **The Benefits and Limitations of Hydrostatic Testing** in which the purpose of this paper is to clarify the issues regarding the use of hydrostatic testing to verify pipeline integrity. There are those who say it damages a pipeline especially if carried out to levels of 100 percent of more of the specified minimum yield strength (SMYS) of the pipe material. These people assert that if it is done at all, it should be limited to levels of around 90 percent of SMYS. The challenge is to determine if and when it should be done, the appropriate test level, and the test-section logistics that will maximize the effectiveness of the test.

By way of summarizing, it is worth reporting that · Test-pressure-to-operating-pressure ratio measures the effectiveness of the test · In-line inspection is usually preferable to hydrostatic testing · Testing to actual yield is acceptable for modern materials · Pressure reversals, if they occur, tend to erode confidence in the effectiveness of a test but usually not to a significant degree · Minimizing test-pressure cycles minimizes the chance for pressure reversals.

Paul D. Watson published the book on **Installation of Pipelines by Horizontal Directional Drilling An Engineering Design Guide** which is prepared for the Prepared for the Design Applications Supervisory Committee (Off/On Shore Supervisory Committee) Pipeline Research Council International, Inc. Its purpose is to serve as a step by step guide for engineers engaged in the evaluation, design, and management of natural gas pipeline construction by Horizontal Directional Drilling (HDD).

Above papers and book written by prominent pipeline engineers assisted in the development of this Thesis

CHAPTER 3
MAINLINE CONSTRUCTION
3.1 ROUTE SURVEY

Equipments

- Theodolite.
- Dumpy level.
- 30 meters measuring tape.
- Ranging rod.
- 5 meters staffs
- Alignment and Location survey

The Surveyor is aware of the general conditions of the terrain before starting survey. A preliminary survey for locating the center line of pipeline alignment on the ground is carried out as follows;

- Preliminary survey is carried out along the route of the proposed pipeline to establish and flag control points.
- The existing features or obstructions along the route that are not shown in available maps or drawings are located and identified. Mining and built up areas are avoided.
- Turning points (TPs) are located considering the following:

Construction viability so as to avoid objects like power, telephone & telegraph poles, walls, tube wells or such other structures falling on the trench alignment, also structures like boundary walls, houses, etc. should be at a sufficient distance.

Ensuring proper angle of crossing by keeping as nearly right angle to road/rail/streams, etc. as possible.

Pipeline Survey is carried out by means of theodolite and ranging rods. Bench marks, intersection points and other survey monuments are installed/identified.

- Wooden pegs fixed at turning points and at 250 Mtrs. on either side of ROW.
- Centerline of pipeline is demarcated by stacking of wooden pegs at an interval of maximum 500 Mtrs for straight-line sections and maximum 10 Mtrs for horizontal bends and turning points.
- Markers on the reference line is at a distance of max 250 Mtrs for straight line section maximum 10 Mtrs for horizontal bend.

Distinct markers near underground/above grounds utilities, contract limits, change of wall thickness etc. are notified and demarcated in white color. Official permissions, if required, is obtained from Concerned authorities.

3.2 CLEARING AND GRADING

Prior to any clearing activity, the surveyor shall become familiar with all provision on the land allocated for the pipeline alignment and shall use the best endeavors to fully comply with such provision and avoid damage to the property and other facilities on or adjacent to the ROW/ROU.

Prior to the clearing operations the surveyor shall stake:

- Markers in the centerline of the pipeline at distances of maximum 100 m for horizontal bends.
- Two constructional markers shall be installed at every existing marker location or at least every 500 mtrs away. Construction markers are painted red.

Obstacles which may hinder the construction and laying of the pipeline all along the pipeline route and for a strip of land of the size provided, is removed.

The ROU / ROW shall be cleared from any obstacles using a JCB / Excavator / Dozer. Any minor difference undulations of the ground level shall be levelled with a motor grader. In the case of natural or artificial deposits of loose soil, sand, heaps of earth or other fills materials; these shall be removed till stable natural ground level is reached so as to ensure the construction of the pipeline ditch in stable ground. All stumps shall be grubbed for a continuous strip, with a width equal to trench top width plus two meters on either side centered on the pipeline centerline. Further, all stumps will be grubbed from areas of the construction Right-of-Use, where Right-of Use grading will be required. Outside of these areas to be graded and the mentioned trench strip, at the option of ACE, the stumps may either be grubbed or cut off to ground level. Any stump cut off must be left in a condition suitable for rubber tired pipeline equipment traffic.

In the case of Right-of-Use clearing and grading on hillside or in steep slope areas, proper barriers or other structures is provided to prevent the removed materials from rolling downhill. The Right-of-Use cross fall not exceeds 10%.

Care is taken not to damage or dislocate the TP markers at the ROW/ROU and the permanent pipeline markers and boundary pillars in case of common ROW. Surveyor shall ensure that the markers indicated in the Approved for Construction Alignment sheet are maintained in the ROW/ROU. The surveyor is responsible for the maintenance and replacement of these markers until the permanent markers are placed.

Banks of irrigation canals and other water crossings higher than adjacent ground shall be graded only after obtaining permissions from the concerned authorities, if permitted only and alternatively ramps with proper slope shall be made. No temporary or permanent deposit of any kind of material resulting from clearing and grading shall be permitted in the approach to roads, railways, streams, ditches, drainage ditches and any other position which may hinder the passage and/or the natural water drainage.

Earthen canals lined by earth deposits and are usually covered using a concrete or steel pipe for the passage of equipment. The damaged permanent field canals shall be reconstructed after Completion of backfilling, as original ground. This restoration is achieved by the retrieval of the pipes form the canal and by excavating the restoring the earthen lining of the canal back to its original state.

While grading pipeline level, consider the level of any nearby existing or planned road for future development, which will affect the pipeline level when laid. Maintain and preserve survey details such as benchmarks and intersection /

turning points until all construction operations are complete. These details shall also be incorporated in the final as-built drawings.

3.3 TRENCH EXCAVATION

EQUIPMENT

The following equipment shall be used in excavation of trench for underground pipeline:

- Hydraulic Excavator / Backhoe

METHODOLOGY

The following methodology shall be followed in excavation of trench for installation of the underground pipeline:

- Pipeline trench shall be dug by any method that may be necessary or directed on the cleared and graded right-of-way according to the routes as stated and approved by Engineer-In-Charge.

- In cultivable land and other areas specifically designated by the COMPANY, top 300mm of the arable soil on the pipeline trench top width shall be excavated and stored separately, to be replaced in original position after backfilling and compacting rest of the trench.

- The centerline of the trench shall be established from the permanent TP stakes for the existing pipelines in common ROU/ROW and in independent ROU/ROW. Trench shall be excavated on surveyed route as staked in independent ROU and the trench parallel to the existing pipeline shall be as per approved drawing in common ROU/ROW.

- Crossings shall be provided across the ROU/ROW where necessary to permit general public to cross over.

- The specified width as per standard trench dimensions plan shall be measured at the bottom of the trench. The trench shall be shut with square bottom so that the full width is available for providing slack in the line at the time of laying.

- Due care shall be exercised so that the soil from trenching operations intend to be used for backfilling is not mixed with loose debris or foreign matter. In steep slope area or on the hillside, before commencing the works, proper barriers or other protection shall be provided to prevent removed materials from rolling downhill.

- When open cut is made across I paths and walkways etc. temporary diversion shall be provided. Trenching operations shall as far as possible be kept ahead of the lining up and welding operations.

- The bottom and side of the finished trench shall be uniformly, graded and must be free of loose rock, hard clods, large gravel, protruding roots or rock projects, bush, skids, sticks, welding rods or others hard objects and debris which could damage the coating when the pipe is lowered in.

- All sewers drain ditches, and other natural ways involved in the execution of the works shall be maintained open and operational. The same applies to canals, pipelines, and buried facilities crossed by the ditch for which temporary pipeline shall be laid, if required, and proper temporary installations provided.

- Where the trench is across or adjacent to roads, highways, railways, canals ravines and other water courses or land falls and at locations where the contour of the land may require additional depth to eliminate unnecessary bending of pipe, such additional depth shall be dug as shown in the construction Drawings or as directed by the Engineer-In-Charge to reduce to a minimum, the required number of bends to lay the pipes to conform with the contour of the ground and shall maintain a normal covering by cutting the trench slightly deeper at the crest of ridges and by gradually depending the ditch in approaches to crossings.

- The trench shall be made wide enough where slack loops are lowered into the trench so that no coating is rubbed off or abraded at the sides.
- If unforeseen obstacles appear during excavation work (old foundations, posts, bunkers, etc.), these must be removed in accordance with the indications of and in consultation with the Owner and/or the Engineer and possibly the Authorities concerned to at least 0.50 m below the underside of the pipe to be laid and evacuated from the site. "Good filling soil" should subsequently be used for backfilling.

Table 3.3.1 Normal cover and Trench Dimensions

Sr.No.	Location	Minimum Cover in meters
a	Normal Terrain	1.2
b	Industrial, Commercial and Residential area	1.5
c	Rocky terrain	1.5
d	Minor water crossing / canal / drain / nala	1.5
e	Drainage, ditches at roads/railway crossings	1.5
f	Cased / Uncased road crossings	1.5
g	Cased Railway Crossings	1.7
h	Major River Crossings (Below scour	2.5
I	Major River Crossings (Below scour level) Open Cut	2.5 (Normal Soil) / 1.5 (Rocky)
J	Marshy areas/areas prone to flooding	1.5
K	HDD Crossing at Canal (Below LBL)	5.0

Notes :

1) The above mentioned minimum cover requirements shall be valid for all class locations. Cover should be measured from the top of pipe coating to lower level as the case may be.

2) Before and during the laying of pipeline the water table shall be brought down to 300 mm below the excavated level of trench bottom.

3) In cross country areas, the pipeline trench shall be backfilled with excavated soil, unless warranted by seismic analysis, wherein the backfill material shall be as per the recommendation of such analysis.

4) Select backfill/slope breakers shall be provided in the trench in steep areas to prevent washout of trench backfill.

5) In case of rivers/water bodies, which are prone to scour and erosion, the safety cover shall be provided below the predicted scour level.

6) In rocky areas the trench bottom shall have a sand/clean graded earth padding of 150mm after installation of pipeline, sand padding shall be placed around and on top of the pipe so that thickness of compacted padding on top of the pipe corrosion coating shall be at least 150 mm. Rock shields are to be used for backfilling in rocky areas.

7) At parallel alignment with roads, additional 300mm of cover over and above as indicated above shall be maintained.

8) The OFC shall be buried in the same trench as the pipeline at a distance of 300MM from the adjacent pipeline OD. For OFC laying at Crossings, refer Clause 8.13 of Document No. 290805-001-DB-6001 Rev E.

10) Additional soil cover other than specified above shall be provided at locations indicated by statutory/ local authorities or in areas likely to have an increased risk of impact damage or third party interference as per agreements between COMPANY and authorities.

3.4 WELDING

General

Welding procedure qualification shall be carried out in accordance with the relevant requirements of API 1104 latest edition and Client's specification.

Welding shall be carried out by manual Shielded Metal Arch Welding Process (SMAW).

Once welded specimens are visually cleared, it shall be subjected to Radiographic testing and subsequently to destructive testing. Destructive testing shall be done as per API 1104 standard.

SUMMARY OF PROPOSED WPS

Process	: SMAW
Type	: Manual
Base Material	: API 5L Gr. X-52 Carbon Steel Line Pipes
Pipe Outside Diameter	: 10" Diameter
Pipe Wall Thickness	: 6.4/7.1mm
Applicable Specifications	: API 1104 Latest Edition (Standard for Welding of Pipeline & Related Facilities)
Pipe diameter range	: 10"
Pipe thickness range	: 6.4 to 7.1 mm
Joint Design	: Single V-Groove Butt Joint

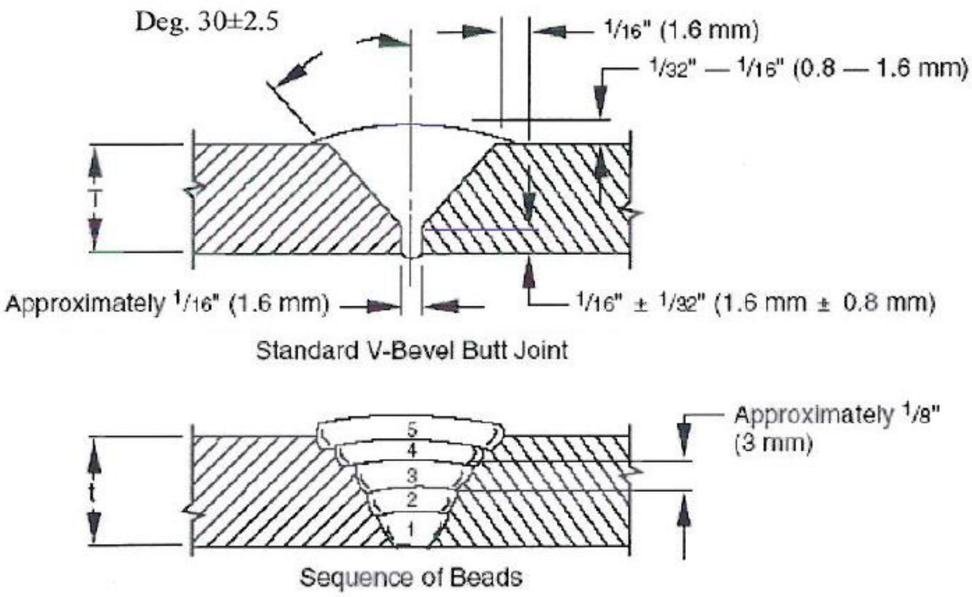


Fig 3.4.1 Sketch showing joint design for 10" Dia pipe

METHODOLOGY

PREPARATION FOR WELDING

All welding for pipe diameter 100 mm and larger shall be done in accordance with the latest edition of API Standard 1104. Welds shall be made by the manual shield metal arc method. Before welding all foreign materials shall be removed from the beveled ends.

If any of the beveled ends of pipe are damaged to the extent that satisfactory welding contact cannot be obtained, the damaged pipe ends shall be cut and field beveled with beveling machine. Should laminations, split ends or other defects in the pipe be discovered, the length of pipe containing such defect shall be segregated, repaired or removed from the line.

This contingency of detection shall hold good during various stages of pipeline operations like welding, bending, coating and wrapping etc. Should any other defects like scratches, weld sparks, indentation be detected, the same shall be removed / repaired.

CLEANING OF EDGES AND BEVEL INSPECTION

The edges to be welded shall be properly cleaned. In particular, any oil, bitumen, grease and paint shall be removed by flame or solvents. Earth, oxide, rust, sand and any other material, which could be detrimental to the weld, shall be removed by means of grinding and / or a wire brush. This shall be effected inside and outside and for a minimum distance of 25mm from the edge of the weld bevel.

The bevels shall be thoroughly inspected at this stage. On pipes which have been cut back, a zone extending 25mm back from the new field bevel, shall be ultrasonically tested to the requirement of the line pipe specification to ensure freedom from laminations. The new bevel shall be subjected to 100% visual and 100% dye penetrant/ MPI tests.

ALIGNMENT, FIT UP AND SPACING

Immediately prior to line-up inspect the pipe ends inside and outside for damage, dents, laminations etc. Pipe for welding shall be set up, correctly spaced, allowing for temperature changes during welding, in correct alignment and shall in no circumstances be sprung into position. Temporary attachments of any kind shall not be welded to the pipe.

Components to be welded shall be aligned, spaced and fitted up so as to hold the edges, during welding, at a proper distance to obtain full root penetration. Root gap shall be as per the approved WPS . During alignment and fit - up, first pipe will be rested and locked on the sand bags and the second pipe will be held by side boom with internal fit-up clamp (Mechanical), the second pipe will be carefully lowered on pre - positioned sand bags. The height of the support must be such that each weld is at 50 cm above the ground during welding and after weld, height of support shall be 30 cm. Pre-heating shall be carried out as per WPS. Earthing clamps used for welding return circuit shall only be placed on bevel area or circumferential welds.

Alignment of two pipeline component of different nominal thickness and same outside diameter, shall be carried out by tapering the inner surface of the thicker component with a taper not steeper than 1 in 4.

Seam orientation of welded pipe shall be selected to ensure that at the circumferential welds, the longitudinal welds shall be staggered in the top 90° of the pipeline, or 250mm whichever is the lesser. A longitudinal joint shall pass an appurtenance of a structural element at a minimum distance of 75mm.

All welding equipment, line-up clamps, beveling machines and other welding tools, materials and equipment are to be used in welding operations and must be maintained in a satisfactory condition. Hammering not permitted.

Welding machines shall be operated within the amperage and voltage ranges recommended for each size and type of electrode to ensure proper fusion and maximum penetration.

All welding electrodes and their storage & handling shall conform to the requirements of API Std.1104 latest edition. Electrodes that show signs of deterioration or damage shall be rejected. Stubs of welding rods and pieces that are rejected shall be disposed of at suitable place at the end of each day's work.

WELDING PROCEDURE

Prior to start of production welding, a pipe welding procedure shall be established, qualified and recorded for submission to the Company / for approval and adhered with relevant API Standard.

All position welds shall be made with the pipe resting on suitable and sufficient number of skids with the work clearance as specified in the relevant API Standard.

The number of beads required shall be governed by the wall thickness of the pipe, provided that the completed weld shall have a substantially uniform cross section around the circumference of the pipe. The root bead shall be applied completely around the pipe and immediately run by a grinder and the grove shall be thoroughly cleaned for visual inspection of all free scale, slag or flux and other foreign material prior to the application of successive beads.

The stringer bead must approach full and complete penetration throughout the periphery of the weld and build up with reinforcement at the root.

The hot pass shall fully penetrate the pipe level at each side of the stringer making a deposit heavy enough to avoid pin holing. The completed weld is to be cleaned free of all scale, the standards of acceptability are as given in relevant API Std. The minimum and maximum limits of reinforcement and the width of completed welds shall be in accordance with relevant API Std.

Welding shall not be carried out when weather conditions are unsuitable as per the provisions of relevant API Std. In the event of wind, rain or low temperatures which may affect the stability of the arc, welding tents or other suitable protection shall be used. If the welding is interrupted at the end of the welding pieces, isolating blankets should be put on the weld to avoid a quick cooling of the weld.

Before any pipe length is cut the painted serial No. & Heat No shall be transferred to the either side of the joint which is to be made by cutting & record shall be prepared as per approved format.

After completing every pass, the same shall be cleaned / flattened by grinding and power brushing.

Interruption between first pass and second pass and to third pass shall be as per the approved WPS. After completion of the third pass welding may be suspended if required, so as to allow the weld joint to cool down provided the thickness of the weld metal deposited shall be 50% of the pipe thickness or minimum of 03 passes whichever is more. Upon restarting the welding pre-heating shall be carried out.

After completion of welding visual inspection shall be done and all the surface defects shall be removed as per the specification. NDT shall be carried out as per the approved NDT procedures. Repairs shall be done as per approved WPS and if required it shall be tested for NDT.

3.5 COLD FIELD BENDING

Machinery

- Hydraulic Pipe Bending Machine with Lined Bending Die Sets
- Degree Protractor
- Hydra Crane
- Lifting / Choker Belts
- Holiday Testing Machine
- D Meter

Cold field bend is made as explained below:

Trigonometric Survey will be done by the surveyor to establish number and degree of Bends required ensuring that the installed pipe will confirm to the contours of the trench.

The procedure include amongst other steps - lengths, maximum degree per pull and method and accuracy of measurement during pulling of the bend. After bending if the necessary measurement cannot be achieved satisfactorily from inside, the coating will be removed in order to control the ovality, the wrinkles and the wall thickness.

Over bend is made in such a manner that center of the bend clears the hight points of the trench bottom. Sag bends shall fit the bottom of the trench and side bends shall confirm and leave specific clearance to the outside wall of the trench.

The pads, dies and rolls of the bending equipment shall have relatively soft surface to avoid damage to the pipe coating, wherever applicable, fully retaining bending shoes shall be used.

The ends of each bend length shall be straight and not involved anyway in the bending. The length of the straight section shall permit easy joining. In no event shall the end of the bend be closer than 1.5 m from the end of a pipe.

The radius of cold field bends shall be as per the following:

- For 10" OD Pipeline and smaller the radius of cold field bend shall not be less than 18D. Where D is the Outer Diameter of the Pipeline.

- Bending will be performed with machines that ensure continuous bending without wrinkles or undulations in the curved pipe section. A bending mandrel is compulsory if **D/t 50** (outside diameter / thickness).

- A bending mandrel must be used if during bending, wrinkles or undulations occur or if the ovalisation tolerances cannot be respected. When the ambient temperature is less than 0°C it is forbidden to bend P.E coated pipes. The thickness of the pipe wall on the outside of the bend must remain within the tolerance limits given for pipes.

- Clamping metal to the inside of the bend must be such that the inner diameter of the pipe remains within the ovalisation tolerances. If necessary, the coating will be removed completely for this purpose. For successive bend pipes with a longitudinal welded joint, this joint shall be alternatively on the upper and lower side.

- Ovalisation after bending will be maximum 2.5% of the outside diameter at any point of the pipe. If wrinkles occur, the permissible fault depths shall be less than 0.01 times the distance between two consecutive peaks. A gauging plate of soft steel (length = 1.5 x O.D., dia 95% of I.D.) shall be pulled through the field bends to check compliance with the above requirements. The plate dimensions will depend on the characteristics of the pipe and the different permissible tolerances.

- Pipes with longitudinal welds shall be bent in such a way that the weld lies in the plane passing through the neutral axis of the bend which shall be installed positioning the longitudinal weld in the upper quadrants. If horizontal deviations are to be achieved by joining more adjacent bends, the bending of the pipe lengths shall be made by positioning the longitudinal welds alternatively 70mm above and below the plane passing through the neutral axis in such a way that the bends are welded with the longitudinal welds displaced by about 150mm and situated in the upper quadrants. In case of vertical bends formed from a number of pipe lengths, the longitudinal welds shall be positioned on the plane passing through the neutral axis of the bend to the right and left alternatively.

3.6 TIE IN WELDING

The tie-in of two sections shall be carried out only after the section has been welded and lowered and preferably back filled except for the ends which are to be joined which shall be kept on skids or kept in the ditch and shaded.

The tie-in should be done in such a way as to leave no strain in the pipe. If necessary, redressing of the trench shall be done to eliminate force or strain in the pipe.

When a welded section so overlaps as to prevent a proper tie-in, welding the line-up shall be made by moving ahead the section or by carefully cutting of the overlapping end.

As and when a Tie-in joint is planned during the lowering of pipeline, the same shall be recorded in Tie-in record book maintained by the respective Welding Engineer.

The tie-in operation includes necessary cutting, beveling, line-up, cleaning, welding, priming, coating and wrapping, lowering in, backfilling for the tie-portion as per standard practice. Necessary widening of the trench should be carried out as per requirement.

All reports of Tie-In along with NDT reports shall be submitted to for review and approval. Cleaning, Priming, coating and other activities shall be performed as per approved procedures.

The root gap shall be accurately checked and shall confirm to the qualified welding procedure. All spaces between bars or at least 60% of first pass shall be welded before the clamp is released and pipe remaining adequately supported on each side of the joint.

Segments thus welded shall be equally spaced around the circumference of the pipe. Slag etc. shall be cleaned off and the ends of the pass shall be prepared by grinding. So as to ensure continuity of the weld bead.

Qualified welders shall carry out welding. While welding is in progress, care shall be taken to avoid any kind of movement of the components I pipe, shocks vibration and stresses to prevent occurrence of weld cracks.

Electrode starting and finishing points shall be staggered from pass to pass.

Arc strikes outside the bevel on the pipe surface shall not be permitted. Accidental are strikes shall be repaired as per approved procedure.

All finished welds shall be visually inspected for parallel and axial alignment of the work, welds, surface porosity and other surface defects.

All tie-in weld shall be 100% radiographed, in addition, ultrasonic inspection may be required for certain critical welds of the pipeline (i.e. tie-ins, welding of valves, flanges) randomly selected at Company's discretion.

Parts being welded and the welds shall be protected by windshields made of metallic, frame covered by Canvas, whenever necessary, to protect from rain and strong winds.

The completed welds shall be covered with asbestos cloth covered by GI sheets, whenever necessary, to protect from bad weather conditions. The reports are submitted to for review and approval.

For Tie-In of adjacent sections of pipeline already pressure tested also called golden joints and for final joints, a single length pup or off cuts, which have been hydrostatically pre-tested shall be used.

All quality records generated during the welding of Tie-In joints

Field welding of pipeline Tie-In joints shall be done as per Qualified Welding Procedure Qualification.

A Tie-In pit or bell hole of suitable length, depth and width shall be cut to enable to work freely inside the trench. Proper care shall be taken so as not to allow pit to collapse or pit wall caving in. Necessary supports shall be used wherever required.

In connecting pipes, special items, fittings and equipment where different wall thickness are to be welded, ACE shall follow the procedures indicated in ANSI B31.4, as applicable.

Cut pipe bevel ends shall be examined for laminations by Dye Penetrant Testing (bevel edge) for laminations. Defective pipe length shall be cut back until laminated section is removed and re-beveled.

Alignment of the Tie-In joint shall be done using external clamp capable of removing offset and misalignment is minimized.

3.7 NON DESTRUCTIVE EXAMINATION

EQUIPMENT

- X ray Crawlers with Module/ Battery packs & Drive Assembly.
- X-ray Machine with Control panel & cables. Iridium — 192 Gamma ray camera.
- Pilot Command
- Survey Meter & Dosimeter
- Densitometer.
- Film reviewing facility, Dark Room Accessories & Consumables
- Films, chemicals and water.

RADIOGRAPHY EXAMINATION

The radiographic procedure and technique adopted shall conform to the requirements mentioned in Article 2, as well as Article 22 of ASME Sec. V. Source side pentameter shall be used in establishing radiographic procedure / technique. Radiographic inspection shall be carried out in accordance with the provisions of API 1104 (2005).

The acceptable limits of defects and removal of defects shall be as per the relevant codes of fabrication. Contractor shall be responsible for carrying out radiography, rectification of defects and re-radiography of welds rectified / repaired.

Radiographic examination is done by using x-rays and Gamma rays. Only HPCL approved agencies shall be engaged for radiography works. Before start of production radiography procedure qualification shall be carried out as per Appendix-1, 2 & 3.

The following techniques are carried out for radiographic works

- For mainline joints, the radiography shall be taken using internal crawlers by single wall single image technique.
- For Tie-in joints and joints with fittings where internal crawlers can not be used, the radiography shall be taken using external x-ray machine by double wall single image technique.
- In case of inaccessible main line joints and Tie-In joints radiography using Gamma ray source with slow speed film (AGFA D4 or Equivalent) shall be done with prior permission from HPCL and required sensitivity shall be obtained.

All the repaired areas is re-radiographed covering additional 6" of weld length on either side of repaired area and while evaluating the repair films, the interpreter shall compare, each section of the weld with original films to assure the repair was correctly marked and original defect is removed completely.

Case 1 – By using Internal X-Ray Crawler (Single wall – Single Image technique)

Prior to start of radiographic work procedure qualification is done by actual demonstration of the technique.

This procedure is adopted to radiograph all the production welds other than tie-ins. In this technique the number of exposure shall be one only. The minimum length of the film shall not be less than complete circum. length and to have sufficient overlap at the ends.

The position markers shall be at 05 cm intervals from datum point (zero point shall be on top of pipe) and the division shall run clockwise in ascending order, viewed in the direction of pipeline laying progress around complete circumference.

The unexposed film packed in the cassette ready with the joint identification number and I.Q.Is shall be wrapped around the circumferential weld at equal distances. The x-ray crawler shall be inserted from the open end of the pipe and shall be propelled by battery power to the place of interest by use of a remote control. Radiation safety regulations must be taken into account. Radiation source shall be positioned within 5 mm of centre of weld circle. Radiation angle with respect to weld and film is 900. The machine emits radiation as per pre-set exposure time.

Marker system shall be used to produce permanent identification on the radiograph with the following information:

- Project Name & Contractor's Name
- Weld Number, Dia. & Thickness of Pipe
- Welder's Identification
- Repair identification marks
- Date of Radiography

The marker is placed at approx. 3.5 mm or more away from the area of interest.

Case 2 - By Using External X-ray Equipment (Double wall, single image technique)

Prior to start of radiographic work procedure qualification is done by actual demonstration of the technique at site.

This procedure is adopted to radiograph tie-in / repair joints or joints which are inaccessible to internal x-ray crawler. In this technique the number of exposures shall be four per weld minimum subject to demonstration of sensitivity and required density. The minimum length of each film shall not be less than 300 mm and should maintain a minimum film overlap of 40 mm.

Maximum film length (diagnostic film length) per exposure shall not be more than that qualified in the procedure.

The equipment shall be positioned so that the radiation beam passes through the center of the section under examination and will be offset from the plane through the weld by the minimum distance required to prevent the image of one side of the weld falling the image on the other side. The film will be placed diametrically opposite the focal point with a minimum of 4 number exposures at 900 displacements.

The position markers shall be at 05 cm. intervals from datum point (zero point shall be on top of pipe) and the division shall run clock-wise in ascending order, viewed in the direction of the pipeline laying progress around complete circumference.

Marker system shall be used to produce permanent identification on the radiograph with the following information:

- Project Name & Contractor's Name
- Weld Number
- Dia. & Thickness of Pipe
- Welder's Identification
- Repair identification marks
- Date of Radiography

The marker shall be placed at approx. 3.5 mm or more away from the area of interest.

Dark Room Facilities

- Proper dark room with film viewing arrangements shall be made and film shall be kept in dry place where the conditions will not detrimentally affect the emulsion.
- Records are maintained for the qualification of each technique.
- Radiography technique shall be as per the requirement of ASME SEC V
- Operators Qualification: Level — II in radiography.

LIQUID PENETRANT EXAMINATION

Whenever such tests are specified, the tests shall be carried out on joints chosen by the Inspector as per ASME Section V article 6 and 7 respectively.

For austenitic stainless steels and other non-magnetic materials, liquid (dye) penetrant test is carried out. For carrying out this test, the materials shall be brought within a temperature limit of 15° C to 50°C.

The entire area of the accessible finished weld surface shall be examined. Selected root runs, subject to a maximum of 10%, before finished weld, may also be examined at the discretion of the Company. Wherever LP tests are specified, either LP test may be used. But wherever only MP test is specified, LP method of examination may be used only if MP examination is impracticable.

Materials

Materials used for PT Examination are Check-Met or equivalent, which are to be spray can type.

The chemicals used for the above shall not contain harmful halogen and sulphur. The content of each of the above is limited to 25ppm.

Visible Solvent removable penetrants shall be used. The penetrant contains a dye, having a contrast color, which can be seen readily in day light or under normal interior illumination.

Cleaning

It is essential that the part of surface to be examined shall be cleaned. All rust, scale, welding flux, spatter etc., shall be removed by suitable method such as grinding and wire brushing etc., followed by cleaning with acetone / trichloroethylene.

Drying

It is essential that the part of surface to be examined be sufficiently dried prior to application of penetrant.

Penetrant Application

The surface to be tested shall be thoroughly coated with penetrant by spraying and/or by brush application. The Dwell time for the penetrant shall 10-15 Minutes or as recommended by manufacturer. The temperature of the area to be inspected shall be between 15°C & 50°C.

If using spray method, the spray nozzles should be kept at a distance of 15 to 30cm from the job. The penetration time shall be 15 to 20 Minutes and/or as recommended by manufacturer. In case of an investigation, necessitating a great sensitivity, it can extend up to 30 minutes.

After suitable penetration time has elapsed, excess penetrant remaining on the surface shall be removed by wiping with clean fiber free cloth dampened with cleaner. Penetration time shall be as per manufacturer recommendation.

Surface Cleaning

Excess penetrant shall be very carefully removed from the examined surface; otherwise it could produce a background blushing, capable of masking defects or interfering with their accurate identification. Excess penetrant should be removed by soft wet rags.

After removing the excess penetrant, the examined surface shall be dried by normal evaporation or forced air.

Developer Application

The developer shall be uniformly applied over the surface by spraying, the spray nozzles should be kept at a distance of 15 to 30cm from the job. Aerosol type of spray shall be continuously agitated in order to prevent setting of solid particles dissolved in the liquid. Inspection shall be made after a minimum of 7 minutes and not later than 30 minutes after the developer is applied so as to prevent the dye from diffusing in the developer coating.

If a discontinuity is on the surface, the dye penetrant will draw a coloured pattern on the white background.

Any doubtful indications shall be ground out to evaluate their characteristics. Then a second PT of the area shall follow according to the same procedure as the first one of show if the false indications were eliminated.

Final Cleaning

When the Inspection is conducted the penetrant and developing materiel shall be removed as soon as possible by means of wiping with a cloth and/or by spraying cleaner on the surface.

Evaluation of Indications

Bleeding out of the penetrant will indicate defects that occur as Mechanical discontinuities on the surface.

Usually a crack or similar opening will show a red line. Light cracks, porosity or welded lap will show a broken line.

Gross porosity may produce large indication covering an entire area of weld. Fine porosity is indicated by random red dots.

ULTRASONIC TESTING

This procedure intends to describe the ultrasonic test for detecting discontinuities in weldment and HAZ.

This procedure is in line with requirement of ASME Sec. V and API 1104. All ultrasonic tests are performed manually by A scan pulse echo method employing contact through Couplant film.

PERSONAL QUALIFICATION

Personal performing ultrasonic testing according to procedure shall be qualified and certified of U.T. level — II as per ASNT SNT -TC-IA. All qualification certificates must be current.

SURFACE PREPARATION

The finished contact surface is to be in the uncoated condition and free of weld spatter and any roughness that would interfere with free movement of the search unit I probe or impair the transmission of ultrasound.

The weld surface must be finished so that they cannot mask or be confused with reflection from defects and must merge smoothly into the adjacent base material.

The adjoining base material through which the ultrasound will travel while doing ultrasonic testing must be completely scanned with a normal beam / straight beam probe to detect discontinuities, at least 1.25 x longest skip distance to be used which might affect the angle beam result. This does not form the base for acceptance / rejection criteria for the weld but the presence with in the beam path shall be recorded in the report.

EQUIPMENT & PROBES

Ultrasonic instrument used is A scan pulsed reflection type

Flaw detector : Model EINSTIEN II (Modsonic)

Probes used : 0° (Normal / straight), 45°,60° & 70° - angle probe.

Frequency : 4 MHz

Crystal size : 8.9mm Angle and 10mm/24mm dia. normal probe.

CALIBRATION

The recommended equipment configuration (system check) done by miniature calibration V2 block.

The technician who performs must check instrument and probes. This includes screen height linearity, amplitude control linearity and horizontal linearity at every three months and beam index / exit point and beam angle at the start of work that is at every 8 hours.

Range and other calibration are done at prior to the start of each working shift or at minimum 4 hours interval whichever is earlier.

Acceptance criteria for linearity are in accordance with ASME Sec. V Article 5, mandatory Appendix.

3.8 JOINT COATING BY SHRINK SLEEVE SYSTEM

Coating of the welded joints must be in possession of a certificate of qualification issued by the supplier. All qualified blasters I insulators shall be provided with identity cards.

Materials shall not be older than their period of validity at the time of application. The coating material used shall be Heat Shrinkable Sleeve and properties of coating material shall confirm to the relevant specification .

The approved Heat shrink sleeve shall have sufficient length and shall overlap the factory applied coating by minimum 50 mm on both sides after shrinking. It shall have a pre-attached reinforced closure strip which shall be located at 10' o clock or 2' o clock position on the pipe. Overlap between the sleeve and closure patch shall be minimum 100mm. Heat shrink sleeves shall comply with EN 12068 certified.

All batch test certificate shall have

1. Brand Name & Type (Raychem make, HTLP 80 / Direx)
2. Material Description

3. Batch No
4. Manufacturing Date and Expiry Date
5. Specific Storage and Handling Instructions

All materials shall be stored in sheltered storage and protect from direct sunlight and the storage shall be as per the recommendations of manufacturer.

Equipment

a. Sand blasting sand for Surface Preparation,

b. Sand blasting hopper,

c. Air compressor with moisture separator,

d. Sand Blasting Gun

e. LPG Burners, hose & LPG Cylinders and Regulators

A sufficient number of fully automatic full circle holiday detectors will be available with visible and audible alarm system for inspection for coating. The relevant inspection reports shall be prepared upon completion of acceptable inspection.

Materials

a. Heat Shrinkable Sleeves (Raychem make, HTLP 80 - Direx).
b. Epoxy Bulk Kit. (Raychem make)
c. Applicator Pad with mixing cup & stick (1 per joint).
d. Polyethylene Repair Patch (Perp).
e. Straight Silicone Roller/Curved Silicon Roller.
f. Melt stick
g. Filler Mastick

Measuring and Test Equipment

a. Peel Gauge Tester.
b. Peel cutter knife.
c. Pyrometer/ infrared temp gun.
d. Holiday Detector.
e. Hygrometer
f. Coat meter
g. Wet film thickness gauge
h. Press-O-Film
i. Micrometer

Procedure qualification:

The application procedure shall as per the recommendation of the manufacturers, which ever are most stringent and shall be demonstrated during the procedure qualification. All field joint coating shall be done as per the above approved field joint coating qualification records / procedure.

Surface Preparation

Uncoated steel surface and adjacent line coating (100 mm) shall be free from oil, grease, salts and other contamination. All weld spatter, flux and scale shall be removed. Suitable solvent, which does not leave any individuals like benzene, xylene equivalent, shall be used. Kerosene shall not be used for cleaning. The solvent cleaning procedure shall be as per SSPC-SP1.

Prior to surface cleaning, the surface shall be completely dry. Uncoated steel surface shall then be blast cleaned with sand to a finish equivalent to SA 2.1/2 of Swedish Standard SIS-055900 and have profile of 50 - 70 microns. Roughness shall be checked with PRESSO Film of 50 - 70 microns profile. White latex paint if any, on the line coating shall be removed (100 mm) by gentle blast cleaning. The blast cleanliness **shall** be checked on every joint and the roughness profile shall be checked 1 out of 10 joints.

Blast cleaned field joints shall be coated with in 2 - 4 hours according to the conditions below,

RH > 80% - 2 Hours

70% < RH < 80% - 3 Hours

RH < 70 % - 4 Hours

The ends of existing pipe protective coating shall be inspected and chamfered at an angle of 15° to 30° or less prior to application. Unbounded portion of the coating shall be removed and then suitably trimmed portions where parent coating is removed shall also be prepared as mentioned above. Protection coating shall be done immediately after completion of surface preparation.

WEATHER CONDITIONS WHEN CARRYING OUT THE WORK

In order to achieve optimum results during the coating work, it is essential that no condensation occurs on the blasted or cleaned surface or between the different layers. For this reason, During blast cleaning the pipe surface temperature shall be simultaneously more than 5° and more than 3°C above ambient Dew Point, while the ambient Relative Humidity shall not be greater than 85%.

APPLICATION OF HEAT SHRINK SLEEVE

The application of heat shrink sleeve shall be as per the recommendation of the manufacturer and as qualified during the **field** procedure qualification test. Before installing the wraparound sleeve, the bare steel surface shall be pre heated over the surface to remove the moisture. The minimum preheat temperature shall be as recommended by the manufacturer which shall be maintained during the applications and shall be checked by pyrometer. The solvent free the epoxy primer shall be mixed and applied prior to sleeve application as per manufacture's recommendations. The sleeve shall be installed immediately after epoxy application but not later than the drying time of epoxy.

The Heat shrink sleeve shall be wrapped loosely around pipe, centering it over the weld area and evenly overlapping the adjacent pipe coating in a cigarette fashion.

The LPG gas torch is adjusted to have a bushy yellow flame of approximately 50 cm. Using the yellow portion the flame the closure backing is evenly heated until the pattern of the fabric reinforcement is visible.

A minimum overlap of 50 mm is to be ensured (after shrinking) with the factory coating. The sleeve is so wrapped that closure patch is positioned to one side of the pipe in 2' 0 clock or 10' 0 clock position.

Preheat temperature as per manufacture recommendations.

The closure patch is pressed in position centering over the exposed sheet end. Overlap between the sleeve and closure patch shall be minimum 100 mm.

The closure backing is patted down with gloved hands and gently working them outwards from the center of the closure. This eliminates possible entrapped air and ensures good bonding. For this purpose the small hand roller will be run over the closure backing.

Using the LPG gas torch, beginnings at the center of sleeve heat circumferentially around the pipe, using a constant paint brush motion.

During shrink down, an occasional check of adhesive flow with finger will be made. Wrinkles should disappear automatically.

When the sleeve has been shrunk on to the joint area and is still hot and soft, a small hand roller shall be run over the same to push out any trapped air, particularly attention to be paid to the weld and cut back area and if necessary the areas may be reheated to roll out air.

The sleeve is fully recovered when all the following have occurred:

- The sleeve has fully conformed to the pipe and adjacent coating.
- There are no cold sports or dimples on the sleeve surface.
- Weld bead profile can be seen through the sleeve.
- After sleeve is cool adhesive flow is evident on both the edges.

If there is air trapped, hand roller will be used to remove it In case of unacceptable installation, the sleeve shall be removed and replaced in accordance as specified above.

Pre-Qualification of Field Joint Coating System

The field joint coating system materials and the procedures proposed by ACE shall be pre-qualified during the sleeve installation start-up phase. Five joints (5) shall be coated with the requirements of this specification and then inspected and tested in accordance with the requirements of this specification with respect to the following :

1. Surface preparation cleanliness, roughness profile and dust contamination
2. Pre-heat temperature (as applicable)

3. Primer thickness
4. As applied coating thickness
5. Holiday detection
6. Peel test at (+) 23°C & (+) 60°C on pipe surface & factory applied coating and at over laps (as applicable). If required to achieve the temperature of (+) 60°C, suitable thermal blanket may be used.
7. Visual appearance and void after installation on the body, area adjoining the weld and area adjoining the factory applied coating. (To establish voids adjoining the weld and factory coating a strip of 25 mm wide and 200 mm long shall be stripped and examined).

Visual Inspection :

A visual inspection for sign of punctures, dents or air entrapment etc. shall be carried out. Weld bead profile shall be visible through the sleeve. Pattern of fiber reinforcement shall be visible through the sleeve. Pattern of fiber reinforcement shall be visible on the closure patch. Mastic extrusion on either of the sleeve shall be examined. The external appearance of the sleeve shall be smooth. The ends of the sleeve shall be firmly bonded to the mill coating.

Holiday Detection

The holiday detector used shall be checked and calibrated daily with an accurate DC voltmeter. The holiday detector shall be used with a full circle spring to detect the defects on the entire surface of field joint coating . The detector shall be set at a DC voltage of 25KV. Holiday check to be carried out after the joint has been cooled below 50°C

Peel Test

Peel test shall be carried out on one of every 50 joint coating or one joint coating out of every day's production whichever is stringent.

From each test sleeve, strip of size 25 mm x 200 mm shall be cut perpendicular to pipe axis and slowly peeled off.

After removal of strip the bulk of adhesive shall remain adhered to the pipe showing no bare metal and it shall be essentially free of voids, otherwise, test shall be considered failed. Repair shall be carried out with PERP as per coating repair procedure.

If the sleeve taken away for peel test does not meet the requirement as stated above, adjacent two sleeves shall be tested. If the adjacent two sleeves are acceptable the test rate shall be increased to one sleeve for every twenty-five. If either or both the sleeves do not meet the requirements mentioned above, the field coating shall be stopped and the manufacturer's expert shall be mobilized.

Thickness Measurement

The total thickness of heat shrinkable wraparound sleeve in the as applied condition shall be as follows:

Table 3.8.1 Thickness measurement

Pipe Size (Specified Outside Diameter)	Thickness (mm)	
	On Pipe Body (Min.)	On Weld Bead (Min.)
Up to 18" (457 mm)	2.2 mm	1.8mm

The coating thickness shall be checked by non-destructive methods for each field joint. Average thickness of the as-applied coating on pipe body shall be established based on measurement at min. eight locations i.e. four measurement on either sides of the girth weld at 3, 6, 9, & 12 O'clock positions. To establish the minimum thickness on the girth weld, four measurements shall be taken on apex on the weld at 3, 6, 9 & 12 O'clock positions. All such measurements shall be recorded.

Generally defects repair on field joint coating are not permitted. Defects/Repairs, if any, detected during the holiday testing / peel testing /

visual testing shall be repaired as per approved procedure and as per manufacture standard and shall be limited to one location per field joint coating. The repairing of the defects/peel test locations shall be done as per the manufacturer's recommendation and shall be established during the field procedure qualification test. When defects / repairs in more than one locations are detected during the field testing the entire coating shall be rejected and fresh coating is done. All repaired area shall be checked for holidays and visual defects after completion of the repair.

3.9 PRE HYDROTESTING

The section of these Pipelines shall be tested as a single string.

All weld joint shall be exposed and should be cleaned properly from rust and other foreign materials.

Pre - tested, "Testing Header" of same pipe material grade shall be welded at the either side of the section. A diagram indicating all fittings, vents, valves, test header, temporary connections etc, to be shown. All fittings and valves used on header should be 600 rating.

The section of the pipeline for the crossings shall be tested as a single string. The minimum hydrostatic test pressure shall be 1.4 times of design pressure for gas pipeline. The combined equivalent stress in the pipeline due to bending and test pressure shall not exceed 90% of the SMYS of the pipe material. Test section shall be visually examined for leaks/ defects, etc.

After the temperature has been stabilized,/the pressure shall be maintained in the pipeline for at least 6 hours and recorded .Calibrated 6" dial pressure gauge one at pressurization point and at other highest point shall be installed during testing. Pressure gauge range should be 1.5 times of test pressure. The accuracy of the pressure gauge to be used is +/- 0.1% of the full scale value.

Before filling water in the pipe section all NDT, pipe log book part A except joint coating shall be completed.

For testing of pipe section clean construction potable water shall be used.

During filling of water proper venting shall be done at the highest point to remove all the entrapped air.

Pipeline section shall be gradually pressurized to the test pressure and intermediate checks shall be done for any possible leakages.

During pressurization warning sign boards shall be displayed as

"KEEP AWAY — SYSTEM UNDER PRESSURE"

Test pressure shall be retained in the section for the 6hours and the section shall be visually examined for leakage and defects. During holding period if the pressure exceeds the maximum allowable test pressure, then necessary bleeding off shall be done to bring the pressure down to the specified pressure.

All necessary pressure, temp records will be maintained and will be recorded on log Book.

Test pressure calculation shall be submitted prior to start of test.

Acceptance of test

The Pre — hydrostatic test shall be considered acceptable if no visible leak / any pressure loss is observed during hold period. The above procedure shall be repeated, if found any leak.

Termination

After acceptance of test the section shall be depressurized and water shall be removed completely from the section.

3.10 LOWERING AND BACK FILLING

EQUIPMENT

- Side Booms
- Back Hoes
- Excavators
- Lowering Belts
- Holiday Detector

METHODOLOGY

LOWERING PIPE IN TO TRENCH

The pipeline section is lowered:

- After inspection of coating and wrapping of welded pipeline section and clearance
- After satisfactory completion of trench, bottom level shall be checked to get the required minimum cover.

The pipe shall fit in the trench without being forced to remain in place until the backfilling operation is completed. Any extra excavation that may be required for this purpose shall be done.

Lowering-in must be carried-out in the presence of the Owner representative and/or the Engineer.

During lowering-in, the pipe is not subjected to inadmissible stresses; the pipeline is supported over a sufficient surface area to prevent the supports from penetrating the coating; a sufficient number of machines with the required capacity will be used for lowering-in the pipeline strings. Wire rope slings or other material which may damage the PE coating shall not be used to lift the pipe strings. No slings shall be put around the field coated joints.

Before lowering in, a complete check by a calibrated full circle holiday detector for pipe coating (PE coating) and for field joint coating shall be carried out using at 25 KV with a calibrated holiday detector. The damages if any observed during the examination shall the repaired as per the approved procedure and re-holiday shall be done.

In lowering the line vertical slack loops shall be placed at regular intervals. Slack loops shall move horizontally from side to side of the trench after lowering. Until/ enough of the lowered line is securely anchored by backfill, slack loops shall be suspended above the trench on padded support of sufficient strength to prevent collapsing of the trench and in sufficient number as that the pressure at the points of support will not damage the coating and wrapping. Slack loops shall be lowered into the trench without being forced into it only early in the morning when the pipe temperature is normally at its lowest value, and immediately back-filled. Excessive slack shall be removed by widening the trench as may be necessary.

Vertical and lateral bends of the lowered line must be fitted into the trench with proper clearance. Necessary works required for ensuring proper clearance shall be performed.

The trench into which the coated and wrapped line is to be lowered must present on even and smooth bottom and care shall be exercised to remove from there all hard projecting objects so that the protective coating and wrapping on pipe is not damaged.

The bottom of the trench shall be pre-padded with a minimum of 0.15 M of loose earth / sand in accordance with the specifications given herein for rock trenching which might damage the protective coating and wrapping of pipe.

In no case top soil shall be used for padding trench bottom.

Water present in the trench at the time of lowering in shall be pumped out before lowering the pipe section to enable checking of the conformity of the trench to specifications, if required. If the trench has collapsed, necessary repairs shall be done, as directed by the site Engineer/Engineer-In-Charge.

Across water logged areas, if required concrete weights as per exhibit and heavy coating and wrapping consisting of an extra coat of enamel and an extra wrap of fibre glass in addition to the normal coating and wrapping shall be installed / applied as directed by the Engineer-In-Charge.

After lowering, foreman shall ensure the ends of the pipe strings will be closed using `end Caps' to prevent the ingress of the sand, water etc. until the tie in welds are made. In lowering parallel pipeline in the same trench, the minimum distances between the pipeline indicated in approved drawings shall be maintained. Post padding work shall start immediately after lowering.

CHAPTER 4
MAINLINE HYDROTESTING
4.1 PIPELINE HYDROTEST PRESSURE DETERMINATION

Hydrostatic testing has long been used to determine and verify pipeline integrity. Several types of information can be obtained through this verification process.

However, it is essential to identify the limits of the test process and obtainable results. There are several types of flaws that can be detected by hydrostatic testing, such as:

- Existing flaws in the material,
- Stress Corrosion Cracking (SCC) and actual mechanical properties of the pipe,
- Active corrosion cells, and
- Localized hard spots that may cause failure in the presence of hydrogen.

There are some other flaws that cannot be detected by hydrostatic testing. For example, the sub-critical material flaws cannot be detected by hydro testing, but the test has profound impact on the post test behavior of these flaws.

Given that the test will play a significant role in the nondestructive evaluation of pipeline, it is important to determine the correct test pressure and then utilize that test pressure judiciously, to get the desired results.

When a pipeline is designed to operate at a certain maximum operating pressure (MOP), it must be tested to ensure that it is structurally sound and can withstand the internal pressure before being put into service. Generally, gas pipelines are hydrotested by filling the test section of pipe with water and pumping the pressure up to a value that is higher than maximum allowable operating pressure (MAOP) and holding the pressure for a period of four to eight hours.

ASME B 31.8 specifies the test pressure factors for pipelines operating at hoop stress of ≥ 30% of SMYS. This code also limits the maximum hoop stress permitted during tests for various class locations if the test medium is air or gas. There are different factors associated with different pipeline class and division locations. For example, the hydrotest pressure for a class 3 or 4 location is 1.4 times the MOP. The magnitude of test pressure for class 1 division 1 liquid pipeline transportation is usually limited to 125% of the design pressure, if the design pressure is known. The allowed stress in the pipe material is limited to 72% of SMYS. In some cases it is extended to 80% of SMYS. The position of Pipeline and Hazardous Material Safety Administration (PHMSA) is similar. If the fittings were the limiting factors of the test pressure, then the following situation would arise.

Test Pressure And Materials SMYS

Though codes and regulatory directives are specific about setting test pressure to below 72% or in some cases up to 80% of the SMYS of the material, there is a strong argument on testing a constructed pipeline to "above 100% of SMYS," and as high as 120% of SMYS is also mentioned. Such views are often driven by the desire to reduce the number of hydrotest sections, which translates in reduction in cost of construction. In this context, it is often noted that there is some confusion even among experienced engineers on the use of term SMYS and MOP/MAOP in reference to the hydrotest pressure.

It may be pointed out that the stress in material (test pressure) is limited by the SMYS. This is the law of physics, and is not to be broken for monetary gains at the peril of pipeline failure either immediate or in the future.

In this regard, section 32 of directive No. 66 of the Alberta Energy and Utilities Board in 2005 is of importance. The guidance is specific about the situation. It directs that if the test pressure causes hoop stress in the material exceeding 100% of the material SMYS, then the calculation and the entire hydro test procedure needs to be submitted to the board for review and approval.

STRESS RELIEVING AND STRENGTH

Often there is argument presented that higher test pressures exceeding 100% of the SMYS will increase the "strength" of the material and will "stress relieve" the material. Both arguments have no technical basis to the point they are made. We will briefly discuss both these arguments here:

1. Higher test pressure will "increase the strength." As the material is stressed beyond its yield point, the material is in plastic deformation stage, which is a ductile stage, and hence it is in the constant process of losing its ability to withstand any further stress. So, it is not increasing in strength but progressively losing its strength.

2. The second argument of "stress reliving" is linked with the "increase the strength" argument. The stress relief of material is carried out to reduce the locked-in stresses. The process reorients the grains disturbed often by cold working or welding. The stress relief process effectively reduces the yield strength. Thus, it does not "strengthen" the material. Note: It may be pointed out that a limited relaxation of stresses does occur by hydro testing, but the test pressure should be less than the material's yield point.

Another point to note here is that there is a stage in the stressing of the material where strain hardening occurs and the material certainly gains some (relative) hardness, and thereby, strength. This happens as necking begins but, at that point, unit area stress is so low that the strength of the material is lost and it remains of no practical use, especially in context with the pipe material we are discussing.

Returning to the subject of pressure testing and its objectives. One of the key objectives of the testing is to find the possible flaws in the constructed pipeline. The test develops a certain amount of stress for a given time to allow these possible flaws to open out as leakages. In the following section we shall discuss the relation of these flaws to the test pressure and duration.

CRITICAL FLAW SIZE

The maximum test pressure should be so designed that it provides a sufficient gap between itself and the operating pressure. In other worlds, the maximum test pressure should be > MOP.

This also presupposes that after the test the surviving flaws in the pipeline shall not grow when the line is placed in service at the maintained operating pressure. For setting the maximum test pressure, it is important to know the effect of pressure on defect growth during the testing on the one hand and on the other flaws whose growth will be affected by pressure over the time.

The defects that would not fail during a one-time, high test pressure are often referred as sub-critical defects. However these sub-critical defects would fail at lower pressure if held for longer time. But the size of discontinuity that would be in the sub-critical group would fail-independent of time-at about 105% of the "hold" pressure. This implies that maximum test pressure would have to be set at 5-10% above the maximum operating pressure (MOP) in order to find such defects during the test and also to avoid growth of sub-critical discontinuities after the hydro test pressure is released and during the operation life of pipeline. This is should be the main objective of the hydro test.

If test pressure reaching 100% (design factor of 0.80) of the SMYS is considered, then one must also consider some important pre conditions attached to the procurement of the steel and pipe. Especially important to consider is the level of flaw size that was accepted in the plate/coil used to manufacture the pipe. The test pressure of such magnitude would require that the acceptable defect size be re-assessed. This is because all else being equal, a higher design factor, resulting in a thinner wall, will lead to a reduction in the critical dimensions of both surface and through-wall defects.

Where such conditions are likely it may be prudent to reconsider the level of accepted flaws in the material. The current recommendations in API 5L 44th edition for acceptance level B2 as per ISO 12094 (for SAW pipes) may not be acceptable because it has limited coverage of body and edges and the acceptance criteria is far too liberal, in terms of acceptable size and area of flaws. More stringent criteria must be specified more in line with EN 10160 where level S2 for body and level E2 for edges may be more appropriate to meet the demands of the higher test pressures.

Sub-critical surface flaw sizes at design factors of 0.80 and 0.72 are susceptible to growth at low stress and are time dependent. These flaws are also dependent on the acceptable limits of impact absorbing energy of the material and weld (not part of the discussion in this article).

This increase in depth-to-thickness (d/t) ratio in effect reduces the ligament of the adjoining defects that reduce the required stress to propagate the discontinuity. Critical through-wall flaw lengths are also factors to be assessed. While there is a modest reduction in critical flaw length, it still indicates very acceptable flaw tolerance for any practical depth and the reduction will have negligible influence in the context of integrity management. Note that flaws deeper than about 70% of wall thickness will fail as stable leaks in both cases. This statement implies that mere radiography of the pipe welds (both field and mill welds) may not suffice. Automatic ultrasonic testing (AUT) of the welds will be better suited to properly determine the size of the planer defects in the welds. Similarly the use of AUT for assessing the flaws in the pipe body will be more stringent than usual.

PressureReversal

The phenomenon of pressure reversal occurs when a defect survives a higher hydrostatic test pressure but fails at a lower pressure in a subsequent repressurization. One of the several factors that work to bring on this phenomenon is the creep-like growth of sub-critical discontinuities over time and at lower pressure. The reduction in the wall thickness, caused by corrosion, external damages, is also responsible for a reduction in puncture resistance in the pipe. The reduction in the wall thickness, in effect reduces the discontinuity depth to the material thickness.

This increase in d/t ratio reduces the ligament between the adjoining defects. This effectively reduces the stress required to propagate the discontinuity.

The other factor affecting the pressure reversal is the damage to the Crack Tip Opening (CTO). The CTO is subject to some compressive force leading the crack tip to force-close during the initial test. On subsequent pressurization to significantly lower pressure this “force-close” tip starts to open-up and facilitates the growth of the crack. Hence, if such a pressure cycle is part of the design, then the point of pressure reversal should be considered.

Puncture Resistance

- It may also be noted that there is a modest reduction in puncture resistance with both increasing SMYS and increasing design factor. Note that the maximum design factor is, in some instances, constrained by practical limits on D/t.
- In any event, it should be noted that only a small proportion of large excavators are capable of generating a puncture force exceeding 300 kN and that the reductions in puncture resistance noted would have to be assessed for the integrated approaches to the management of mechanical damage threats.

4.2 HYDROTESTING PRESSURE CALCULATION

DESIGN PRESSURE

The concept and value of high-pressure hydrostatic testing of cross-country pipelines were first demonstrated by Texas Eastern Transmission Corporation. Texas Eastern sought the advice of Battelle in the early 1950s as they began to rehabilitate the War Emergency Pipelines and to convert them to natural gas service. Prior to testing, these pipelines exhibited numerous failures in service due to original manufacturing defects in the pipe. The Battelle staff recommended hydrostatic testing to eliminate as many of these types of defects as possible. After being tested to levels of 100 to 109% of SMYS, during which time “hundreds” of test breaks occurred, not one in-service failure caused by a manufacturing defect was observed. The news of this successful use of hydrostatic testing spread quickly to other pipeline operators, and by the late 1960s the ASA B31.8 Committee (forerunner of ASME B31.8) had established an enormous database of thousands of miles of pipelines that had exhibited no in-service ruptures from original manufacturing or construction defects after having been hydrostatically tested to levels at or above 90% of SMYS.[1] These data were used to establish the standard practice and ASA B31.8 Code requirement that, prior to service, each gas pipeline should be hydrostatically tested to 1.25 times its maximum allowable operating pressure. Later, a similar requirement for liquid pipelines was inserted into the ASME B31.4 Code. When federal regulations for pipelines came along, the precedent set by the industry of testing to 1.25 times the MOP was adopted as a legal requirement.

Both field experience and full-scale laboratory tests have revealed much about the benefits and limitations of hydrostatic testing. Among the things learned were the following:

- Longitudinally oriented defects in pipe materials have unique failure pressure levels that are predictable on the basis of the axial lengths and maximum depths of the defects and the geometry of the pipe and its material properties.
- The higher the test pressure, the smaller will be the defects, if any, that survive the test.
- With increasing pressure, defects in a typical line-pipe material begin to grow by ductile tearing prior to failure. If the defect is close enough to failure, the ductile tearing that occurs prior to failure will continue even if pressurization is stopped and the pressure is held constant. The damage created by this tearing when the defect is about ready to fail can be severe enough that if pressurization is stopped and the pressure is released, the defect may fail upon a second or subsequent pressurization at a pressure level below the level reached on the first pressurization. This phenomenon is referred to as a pressure reversal.
- Testing a pipeline to its actual yield strength can cause some pipe to expand plastically, but the number of pipes affected and the amount of

expansion will be small if a pressure to volume plot is made during testing and the test is terminated with an acceptably small offset volume or reduction in the pressure-volume slope.

Design Pressure for all the Sections in the pipeline project is kg/cm^2 basis i.e., 104.113 kg/cm

- 1.25 times design pressure

  $1.25 \times 104.113\ kg / cm^2 = 130.1413\ kg / cm^2$

Test Pressure for Mainline Hydro test is $130.1413\ kg / cm^2$

HOOP STRESS

Hoop stress = 2St / D

Were

S – Specified Minimum Yield Strength

t – Wall thickness in mm

D – Outside diameter of pipe in mm

For 6.4 mm thickness

Hoop stress = (2 x 52,000 x 6.4) / 273.10 = 2437.20 psi

We know $1\ kg / cm^2 = 14.223$ psi

= 2437.20 / 14.223

For 100 % = $171.36\ kg / cm^2$

For 95 % = $162.79\ kg / cm^2$

For 7.1 mm thickness

Hoop stress = (2 x 52,000 x 7.1) / 273.10 = 2703.77 psi

= 2703.77 / 14.223

For 100 % = $190.10\ kg / cm^2$

For 95 % = $180.59\ kg / cm^2$

4.3 HYDROTESTING CALCULATION

Section - 2:- From KM 224 M 79 to KM 188 FT 70

Pipe Grade: - API 5L PSL-2 Gr.X-52

Total no. of Mainline Joints	2527 joints.
Total no. of Tie-Ins & Free Tie-Ins Joints	443 joints.
Total no. of Pipes	2971 pipes.
Total 6.4 mm thickness section length	36061.04 m
Total 7.1 mm thickness section length	97.11 m
Total over all section length	36158.15 m
Test Header length: -	6.35 m
• Launcher:	3.23 m
• Receiver:	3.12 m
Total Length of Section (Including test headers)	36164.50 m

4.3.1 Geometric Volume of the Section

1. 6.4 mm thickness = 36061.04m

Volume = $\frac{\pi}{4}$ x D^2 x L

D – Inside diameter

L - Length

Outer Dia = 273.10 mm

Inner Dia = 260.30 mm

V = ((3.14 x 0.26030 x 0.26030) / 4) x 36061.04

V = 1918.03 KL

2.) 7.1 mm thickness = 97.11 m

Outer Dia = 273.10 mm

Inner Dia = 258.90 mm

V = ((3.14 x 0.25890 x 0.25890) / 4) x 97.11

V = 5.110 KL

3.) **Test Header**

7.1 mm thickness = 6.35 m

Outer Dia = 273.10 mm

Inner Dia = 258.90 mm

V = ((3.14 x 0.25890 x 0.25890) / 4) x 6.35

V = 0.334 KL

TOTAL VOLUME

6.4 mm	=	1918.03
7.1 mm	=	5.110
7.1 mm (Tester Header)	=	0.334
		1923.474

Total Volume of Section (Including test headers) = **1923.474 KL/m^3**

Corrosion Inhibitor dosage quantities:

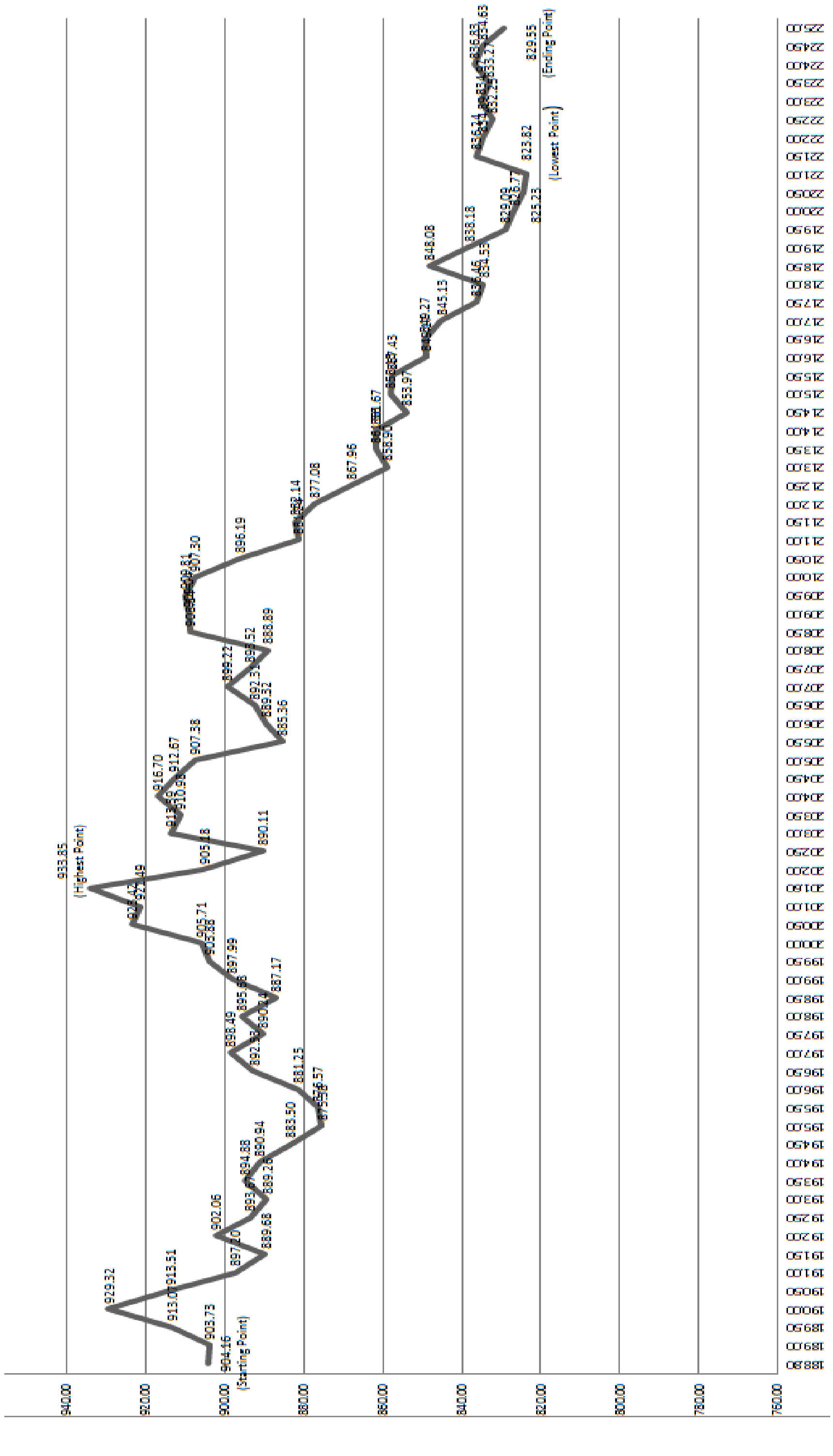
Inhibitor dosage of Indion – 175 as per vendor recommendation 300 ppm

(Dosage x Volume) x 10^{-6}

(450 x 1923.474) x 10^{-6} = 0.86556 KL i.e., 0.86556 x 1000 = 865.56 ltrs

4.4 PRESSURE CALCULATION AS PER ELEVATION CHART

ELEVATION CHART



Sl. No.	Particulars	Start point	End point	Highest point	Lowest point
1.	Chainage	224.991	188.822	201.670	221.000
2.	Elevation	829.55	904.16	933.85	823.82
3.	Pressure (Kg / sq.cm)	158.43	150.969	148.00	159.003

Table 4.4.1 Pressure Calculation as per Elevation Chart

95% of SMYS i.e. 95% of 171.36 = 162.79 kg/cm^2 (Maximum Pressure)

90% of SMYS i.e. 90% of 171.36 = 154.22 kg/cm^2 (Minimum Pressure)

Assume as: 148 kg/cm^2 (Considering a cushion of 4 kg/cm^2 for any change in pressure due to temperature variation)

Starting Point Pressure:

Highest Elevation - Starting Elevation /10 + 130.14

= 933.85 - 829.55/10 + 148

= 104.30/10 + 148

= **158.43 kg/cm^2**

End Point Pressure:

Highest Elevation - Ending Elevation /10 + 130.14

= 933.85 - 904.16/10 + 148

= **150.969 kg/cm^2**

Lowest Point Pressure:

Highest Elevation - Lowest Elevation /10 + 130.14

= 933.85 - 823.82/10 + 148

= **159.003 kg/cm^2**

4.5 METHODOLOGY

Hydrostatic test shall be performed on the entire length of the pipeline. A calculated / predetermined length of pipeline shall be selected for the hydro test based on elevation, availability of water and location of stations.

Hydrostatic test shall commence only after mechanical and civil works completion, i.e., all welds have been accepted and the pipeline has been laid and backfilled according to the specifications. Hydro test shall be performed in accordance with approved hydrostatic test diagram based on pipeline elevation profile and counter number of test section. Hydrostatic test shall include those sections which have been previously tested, viz. Rail/ road crossing, major water crossings including test on banks.

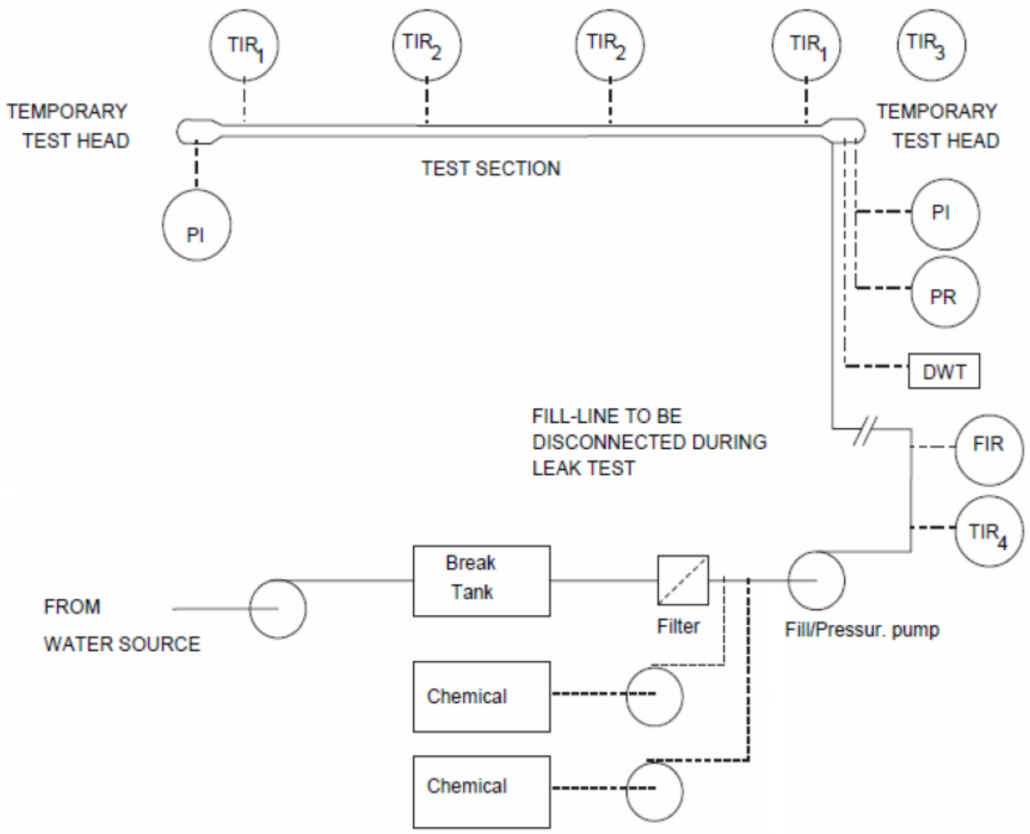
Hydro testing of mainline shall exclude valves at tap — off stations, terminals, pump stations, T-Connections and scrapper station facilities. Temporary test headers shall be provided and the mainline shall be hydrostatically tested between the temporary test headers only.

The equipment / Instruments to be used for performing the work shall include, but not limited to the following:

- Pigs for filling, cleaning and gauging: Cleaning pigs with spring loaded brushes and chisels.
- Four cup hatching pigs.
- Gauging pig with 10mm thick aluminium gauge plate diameter equal to 95% ID of heaviest wall pipe in the test section.
- Fill Pump with differential head 20% greater than the maximum required and a flow rate preferably around 400 MV hr (minimum), 1000 MV hr (maximum). Air Compressor for pigging.
- Positive displacement pump equipped with a stroke counter and capable of exceeding the maximum test pressure by at least 20 bar with pressure relief valve.

- Two Positive displacement meters to measure the volume of water used for filling the lirw having a valid calibration certificate not older than one month. Portable tank of sufficient size to provide continuous supply of water to the pump during pressurization.
- Bourdon pressure gauges of suitable pressure range and accuracy with valid calibration certificate with traceability certificate.
- Dead weight tester with an accuracy of 0.01 bar. Measuring in increments of 0.05 bar and with a valid calibration certificate (not older than one month) and master instrument certificate.
- 24 hours recording pressure 2nos gauges with pressure recording chart and ink gauge tested with dead weight tester prior to use. Accuracy shall be +/- OA% of the full scale value.
- Two Temperature recorder with accuracy of +/- 1% of the scale range Thermocouples with valid calibration certificate with accuracy ± 0.2° C.
- Two Laboratory thermometer 0°C to 60°C range and accuracy + 0.1° C. Measuring cylinder to check quantity of water during air volume calculation. Injection facilities to inject additives in the test medium in the required proportion inciude the injection manifold and block valves.
- Communication equipment suitable for continuous connection between the two ends.
- Temporary test headers fabricated in conformity with ASME section VIII, division 2 with particular reference to Appendix 4 and 5 having sufficient length to accommodate minimum three numbers of pigs. The header shall also have provision for pig stopper.
- Piping and valving arrangement for launching and receiving of pigs independently.
- Pressure let down valve to release pressure after completion of hydro test.

TEST HEAD ASSEMBLY



Legend:

PI = pressure gauge

PR = pressure recorder

DWT = dead weight tester

TIR_1 = pipeskin recording temperature

TIR_2 = soil or seabed recording temperature probes

TIR_3 = ambient air recording temperature

TIR_4 = Line-fill Water temperature recording probe during filling and pressurising

FIR = Volumetric measurement device during filling and pressurising
i.e. flowmeter or pump stroke counter

Fig 4.5.1 Schematic of Test head assembly

MEDIUM

Cleaning, filling and hydro testing shall be performed using soft non aggressive water, free from sand and silt withdrawn from a suitable source in the pipeline route. The water shall be tested in HPCL approved lab for its non-aggressiveness and suitability for using as the test medium. On the basis of water test report the required quantity of corrosion inhibitor etc. shall be added to the test medium with prior approval. The water shall be filtered through 50micron filters.

CORROSION INHIBITOR

The following products are acceptable for corrosion inhibition of the water used for hydro testing:

INDION 175 of M/s Ion Exchange India

Dosage for inhibitor shall be as follows:

- Up to 6 months 500 mg/l
- Above 6 months 750 mg/l

Samples approval are obtained for line fill treatment package for analysis of Sulphate concentration, Fatty Acids concentration and Ammonium concentration with limit not exceed as specified.

TEST PRESSURE

Unless specified otherwise in the Contract, the hydrostatic test pressure shall be at least 1.25 times of design pressure. In no case shall the pipeline be tested at a pressure which develops a hoop stress which is greater then 90% of SMYS.

The test pressure, as calculated above, shall be generated at the highest point in the section under test. The additional static head at any point the pipeline section shall not cause a hoop-stress in excess of 95% of the SMYS of the pipeline material at that point.

Cleaning & Gauging of the Pipeline Test Section

Prior to starting the cleaning operation, the safety checklist shall be filled up. The cleaning operations shall be performed by propelling air driven pigs provided with spring loaded brushes and chisels to remove all mill scale, rust / sand from the internal of the pipe sections. For these purpose temporary headers for air cleaning shall be welded to the test section. The number of pig runs shall depend on the cleaning results. To remove ferrous debris magnetic cleaning pig should be used.

After acceptance of the cleaning, a Gauging pig fitted with gauge plate made of 6 mm thick aluminum plate diameter equal to 95% ID of heaviest wall pipe in the test section shall be propelled between the temporary test heads. A column of clean water shall be pumped in front of the pig for lubrication and to flush out the remaining dirt inside the test section.

The gauge plate shall be taken out of receiving header immediately after taking out of header. Format shall be used for recording the results.

The results of the gauge pig run shall be analysed to evaluate the internal status of the pipeline. A deformed, bent or severally nicked plate or damaged pig shall be evidence of gauging pig run failure and the same shall not be acceptable. The parameters of cleaning & gauging operations shall be recorded every 30 minutes.

Test Section Filling

On acceptance of Gauging, the air pigging headers shall be cut and the temporary test heads already pretested at a pressure equal to the maximum test pressure of the test section shall be welded. The test header to test section weld joint shall be radiographed before starting water filling. Before start of test header welding the filling end test header shall be loaded with three numbers of four cup batching pigs.

The hydro test report of the temporary test headers shall be submitted to HPCL/MMPL prior to start of welding the test header to the test section.

Before the start of water filling ground temperature shall be taken by measuring the pipe temperature at the thermocouples and the same shall be recorded in format.

The filling operation shall begin with pumping of un inhibited water equal to 10% of the volume of test header in front of the first pig.

The first pig shall be launched by pumping about 1.5 km of unihibited water behind the pig. The water column before and after this pig shall act as a cushion to control the movement of the filling pig and hence minimise air entrapment.

The second pig shall be iaunched by pumping in the actual line filling inhibited **water** behind the pig.

The filling shall continue till the second pig reaches the other end of the test section and the pressure at the test end rises to the static head.

Required quantity of corrosion inhibitor shall be injected during the filling operation through any of the nozzles provided on the test header or into the break tank. The quantity of inhibitor shall be controlled by adjusting the flow rate of the dosing pump.

The dosing rate shall be as approved by HPCUMMPL.

During the whole filling operation the valves at the receiving end test headers shall be throttled suitably to maintain adequate backpressure and thus control the ply movement.

The first two columns of water shall be drained out from the receiving end.

The different parameters during filling operation shall be recorded once every thirty minutes.

During water filling temperature of water at pump delivery and the ambient temperature shall be recorded in the temperature recorders. Also pipe wall temperature shall be recorded during filling operation through thermocouples fixed along the pipeline every two hours.

4.6 THERMAL STABILISATION

Once the test section has been completely filled and a minimum pressure of 1 bar (g) has been achieved at the highest point, the thermal stabilization period is started.

Thermocouples for measuring the temperature of the pipe wall shall be installed on the pipeline to be tested :

- 1 thermocouple at about 500 m distance from the pumping head
- 1 thermocouple at every 2500 m of the pipe. The spacing may be increased to maximum 5000 m depending upon the terrain and nature of soil along the alignment of the test section.
- 1 thermocouple at about 500 m distance from the terminal head.

The probe for measuring pipe temperature shall be installed by cutting a small portion (a little bigger than the probe tip) of the coating from the pipe, polishing the exposed portion and fixing the probe to the pipe with quick setting epoxy ensuring firm contact between the probe and pipe. The soil probe shall be poked into the earth adjacent to the pipe.

The temperature reading shall be taken at two hours interval with a calibrated digital temperature read out unit up to 1 decimal place and thermal stabilization shall be considered to have been achieve when a difference not higher than 1°C is attained between the average values of the last two readings.

After completion and acceptance of hydro testing, thermocouples shall be removed and coating repaired as per approved coating repair procedure.

Table 4.6.1 Average Pipe Temperature

Time	Amb. Temp in °C	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	Avg. Pipe Temp in °C
11.00	28	35.5	33.2	34.1	34.3	34.6	33.9	33.6	33.2	33.9	33.5	34.03
1.00	30	35.2	31.8	33.8	33.6	33.8	32.6	32.8	33.0	33.5	32.9	33.3
3.00	35	24.5	24.5	24.0	25	25.3	25.4	25.3	25.7	25	25.3	24.9
5.00	31.3	24.5	24.5	24.1	24.8	25.2	25.2	25.3	25.7	24.9	25.3	24.9
7.00	31	24.4	24.5	24.1	25	25.1	25.2	25.1	25.7	25	25.3	24.9

Table 4.6.2 Average Soil Temperature

Time	Amb. Temp in °C	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Avg. Soil Temp in °C
11.00	28	23.8	23.6	23.8	24	25.2	25.5	24.3	24.8	24.5	25	24.4
1.00	30	24.8	25.5	24.8	24.4	25.2	24.8	23.4	24	23.5	25.0	24.6
3.00	35	23.4	24	23.5	25	25.3	25.4	25.6	25.7	25	25.3	24.8
5.00	31.3	23.4	23.2	23.3	24.5	24.8	25.5	24.8	24.4	24.4	25.2	24.3
7.00	31	23.3	24.0	23.2	23.5	24.3	24.9	24.8	24.8	24.2	25.1	24.2

4.7 PRESSURIZATION

- Mobilize high-pressure pump and test equipment at pressurization area. Install one pressure gauge in parallel with the dead weight tester.
- Fill up and sign pipeline pre-pressurization safety checklist.
- As soon as the temperature stabilization is achieved, the pressure shall be raised at a moderate and constant rate not exceeding 2-bar per minute.
- The pressurization shall be cycled with the sequence shown in the following pressure sequence.
- Pressurize to 50% of test pressure, hold pressure for one hour, perform air volume test and drop pressure to static head.
- Pressurize to 75% of test pressure, hold pressure for one hour, perform air volume test and drop pressure to static head.
- The parameters (Volume required) during pressurization shall be recorded throughout the cycle.
- Each 5 bar increments up to 80% of the test pressure as recorded by deadweight tester.
- Each 2 bar increments between 80% to 90% of the test pressure as recorded by deadweight tester.
- Each 0.5 bar increment between 90% to full test pressure as recorded by deadweight tester.
- Pressurize to test pressure, perform air volume test and raise pressure to the test pressure once again.
- In case, during the hold period indicated above, a decrease in pressure to the test pressure is observed, the above operation shall not be repeated more than twice, after which the line shall not be considered capable of test, until the cause for the lack of water tightness is eliminated and additional pig passage performed to remove air pockets.

- On acceptance of the air volume the pipeline pressure shall be raised to the test pressure and pressure stabilization period shall commence.

4.8 AIR VOLUME CALCULATION

In order to check the presence of air in the pipeline, two separate consecutive pressures lowering of 0.5bar shall be carried out after pressurizing to test pressure.

For calculation of air in the pipeline the second pressure lowering shall be used, and the relevant drained water shall be accurately measured (V_1). This amount measured shall be compared to the theoretical amount (Vp) corresponding to the pressure lowering that has been carried out, by using the procedure outlined in Clause 15.1 of this specification. If no air is present in the length under test:

$$V_1 / Vp = 1$$

In order that the above ratio is acceptable, it shall not differ by more than 6% (i.e.1.06). If the air found in the pipeline is within the above established tolerance, then the pressurizing can continue. If the ratio V_1 / V_p exceeds 1.06, the hydrostatic testing cannot go on and additional pig passages shall be performed to remove the air pockets.

The test shall be repeated as per the above procedure until above estimated tolerances are satisfied. The pressurizing can then continue, to reach the value of the test pressure.

WATER COMPRESSIBILITY FACTOR

V/S

PRESSURE AND TEMPERATURE

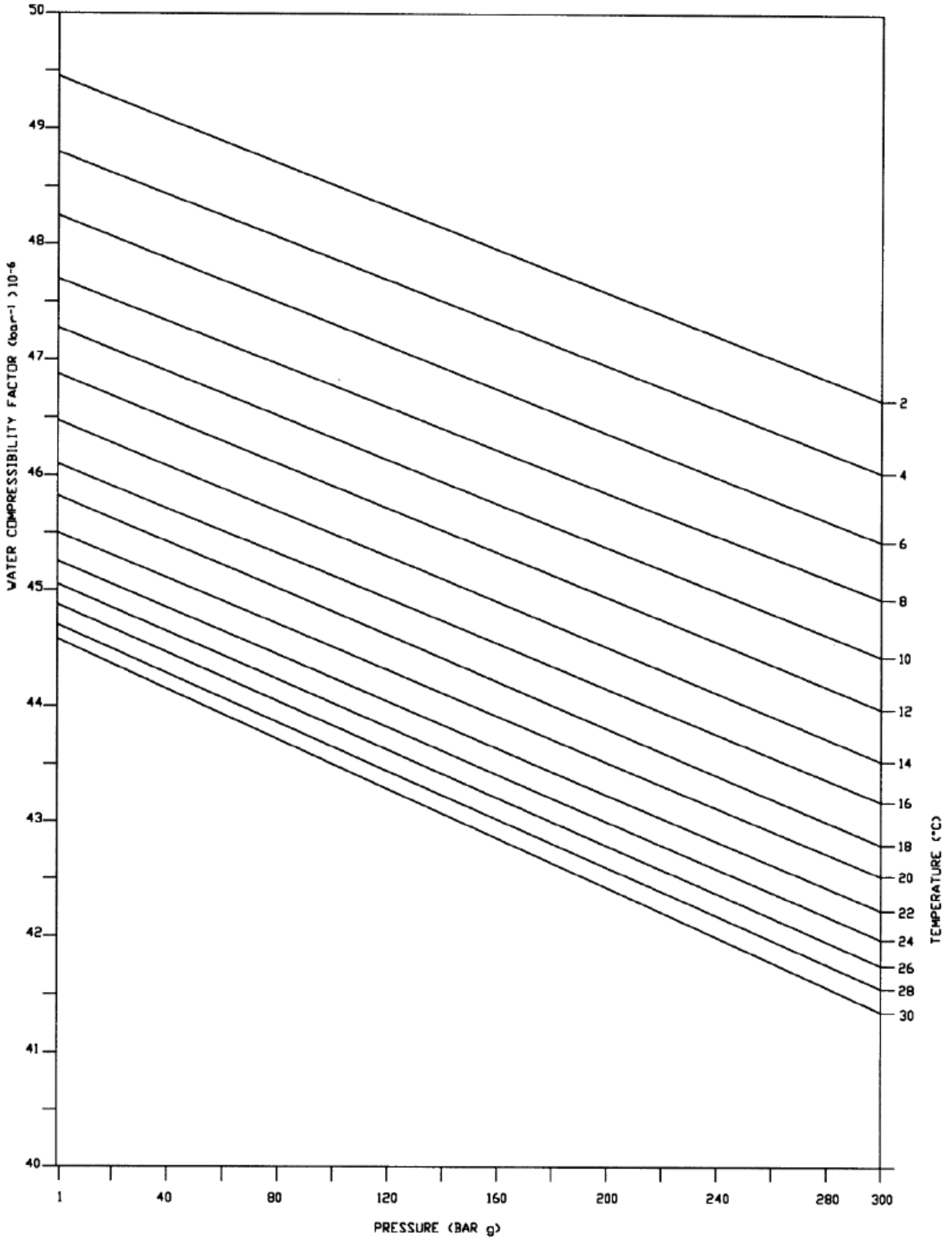


Fig 4.8.1 Water Compressibility factor V/s Pressure and Temperature

CALCULATIONS

The theoretical water amount that is necessary for filling the section to be tested shall be obtained from the geometrical volume of the section considering the pipe tolerances. The theoretical water amount that is necessary for pressurizing the section shall be calculated by means of the following formula:

$$\mathbf{V_P = ((0.884\ ri / t) + A) \times 10^{-6} \times V_t \times \Delta P \times K}$$

Where

V_P = Computed water amount required to raise by P the pressure in the section to be Tested (m^3)

V_t = geometrical volume of the section (m^3)

ΔP = pressure rise (bar)

ri = nominal inner radius of the pipe(mm)

t = nominal pipe thickness (mm)

A = isothermal compressibility value for water at the pressurization temperature in the P range (bar -1) x 10^6

(Refer water compressibility factor v/s pressure and temperature charts. For temperature above 30°C the value may be extrapolated)

K = a dimensionless coefficient that is equal to a value of 1.02 for longitudinally welded pipe.

For pressure at 50% the air volume calculation is

ri = 130.15

t = 6.4

A = 44.18

V_t = 1923.474

ΔP = 0.5

K = 1.02

On substituting the values on the above equation we get

$$Vp = 60.92$$

At 1st lowering

(Pressure 79.67 kg /sq.cm and Temperature 25.4°C)

Vi = 50 liters

$$Vi / Vp = 0.81 \leq 1.06$$

At 2nd lowering

(Pressure 79.17 kg /sq.cm and Temperature 25°C)

Vi = 55.8 liters

$$Vi / Vp = 0.9 \leq 1.06$$

	Dead Weight Tester (kg / sq.cm)	Pressure lowering (kg/sq.cm)	Volume of water drained (liters)
Initial	80		
1st lowering	79.67	0.5	50
2nd lowering	79.17	0.5	55.8

Hence Air Volume is accepted and released for depressurization.

For pressure at 75% the air volume calculation is

ri = 130.15

t = 6.4

A = 44.0

V_t = 1923.474

ΔP = 0.5

K = 1.02

On substituting the values on the above equation we get

$$Vp = 60.8$$

At 1st lowering

(Pressure 120 kg /sq.cm and Temperature 24.6°C)

Vi = 48 liters

$$Vi / Vp = 0.78 \leq 1.06$$

At 2nd lowering

(Pressure 119.5 kg /sq.cm and Temperature 24.6°C)

Vi = 51 liters

$$Vi / Vp = 0.83 \leq 1.06$$

	Dead Weight Tester (kg / sq.cm)	Pressure lowering (kg/sq.cm)	Volume of water drained (liters)
Initial	120.5		
1st lowering	120	0.5	48
2nd lowering	119.5	0.5	51

Hence Air Volume is accepted and released for depressurization.

4.9 HYDROSTATIC TESTING

After the section has been pressurized and the air volume test has given acceptable results the test pressure shall be held for a minimum of 24 hours after stabilization. After temperature and pressure has stabilized, the injection pump shall be disconnected and all connections at the test heads shall be checked for leakage. The pressure recorders shall then be started with the charts in a real time orientation for continuous recording throughout the test.

During the testing period the following measurements shall be recorded/ reported

a. Every one hour pressure measurements from dead weight testers.

b. Every two hour the ambient temperature and the pipe temperature at the thermo couples.

All data shall be recorded on appropriate forms attached to the hydrostatic test procedure manual. Care shall be taken that the maximum test pressures are not exceeded. Bleed-off water shall be accurately measured and recorded.

Table 4.9.1 24 Hour Hold Period

Time (Hrs)	**Dead Weight Tester in Kg / Sq.cm**	**Ambient Temp in °C**	**Average Pipe Temp°C**	**Average Soil Temp in °C**
8.15 am	160	19.2	24.9	24.41
9.15 am	160	20		

10.15 am	159.94	27.5	24.9	24.4
11.15 am	159.93	28		
12.15 pm	159.91	30.5	24.9	22.38
1.15 pm	159.90	29		
2.15 pm	159.90	32	24.9	24.38
3.15 pm	159.89	31.5		
4.15 pm	159.86	31	25.03	24.33
5.15 pm	159.85	30.5		
6.15 pm	159.85	27	25	24.34
7.15 pm	159.83	21		
8.15 pm	159.79	19	25	24.64
9.15 pm	159.76	18		
10.15 pm	159.76	17.6	24.8	24.17
11.15 pm	159.72	17		
12.15 am	159.70	17.5	24.7	24.33
1.15 am	159.71	18		
2.15 am	159.69	17	24.7	24.35
3.15 am	159.67	15.5		
4.15 am	159.66	15	24.7	24.15
5.15 am	159.66	15		
6.15 am	159.66	13.5	24.8	24.37
7.15 am	159.66	15.5		
8.15 am	159.63	21	24.7	24.28

Calculation of Pressure change due to water temperature

Difference between the water thermal expansion and the steel thermal expansion factor (°C $^{-1}$) 10 $^{-6}$

°C bar	1	2	3	4	5	6	7	8
.981	-98.62	-79.89	-61.81	-44.34	-27.47	-11.14	+4.66	+19.98
10	-95.55	-76.94	-58.99	-41.65	-24.89	-8.67	+7.02	+22.23
20	-92.15	-73.68	-55.86	-38.64	-22.01	-5.92	+9.65	+24.74
30	-88.74	-70.40	-52.72	-35.63	-19.14	-3.16	+12.29	+27.26
40	-85.32	-67.12	-49.58	-32.62	-16.24	-0.41	+14.93	+29.78
50	-81.90	-63.84	-46.43	-29.60	-13.36	+2.36	+17.57	+32.31
60	-78.47	-60.55	-43.27	-26.58	-10.46	+5.15	+20.23	+34.85
70	-75.03	-57.25	-40.10	-23.54	-7.56	+7.92	+22.89	+37.39
80	-71.60	-53.96	-36.94	-20.51	-4.65	+10.70	+25.55	+39.94
90	-68.16	-50.66	-33.77	-17.47	-1.73	+13.50	+28.23	+42.50
100	-64.72	-47.35	-30.60	-14.43	+1.18	+16.29	+30.90	+45.05
110	-61.28	-44.05	-27.43	-11.38	+4.10	+19.08	+33.58	+47.61
120	-57.84	-40.74	-24.26	-8.34	+7.02	+21.88	+36.26	+50.18
130	-54.40	-37.44	-21.08	-5.29	+9.95	+24.68	+38.94	+52.75
140	-50.96	-34.13	-17.90	-2.25	+12.87	+27.49	+41.63	+55.32
150	-47.53	-30.83	-14.73	+0.80	+15.79	+30.29	+44.31	+57.89
160	-44.10	-27.53	-11.56	+3.85	+18.72	+33.10	+47.00	+60.46
170	-40.67	-24.23	-8.40	+6.89	+21.64	+35.90	+49.69	+63.04
180	-37.24	-20.94	-5.23	+9.94	+24.56	+38.70	+52.37	+65.62
190	-33.83	-17.65	-2.06	+12.98	+27.48	+41.51	+55.06	+68.19
200	-30.42	-14.37	+1.09	+16.01	+30.40	+44.30	+57.75	+70.77
210	-27.02	-11.09	+4.25	+19.04	+33.31	+47.10	+60.43	+73.34
220	-23.63	-7.82	+7.40	+22.06	+36.22	+49.90	+63.12	+75.90
230	-20.24	-4.56	+10.54	+25.08	+39.13	+52.69	+65.80	+78.48
240	-16.87	-1.30	+13.67	+28.10	+42.03	+55.48	+68.48	+81.05
250	-13.50	+1.94	+16.79	+31.11	+44.92	+58.26	+71.15	+83.61
260	-10.14	+5.17	+19.90	+34.12	+47.81	+61.04	+73.81	+86.81
270	-6.80	+8.39	+23.00	+37.11	+50.69	+63.80	+76.48	+88.73
280	-3.48	+11.60	+26.11	+40.09	+53.56	+66.57	+79.14	+91.29
290	-0.17	+14.80	+29.19	+43.07	+56.43	+69.33	+81.78	+93.83
300	+3.13	+17.98	+32.27	+46.03	+59.29	+72.08	+84.83	+96.38

°C bar	9	10	11	12	13	14	15
.981	+34.82	+49.22	+63.20	+76.78	+89.99	+102.83	+115.34
10	+36.97	+51.26	+65.15	+78.64	+91.75	+104.51	+116.93
20	+39.36	+53.55	+67.33	+80.71	+93.72	+106.39	+118.71
30	+41.76	+55.84	+69.51	+82.79	+95.70	+108.26	+120.49
40	+44.18	+58.14	+71.70	+84.87	+97.68	+110.14	+122.28
50	+46.60	+60.45	+73.90	+86.96	+99.68	+112.04	+124.07
60	+49.02	+62.76	+76.10	+89.07	+102.67	+113.93	+125.88
70	+51.44	+65.08	+78.32	+91.17	+103.68	+115.84	+127.69
80	+53.88	+67.40	+80.53	+93.29	+105.69	+117.76	+129.50
90	+56.32	+69.73	+82.75	+95.41	+107.70	+119.67	+131.32
100	+58.77	+72.07	+84.98	+97.53	+109.73	+121.59	+133.15
110	+61.21	+74.41	+87.22	+99.66	+111.75	+123.52	+134.98
120	+63.67	+76.74	+89.45	+101.79	+113.79	+125.46	+136.82
130	+66.12	+79.09	+91.69	+103.93	+115.83	+127.39	+138.67
140	+68.58	+81.45	+93.93	+106.07	+117.87	+129.34	+140.51
150	+71.05	+83.80	+96.18	+108.21	+119.90	+131.20	+142.37
160	+73.51	+86.15	+18.43	+110.36	+121.96	+133.74	+144.22
170	+75.97	+88.51	+100.68	+112.51	+124.01	+135.19	+146.08
180	+78.44	+90.87	+102.94	+114.66	+126.06	+137.15	+147.94
190	+80.91	+93.23	+105.19	+116.82	+128.12	+139.11	+149.81
200	+83.37	+95.59	+107.45	+118.97	+130.17	+141.07	+151.68
210	+85.84	+97.95	+109.71	+121.13	+132.24	+143.03	+153.55
220	+88.30	+100.31	+111.97	+123.29	+134.29	+144.99	+155.42
230	+90.67	+102.67	+114.23	+125.45	+136.36	+146.96	+157.30
240	+93.22	+105.03	+116.48	+127.60	+138.42	+148.93	+159.18
250	+95.69	+107.39	+118.74	+129.76	+140.48	+150.90	+161.05
260	+98.14	+109.74	+121.00	+131.92	+142.54	+152.87	+162.93
270	+100.60	+112.10	+123.25	+134.08	+144.61	+154.84	+164.81
280	+103.05	+114.44	+125.50	+136.24	+146.67	+156.84	+166.69
290	+105.50	+116.79	+127.75	+138.39	+148.73	+158.78	+168.57
300	+107.94	+119.13	+130.00	+140.54	+150.79	+160.75	+170.45

°C bar	16	17	18	19	20	21	22	23
.981	+127.52	+139.41	+151.00	+162.31	+173.37	+184.18	+194.75	+205.08
10	+129.02	+140.83	+152.36	+163.58	+174.56	+185.30	+195.79	+206.07
20	+130.71	+142.42	+153.85	+165.00	+175.90	+186.55	+196.96	+207.16
30	+132.40	+144.02	+155.35	+166.42	+177.23	+187.80	+198.14	+208.26
40	+134.10	+145.62	+156.87	+167.85	+178.58	+189.07	+199.33	+209.37
50	+135.80	+147.24	+158.39	+169.29	+179.93	+190.34	+200.52	+210.49
60	+137.51	+148.86	+159.92	+170.73	+181.29	+191.62	+201.72	+211.61
70	+139.22	+150.49	+161.46	+172.18	+182.66	+192.91	+202.93	+212.74
80	+140.95	+152.11	+163.00	+173.64	+184.03	+194.20	+204.14	+213.88
90	+142.67	+153.75	+164.56	+175.10	+185.41	+195.50	+205.36	+215.03
100	+144.42	+155.40	+166.11	+176.58	+186.80	+196.80	+206.59	+216.17
110	+146.15	+157.04	+167.66	+178.05	+188.20	+198.12	+207.82	+217.33
120	+147.90	+158.70	+169.24	+179.54	+189.59	+199.44	+209.06	+218.49
130	+149.65	+160.36	+170.81	+181.02	+191.00	+200.75	+210.31	+219.66
140	+151.40	+162.03	+172.39	+182.51	+192.41	+202.09	+211.56	+220.84
150	+153.16	+163.70	+173.98	+184.00	+193.82	+203.42	+212.81	+222.02
160	+154.93	+165.37	+175.56	+185.51	+195.24	+204.76	+214.08	+223.20
170	+156.69	+167.05	+177.15	+187.02	+196.66	+206.10	+215.34	+224.39
180	+158.47	+168.73	+178.75	+188.53	+198.09	+207.45	+216.61	+225.58
190	+160.24	+170.42	+180.35	+190.05	+199.52	+208.80	+217.89	+226.79
200	+162.01	+172.10	+181.95	+191.57	+200.97	+210.16	+219.17	+227.99
210	+163.80	+173.80	+183.55	+193.09	+202.40	+211.53	+220.46	+229.20
220	+165.58	+175.49	+185.16	+194.62	+203.85	+212.89	+221.74	+230.41
230	+167.36	+177.19	+186.78	+196.14	+205.30	+214.26	+223.04	+231.63
240	+169.16	+178.89	+188.39	+197.68	+206.75	+215.63	+224.33	+232.85
250	+170.94	+180.59	+190.01	+199.21	+208.20	+217.00	+225.63	+234.08
260	+172.73	+182.30	+191.63	+200.75	+209.66	+218.40	+226.93	+235.31
270	+174.53	+184.00	+193.25	+202.29	+211.12	+219.77	+228.24	+236.54
280	+176.32	+185.70	+194.88	+203.83	+212.59	+221.16	+229.55	+237.77
290	+178.11	+187.42	+196.50	+205.37	+214.05	+222.54	+230.86	+239.01
300	+179.90	+189.13	+198.13	+206.92	+215.51	+223.93	+232.18	+240.26

°C bar	24	25	26	27	28	29	30
.981	+215.22	+215.14	+234.88	+244.41	+253.79	+263.00	+272.03
10	+216.13	+225.99	+235.66	+245.13	+254.44	+264.59	+272.57
20	+217.15	+226.94	+236.53	+245.94	+255.18	+264.27	+273.18
30	+218.18	+227.88	+237.41	+246.75	+255.93	+264.95	+273.80
40	+219.21	+228.85	+238.30	+247.58	+256.69	+265.64	+274.42
50	+220.25	+229.82	+239.20	+248.40	+257.45	+266.33	+275.07
60	+221.30	+230.79	+240.11	+249.24	+258.22	+267.04	+275.70
70	+222.35	+231.78	+241.02	+250.08	+258.99	+267.75	+276.35
80	+223.42	+232.77	+241.94	+250.93	+259.78	+268.47	+277.01
90	+224.48	+233.76	+242.87	+251.79	+260.57	+269.19	+277.66
100	+225.56	+234.76	+243.79	+252.66	+261.36	+269.92	+278.33
110	+226.64	+235.78	+244.73	+253.53	+262.17	+270.77	+279.01
120	+227.73	+236.79	+245.68	+254.40	+262.98	+271.41	+279.69
130	+228.82	+237.81	+246.63	+255.28	+263.69	+272.16	+280.38
140	+229.92	+238.84	+247.59	+256.18	+264.62	+272.92	+281.08
150	+231.03	+239.87	+248.55	+257.07	+265.44	+273.69	+281.78
160	+232.14	+240.91	+249.52	+257.97	+266.28	+274.46	+282.49
170	+233.26	+241.96	+250.49	+258.88	+267.12	+275.23	+283.20
180	+234.38	+243.01	+251.47	+259.79	+267.97	+276.01	+283.92
190	+235.51	+244.06	+252.46	+260.71	+268.82	+276.80	+284.64
200	+236.64	+245.12	+253.45	+261.63	+269.67	+277.59	+285.37
210	+237.77	+246.18	+254.45	+262.50	+270.54	+278.39	+286.11
220	+238.91	+247.26	+255.45	+263.49	+271.40	+279.19	+286.85
230	+240.06	+248.33	+256.46	+264.43	+272.28	+280.00	+287.59
240	+241.21	+249.41	+257.46	+265.37	+273.16	+280.82	+288.35
250	+242.36	+250.49	+258.48	+266.31	+274.04	+281.63	+289.11
260	+243.52	+251.58	+259.49	+267.27	+274.92	+282.46	+289.86
270	+244.68	+252.66	+260.52	+268.23	+275.82	+283.29	+290.64
280	+245.84	+253.76	+261.54	+269.18	+276.71	+284.12	+291.40
290	+247.01	+254.86	+262.57	+270.15	+277.61	+284.95	+292.18
300	+248.18	+255.96	+263.60	+271.11	+278.51	+285.79	+292.95

The **pressure change** due to a water temperature change shall be calculated through the following formula:

$$\Delta P = [\ B\ /\ (\ 0.884\ (ri\ /\ t)) + A\ )\ ]\ x\ \Delta T$$

Where

ΔP = pressure change resulting from a temperature change (bar)

ΔT = algebraic difference between water temperature at the beginning of the test and Water temperature as measured at the end of the test (°C)

B = value of difference between the thermal expansion of water at the Pressure and Temperature as measured at the end of the test and that of steel (°C) x 10^6

A = Isothermal compressibility value for water as estimated at pressure and

temperature value obtained at the end of test (bar $^{-1}$) x 10^6

ri = Nominal inner radius of the pipe (mm)

(in case of the test section having multiple wall thickness, “ri” shall Correspond

to the wall thickness, having the maximum total length in the given test section)

t = nominal pipe thickness (mm)

Description	Pressure in Kg / Sq.cm	Pipeline Temperature in °C
Start of test	160	24.9
End of test	159.63	24.7

Value of B at pressure 159.63 kg / sq.cm and temperature 24.7 °C

B = 239.81

A = 43.5

Δt = 0.2

ri/t = 20.35

On substituting this values on the above equation we get

ΔP = 0.780

ACCEPTANCE CRITERIA

The hydrostatic test shall be considered as positive if pressure has kept a constant value throughout the test duration, except for change due to temperature effects.

The pressure change value as a function of temperature change shall be algebraically added to the pressure value as read on the meters. The pressure value thus adjusted shall be compared with the initial value and the test shall be considered as acceptable if difference is less than or equal to 0.3 bar.

On successful completion and acceptance of the hydrotest, the pipeline shall be slowly depressurized at a moderate and constant rate.

EVALUATION OF HYDROTEST

$$\mathbf{P = (P_1 - (P_2 + \Delta P))}$$

Where

P_1 = Initial Pressure and P_2 = Final Pressure

P = (160.0 – (159.63 + 0.780)) = -0.41

Hence the Hydrotest is acceptable.

LEAKS

If during the pressurization period or during the test periods any defects is observed these shall be investigated.

If any leaks are observed the section shall be initially visually inspected to check the eventual leaking point. No work shall be carried out to repair leaks until the pressure has been reduced to a sage pressure (i.e. static head plus 1 Kg.) and the water drained as per approved de-watering procedure.

IDLE TIME PRESERVATION

Upon successful completion of hydrotest the pipeline system shall be depressurized & preserved by allowing the inhibited water to remain by allowing the inhibited water to remain inside the pipeline till it is dewatered and subsequent handing over the entire pipeline.

4.10 LEAK DETECTION

To locate buried leaking pipe, the following procedure by elimination shall be followed:

- To cut the section in an intermediate position
- To insert two test heads
- To reflood the sections
- To pressure the two sections
- To determine the faulty section.

This procedure shall be applied until the determination of the defect. As soon as the defect has been located and repaired, the test section shall be tested again.

All leaks and failure within the pipewall or weld seams shall be repaired by replacement of entire joints in which leakage or failure occurs. The repair shall be done as per the approved procedure. After completion of repairs, the hydrostatic test shall be repeated. All cracks and splits resulting from failure shall be coated with an application of grease to preserve the characteristics of failure from corrosion. Joint of failed pipes shall be marked with paint, with a tag indicating failure details, date and location of failure and pressure at which failure occurred.

LEAK LOCATING METHODS

Method	Suitable for Onshore Pipelines	Necessary to replace Line-fill Water	Special Equipment and/or personnel	Comment
Visual inspection	Yes	No	No	Primarily for aboveground test section
Visual inspection using fluorescent or colour dye	No	No	Yes	Useful for detecting leaks of flanges
Sectioning by cut and cap	Yes	Partially (NOTE 1)	No	Additional method still required to locate leak in suspected section
Sectioning by ice plug	Yes	No	Yes	Additional method still required to locate leak in suspected section
Sectioning by special scraper	Yes	Yes	Yes	Requires pumps at both ends (NOTE 2)
Leak location by differential pressure detection scraper	Yes	Yes	Yes	Requires pumps and instruments at both ends
Leak location by flow detection scraper	Yes	Yes	Yes	Requires pumps at both ends
Leak location by ultrasonic scraper	Yes	Yes	Yes	Scraper velocity < 0.5 m/s at test pressure
Acoustic probes with cross-correlation	Yes	No	Yes	Probes at 100 m intervals
Gas detection	Yes	Yes	Yes	Helium is more sensitive than other gases

4.11 PIPELINE BULK DEWATERING

Upon successful completion of the hydrotest and if required, the section shall be dewatered by propelling the third pig in the test header. Necessary arrangement shall be made for safe disposal of hydrotest water by making suitable drains. Before releasing the water for draining the section, neutralize the test water and procedure for treatment of inhibited water to prevent pollution prior to start of dewatering.

Upon completion of the testing and dewatering operation, any provisional traps for pigs and all other temporary installation relating to the test shall be removed. Subsequently the individual sections of the line already tested shall be jointed in accordance with the requirements of relevant specifications issued for the purpose.

Once dewatering is over, the sectionalizing valve and other valve assemblies shall be installed at the respective locations in accordance with the relevant procedures and specifications. All thermocouples installed in the pipeline shall be removed and damaged corrosion coating shall be repaired using approved procedure and materials and holiday checked.

CHAPTER 5

HORIZONTAL DIECTIONAL DRILLING

Horizontal directional drilling (HDD) also known as Directional Drilling is a method of trenchless technologies used in the installation of oil and gas pipelines as well as other utilities under watercourses, roads, rail lines, steep slopes and other obstacles.

Scope of work

Hinsuatan petroleum Corporation limited (HPCL) proposes to lay underground LPG pipeline with Horizontal Directional Drilling of about 367.24 meters across the Hemavathi river.

Machine Specification- ZT 35 Direction Drilling Rig

Max thrust Force	:	350kN	Max Spindle torque	:	14kNm
Max Pullback force	:	350kN	Entry drill Angle	:	12-20º
Diesel Engine Power	:	160 kW	Spindle speed	:	0-130 r/min

5.1 HDD Methodology

Survey

At first soil investigation and the obstacle to be crossed should be surveyed properly before the work start. The profile and cross section is recorded and also entire line crossing properly marked.

Design

For each crossing, the required pipeline configuration is determined in order to allow smooth pull in the crossing entry point and admissible stress in the supported pipeline string. Pipeline combined stress should not exceed 90% of the SMYS for line pipe material of minimum thickness used to make string.

All calculations and the number of required supports must be specified. Description of the supports, their co-ordinates and capacity in metric tons are furnished. Based on results of design and engineering the construction drawing for the river crossing is made. Construction drawing indicates the pipeline profile with levels furnished at sufficient intervals for proper control during construction. Other relevant details i.e. entry and exit angles radius of bends, etc. shall also be indicated. The total length of pipeline required as well as the maximum tension required on the pull head of the rig is calculated.

Minimum cover for pipe

The following minimum requirements of cover to the pipe should be maintained.

For road crossing : 1.4m from top of road to top of pipe

For railroad crossing : 1.7m from base of rail to top of pipe.

For Canal/Stream crossing : 1.5m from lowest bed level to top of pipe.

Other utilities like other pipelines, sewer, drain pipes, water mains, telephone conduits and other underground structures, the pipeline should be constructed with at least 500m free clearance from the obstacle.

Preparation of site

1. Preparation of hard standing area as to give suitable safe working conditions for all operations and personnel.
2. Providing a security fenced enclosure for the rig side drilling area.
3. Construction of Drilling Fluid Lagoons, bonded as required with pedestrian fenced perimeter.
4. Preparation of a similar enclosure for pipe side operations, including one mud pit.

Preparation of Pipe string

Complete pipe string should be prepared as a single string for pulling after radiographic inspection and coating of the joint.

Pre-Hydro testing of sections

5. All weld joint should be exposed and cleaned properly from rust and other foreign materials. The "Testing Header" shall be welded at the either side of the section.

6. Calibrated pressure gauges, one at pressurization point and one the highest point shall be installed during testing. Pressure gauge range should be 1.5 times of test pressure.

7. Before filling water in the pipe section, all NDT pipe log book (except joint coating) must be completed.

8. For testing of pipe section clean construction water is used. During filling of water proper venting should be done at the highest point to remove all the entrapped air.

9. Pipeline section shall be gradually pressurized to the test pressure and intermediate check shall be done for any possible leakages.

10. Test pressure should be retained in the section for 24 hours during which the section should be visually examined for leakage and defects etc. The pre-hydrostatic test shall be considered acceptable if no visible leak is observed during the hold period.

11. After acceptance of test the section is depressurized and water is removed completely from the pipeline section.

12. All weld joint must be coated with heat shrinkable sleeve after the pipe string is hydrostatic leak tested and accepted.

Dewatering & Gauging

Hydro test water is removed from the pipeline section followed by gauging operation using gauge plate of 95% of the nominal internal diameter of the pipe.

HDD Operations

An HDD operation normally falls into five major sections as:

13. Mobilization and rig setup
14. Pilot hole drilling
15. Pre-reaming stages
16. Pull back operation
17. Rig down and transfer to adjacent drilling site.

Mobilization and rig setup

The drilling equipment will be transported to the site by road. Since the rig itself has to be re-positioned 2 times at crossing, it is planned to have the auxiliary equipment positioned in such a way that there is no obstruction during the rig move. The drilling rig is setup on centerline and inclination is adjusted to give the ground entry angle in accordance with crossing design. The mixing and pumping installation are setup close to the bentonite storage area. The recycling unit is positioned near the water source. Hoses and cables in between will be installed either at perimeter of the work site.

Pilot hole Drilling: Walk over System

A pilot hole of 6” & 8” diameter is drilled using standard drilling techniques. Drilling Fluid is pumped through the center of the drill pipe through the jet bit to cut sandy and clay formation. Pilot hole progress is monitored in real time using the walkover system.

The walkover system consists of three main components

18. Transmitter
19. Receiver (The walkover unit)
20. Remote (Drillers remote)

Transmitter

There are different types of transmitter depending on the drilling needs; it can track up to 30 meters depth. The transmitters are placed inside the Drill head assembly ahead of the lead piece or the first drill pipe with a bent sub. These work on remote signal principal which is picked up by Tracker carrying the Received over the drill head position.

Receiver

This is the walkover unit that picks up the signals from the drill head, boring under the road or canal. The man holding the Receiver is called the trekker, thus tracking the movement of the drill pipe in real time and marking on the ground. The signal get continuously picked every two seconds, indicating the depth, the pitch (angle of drill head) and the roll (direction it is headed).

Remote

Driller's remote stays on with the driller, which helps him in guiding the drill path. Remote gives the same information to the driller, as it does to the tracker. Driller's remote is however a passive unit unlike the Receiver, which actually locates the drill head under the earth.

The positioning is monitored by Electronic Probe positioned behind the drill bit in a steel housing. A signal is transmitted up the drill string by a ultrasonic waves line to readout unit inside the control cabin and to the walkover operator. Data collected from the down hole instruments provide the inclination of the drill bit and rotational position of the drill. The data combined with accurate record keeping on length of drill pipe inserted in the holes allows simple mathematical computations to be made to record the progress and position of the pilot drill

The pre-determined technical profile should be closely adhered to when drilling the pilot hole. The permitted deviation must not exceed 2 meters laterally and +-1degree vertically from the approved theoretical profile.

Steering

The jetting assembly has a bent housing in general a 1.5º setting. This is in order to give the drill a bias in on direction. By sliding the drill without rotating the down hole-cutting tool, drilling direction can be changed. A combination of sliding and rotation will not change drilling direction. In this way the direction of drilling can be controlled.

Pilot hole completion

The 6” & 8” drill bit exit on the opposite bank, (pipe side) in a pre-trenched excavation. The pre-trenching is carried out in order to collect the drilling mud. At this stage, the drilling Bottom Hole Assembly and the survey tools are disconnected. After re-positioning of the rig, the pilot hole for the 6” line will be drilled using the same procedure

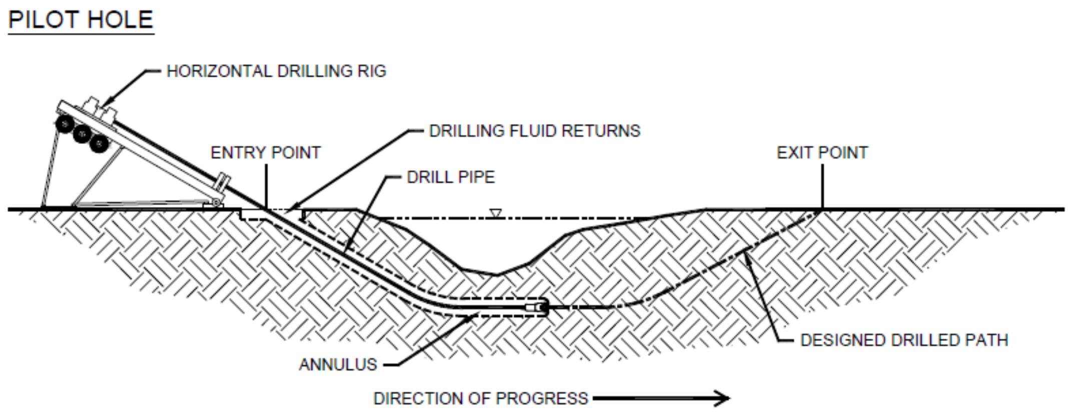


Fig 5.1.1 Pilot hole drilling

Reaming operation

After completion and acceptance of the drilled pilot hole, the pilot hole will have to be enlarged in order to install the product pipe. At the pipe side a reaming tool (fly cutter or barrel Reamer for soft soil) will be connected to the drill string. The hole is back-reamed by rotating and pulling back the drill string towards the rig and adding drill pipe behind the reaming tool so that there is always pipe in the hole.

After completion of each pass, the reaming assembly is disconnected at the rig side whilst at the pipe side a new larger reamer or barrel reamer is connected. During reaming the drilling fluid is coming back to the pipe side and collected into a mud pit. After decantation, the fluid is transferred back to the rig side for re-use. The benefit of the operation is to reduce the overall quantity of bentonite for the project and to save disposal of the bentonite at pipe side since the recycling system is at the Rig side.

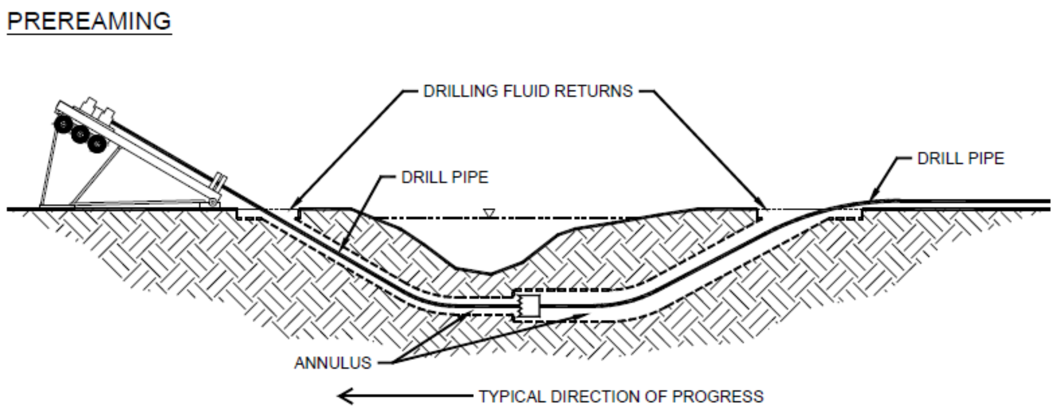


Fig 5.1.2 Prereaming process

Cleaning Pass

To ensure the good condition of the pre-reamed hole, an additional cleaning run will be conducted before starting the pullback operation. After the final cut of 32” with the barrel reamer, the barrel reamer is pulled through the hole from pipe side to rig side to ensure that the hole is open.

Pullback Operation

The pullback of the pre-fabricated pipeline string into the completely expanded drilled hole is the final stage of carrying out horizontal directional drilling. To pull the pipeline, the hole opener or reamer is rotated and pulled back under drilling fluid circulation towards the drilling rig. Due to the connection with the pipeline via swivel and universal joints the pull force is thereby transmitted to the pipeline, but not the torque. The pipeline follows the whole opener or reamer through the drilled hole up the entry pit in front of the drilling rig without rotation. In order to accelerate the pullback process, a slightly smaller diameter hole opener or reamer may be used during the last expansion stage. 32” Diameter Reamer is planned to be used for pull back in front of the swivel.

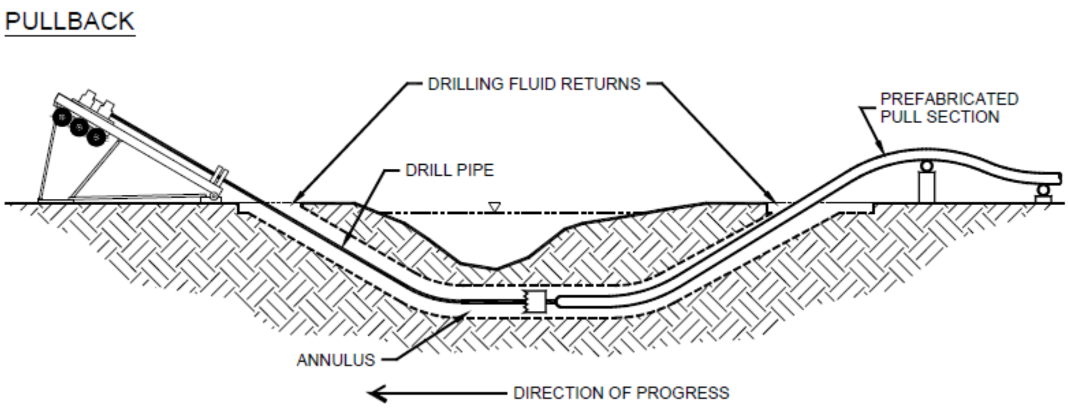


Fig 5.1.3 Pipeline pullback

Final Hydrostatic Test

The complete crossing section is tested after installation. The test pressure should be stipulated in the procedure. After temperature stabilization, Pressure can be retained in the pipeline for a period of 6 hours.

Rig down and Transfer

After the pullback operation the pullback assembly is disconnected from the rig and from the pipeline. The rig down and cleanup of the drilling equipment start on the working platform. At this Stage it is estimated that all equipment can be transferred from site to site within 72 hours after Pullback operation.

5.2 DESIGN OF HDD

<u>Input values and Parameters for installation of 10” carrier pipe</u>

Pipe Dia	D	27.30	cm
Wall Thickness	t	0.71	cm
Internal Dia	ID	25.88	cm
Pipe Grade - API - 5L - *Gr* X		52	Grade
Specified Min. Yield Strength	S	3,659.39	kg/cm^2
Cross Sectional Area	As	59.31	cm^2

Moment of Inertia	I	5,245.45	cm^4
Polar Moment of Inertia	Z	384.28	cm^3
Weight of empty Pipe in air	Wp	0.47	kg/cm
Weight of Water Filled Pipe in air	Ww	0.99	kg/cm
Modulus of Elasticity	E	2039000	kg/cm^2
Soil Friction Angle		30	Degrees
Pre Hydrotest Pressure	Prh	132.5	kg/cm^2
Post Hydrotest Pressure	Poh	132.5	kg/cm^2
Design Pr. Of Pipeline	Pop	106	kg/cm^2
Length of Crossing	L	26739	cm
Entry Angle		12	Degrees
Exit Angle		10	Degrees
Poisson's ratio	m	0.3	
Fluid drag coeff (betn slurry and pipe)	f	0.001759	kg/cm^2
Coeff of friction between pipe and soil	f	0.3	
Buoyant weight of pipe	w	0.2070	kg/cm
Density of mud used	Do	0.00115	kg/cm^3
Max depth of crossing from Rig Level	h	1415	cm
Column height from water level to top of pipe	Hw	700	cm
Column height from Bed to Pipe	Hs	600	cm
Soil Density	Ds	0.00166	kg/cm^2
Water Density	Dw	0.001	kg/cm^2
Coeff of Linear Expansion	a	0.0000117	°C
Difference in Temperature during operation	dT	10	
Proposed ROC	R	27300	cm

Hoop & Tensile Stress Limitation		90% of SMYS	
Combined Stress limitation		90% of SMYS	
Surface Area of Pipe	SA	2293283.155	cm^2
Rig Pulling Capacity		60	Tons

5.2.1 OVERBURDEN PRESSURE AND COLLAPSE PRESSURE

OVERBURDEN PRESSURE

Overburden pressure is the pressure exerted by the weight of the rocks and contained fluids above the zone of interest. Overburden pressure varies in different regions and formations. It is the force that tends to compact a formation vertically. The density of these usual ranges of rocks is about 18 to 22 ppg (2,157 to 2.636 kg/m^3). This range of densities will generate an overburden pressure gradient of about 1 psi/ft (22.7 kPa/m). Usually, the 1 psi/ft is not applicable for shallow marine sediments or massive salt. In offshore however, there is a lighter column of sea water, and the column of underwater rock does not go all the way to the surface. Therefore, a lower overburden pressure is usually generated at an offshore depth, than would be found at the same depth on land.

$$Po = (h*Db + hs*Ds + hw*Dw)$$

$Po = (1415 \times 0.00115) + (600 \times 0.00166) + (700 \times 0.001) = 3.32\ kg / cm^2$

COLLAPSE PRESSURE

$$Pc = 2E / [(1-\mu^2) (D/t)((D/t) - 1)^2]$$

Where

$D/t = 27.30/0.71 = 38.45$

$Pc = 83.10\ kg/cm^2$

Po/Pc = 4.00%

Since the overburden pressure is only 4% of Collapse pressure the pipe is safe.

5.2.2 BOUYANCY OF PIPE

Pipe Volume

Displacement of pipeline in drilling mud where volume

V = 3.14 (D^2/4) where D = 27.30

V = 585.35 cc/linear cm

Buoyancy

Buoyancy in drilling mud where mud density

B = 585.35 x 0.00115

B = 0.673 kg / cm

Net Buoyancy

Net buoyancy of pipeline section being pulled

B – Wp (Weight of the empty pipe in air)

= 0.7 – 0.466 = 0.207

Net buoyancy is 0.207 kg/cm of downward force.

5.2.3 MAXIMUM TENSILE STRESS DURING PULL

Allowable stress = 90% of SMYS

T = 0.9 x S x As

= 195334.2206 kg

Max Predicted pulling load is 6.65 Tons

= 6647.444 / As = 112.08 kg / sq.cm

Percentage of SMYS = 3.06 % of SMYS

Since Max. Tensile Stress is within limits and thus SAFE

Check for Bending Stress

For Longitudinal Bending Stress During installation at ROC = 27300 cm

= Ec/r = 1019.50 kg/cm^2

% of Total SMYS = 27.86 % of SMYS

Hence Longitudinal Bending Stress at above radius is safe.

5.2.4 Radius of Curvature Calculations

Before Installation

Pulling load = 0

Bending load = 90% of SMYS during Overbend or on rollers

Hoop stresses = 90% of SMYS on ground before overbend

Min radius for Temporary pipe handling

Limiting SMYS = [0.84 x 11.74 x SMYS x D /(E x t)] x SMYS

= 2634.50 kg/sq.cm

Bending Stress S = Ec/R

Or R = 10564.58 cm = 105.65m

During Installation

Max Predicted pulling load = 6.65 tons

Longitudinal stress P = F/A = 112.08 kg /sq.cm

Hydrotest stress = 0

Total stress = 1131.58 kg/sq.cm

Total percent of SMYS = 30.9%

After Installation

Min Radius for Permanent pipe installation

Permanent Radius of Curvature – R = (3 * E * 1) / (2 * Z * S * 0.9 * F)

Where F is design factor of 0.50

= 25,352.4 cm = 253.5 m

Permanent Radius Calculation check

Bending stess at ROC = Ec / R = 1019.50 kg/Sq.cm

Longitudinal Stress at Test Pressure= pd / 4t = 1273.68 kg / sq.cm

Total Stresses = 2293.18 kg/sq.cm

Stresses as percent of SMYS = 62.67%

5.2.5 Combined Equivalent Stresses

Before Installation

Hoop stress Sh = pd / 2t

Test pressure Pt = 132.5 kg / sq.cm

Hoop Stress Sh = 2547.36 kg / sq.cm

= 69.6% of SMYS

Bending moment for pipe at 800 cm supports = WwL^2 / 12 = 52,918.12 kg-cm

Bending Stress Sb = BM / Polar MI = 137.71 kg/sq.cm

Combined Long. Stress S11 = m x Sh – Ea. dT + Sb

= 764.21–0.00+137.71=901.91 kg/sq.cm

Combined Long. Stress S12 = m x Sh – Ea.dT – Sb

= 764.21-0.00-137.71=626.50 kg/sq.cm

Resultant Eq.Stress

Resultant 1 = $Sqrt(S1_1^2 - S1_1 \times Sh + Sh^2)$

= 2237.18 kg/sq.cm=61.14 % of SMYS

Resultant 2 = $Sqrt(S1_2^2 - S1_2 \times Sh + Sh^2)$

= 2299.05 kg/sq.cm=62.83 % of SMYS

After installation

Pressure at Final Hydrotest = 132.50 kg/sq.cm

Hoop Stress Sh = 2547.3592 kg/sq.cm

Bending stress at give radius Sb = Ec/r = 1019.50 kg/sq.cm

Combined Long. Stress S11 = m x Sh – Ea. dT + Sb

= 764.21–0.00+1019.50=1783.71 kg/cm^2

Combined Long. Stress S12 = m x Sh – Ea.dT – Sb

= 764.21-0.00-1019.5=-255.29 kg/sq.cm

Resultant Eq.Stress

Resultant 1 = $Sqrt(S1_1^2 – S1_1 x Sh + Sh^2)$

= 2264.27 kg/sq.cm = 61.88 % of SMYS

Resultant 2 = $Sqrt(S1_2^2 – S1_2 x Sh + Sh^2)$

= 1168.26 kg/sq.cm = 31.92 % of SMYS

During operation

Operating pressure = 106 kg/sq.cm

Hoop Stress Sh = pd / 2t = 2037.9 kg/sq.cm

Bending stress at give radius Sb = Ec/r = 1019.50 kg/sq.cm

Combined Long. Stress S11 = m x Sh – Ea. dT + Sb

= 611.37–238.56+1019.50

= 1392.30 kg/cm^2

Combined Long. Stress S12 = m x Sh – Ea.dT – Sb

= 611.37 – 238.56 - 1019.5

= -646.70 kg/sq.cm

Resultant Eq.Stress

Resultant 1 = $Sqrt(S1_1^2 – S1_1 x Sh + Sh^2)$

= 1803.92 kg/sq.cm = 49.30 % of SMYS

Resultant 2 = $Sqrt(S1_2^2 – S1_2 x Sh + Sh^2)$

= 2426.75 kg/sq.cm = 66.32 % of SMYS

5.2.6 ROLLER SPACING DURING PULL

Allowable Bending Moment for Roller Spacing

= [0.84 – {1.74 x SMYS x D / (E x t)}] x SMYS

= 2634.50 kg / cm^2

Max Tensile Load Anticipated = 6.65 tons

P = F / As = 112.08 kg / cm^2

Available stress for Bending Fb = 2522.4169 kg / cm^2

Bending moment = 2 * Fb = 969319.6034 kg-cm

This bending moment will determine the roller spacing.

For Simple spans (In between Rollers) BM = wL^2 / 12

Where w is the weight of pipe in air

Max spacing between rollers = L = sq.rt (969319.6034 x 12 / 0.466)

= 4995.16 cm = 49.9516 m

For Cantilever (on last roller) BM = wL^2 / 2

Where w is the weight of pipe in aire

Max spacing between rollers = L = sa.rt (969319.6034 x 2 / 0.466)

= 2039.27 cm = 20.3927 m

We shall support pipeline by placing rollers at a distance of 24 meters

5.2.7 Pulling requirements

Pulling loads on account of 10” is divided into 3 mann forces. Viz=

= Fluid Drag Resistance + Soil Drag Resistance + Fluid Weight on Pull Head

= pDLf + fwL + DbhA = 4034.6 + 1660.30 + 953 = 6647 kg = 6.65 tonss

In case of Bundle pulling with 6” dia Conduit, pulling loads on account of 6” Conduit are as below:

Pipeline Dia = 16.8 cm

Pipeline Wall Thickness	=	0.56 cm
Pipeline Unit Weight	=	0.22457 kg / cm
Bouy	=	0.25492 kg / cm
Net Bouy	=	0.03 kg / cm

Pulling loads for 6" dia Conduit

= pDLf + fwL + DbhA = 2482.85 + 243.49 + 360.7 = 3087.05 kg = 3.09 tons

Total Pulling Force Required	**=**	**9.73 Tons**
% of Force Required to Rig Capacity	=	16.22 %

CHAPTER 6

RECOMMENDATIONS

6.1 Internal coating

It is common practice to externally coat pipelines to ensure effective operation over the medium to long term. Internal pipeline coatings are also available for this purpose, and are able to provide significant economic benefits to pipeline operation.

The benifits of this are

Increased flow of liquid

A smoother pipe surface leads to significant increase in flow capacity when internal flow coating is used, it is generally accepted that even a one per cent improvement in throughput provides the financial justification for internal coating.

Corrosion protection

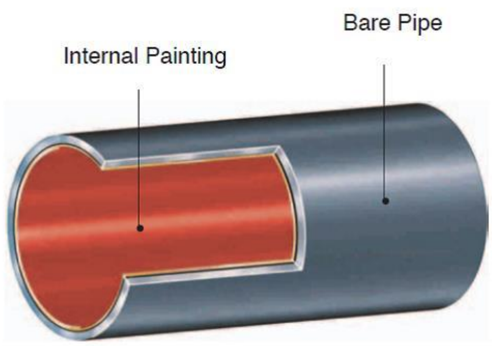


Fig 6.1.1 Internally coated Pipe

Faster commissioning and simplified inspection

Internally coated pipework will also dry faster than uncoated pipe after hydrostatic testing, which means an easier and faster commissioning of the line.

Reduced energy costs in pumping and compressor stations

Internal flow coating can also make a significant difference in reducing pumping or compression costs over the lifetime of the pipeline. These reduced energy costs can provide a financial payback within three to five years of service. It may also be possible to achieve further savings by reducing the number of compressor stations, or compressor size and capacity.

6.2 ROCK SHIELD PROTECTION IN ROCKY AREA

It is a flexible padding designed for the protection of the corrosion coating on pipelines when rocky backfill is encountered. The product is manufactured from HDPE incorporating a special expansion process to provide compressive strength and flexibility. Designed for the protection of the corrosion coating on pipelines when rocky backfill is encountered.

Fig 6.2.1 Rock Shield

Its features are Absorbs impact of uneven backfill, Protects pipe coating from protruding rocks in trench, Minimizes abrasion of coating from pipe movement underground, Protects pipe during future excavations, Unaffected by temperature extremes and wet weather, Cushions against concrete weights, Cuts with a utilityknife, Easy to install.

Fig 6.2.2 Rock Shield on a pipe

6.3 INSTALLATION OF LEAK DETECTION SYSTEMS

The method of leak detection selected for a pipeline is dependent on a variety of factors including pipeline characteristics, product characteristics, instrumentation and communication capabilities, and economics.

EXTERNAL LEAK DETECTION SYSTEMS

Acoustic Emissions

Leak detection in pipelines using acoustic emissions technology is based on the principle that escaping gas creates an acoustic signal as it passes through a perforation in the pipe. Acoustic sensors affixed to the outside of the pipe monitor internal pipeline noise levels and locations. These data are used to create a baseline "acoustic map" of the line. When a leak occurs, the resulting low frequency acoustic signal is detected and analyzed by system processors. Deviations from the baseline acoustic profile would signal an alarm. The received signal is stronger near the leak site thus enabling leak location.

Acoustic sensing can be applied externally to buried pipelines by using steel rods driven into the ground to conduct the sound to a sensor mounted on the rod. The rods are inserted at intervals along the pipeline.

Fiber Optic Sensing

With this technology, fiber optic sensing probes are driven into the soil beneath or adjacent to the pipeline. In the presence of hydrocarbons, the patented covering of the sensor changes its refractive index. This change is registered optically by the sensor and converted to a parts-per-million reading of hydrocarbons.

Vapour Sensing

Hydrocarbon gas sensing systems are more frequently used in storage tank systems but can also be applicable to pipelines. Leak detection using vapour monitoring techniques is a fairly straightforward concept. When a liquid seeps into the soil, vapours migrate from into the surrounding soil pore spaces. Probes are arranged in the soil so that a vacuum may be applied to them. The soil vapours are collected for laboratory or field analysis. Tracers or chemical markers may be added to the product being monitored so that it may be identified from naturally occurring background vapours. When the tracers or markers are encountered during analysis of the vapours, it can be surmised that a leak has occurred.

Flow Meters

Flow measurement is the most important process variable in the operation and control of pipelines; therefore, flow meters are one of the most important instruments installed on a system. Several different types of flow meters are used on pipelines including orifice plates (differential pressure), turbine, positive displacement, mass flow (Coriolis type), and ultrasonic time-of-flight (clamp-on).

Turbine meters

Turbine meters are flow-measuring devices with rotors that sense the velocity of flowing liquid in a closed conduit. The flowing liquid forces the rotor to move with a tangential velocity proportional to the volumetric flow rate. Turbine meters are used extensively on pipelines, especially those carrying petroleum hydrocarbons.

Positive displacement meters

Positive displacement meters measure flow by moving the gas through a pipe section of known volume. The claimed accuracy of these meters if 0.1 to 0.2% of flow. The accuracy of these meters depends on the accuracy to which the dimensions of the pipe section are known, the extent to which it effectively contains the product, and the temperature and pressure conditions under which the measurements are made.

INTERNAL LEAK DETECTION SYSTEMS

Real Time Transient Modelling

This most sensitive, but also the most complex and costly leak detection method in use is real time transient modeling (RTTM). RTTM involves the computer simulation of pipeline conditions using advanced fluid and gas mechanics and hydraulic modeling. Conservation of momentum calculations, conservation of energy calculations, and numerous flow equations are typically used by the RTTM system. RTTM software can predict the size and location of leaks by comparing the measured data for a segment of pipeline with the predicted modeled conditions. This analysis is done in a three-step process. First, the pressure-flow profile of the pipeline is calculated based on measurements at the pipeline or segment inlet. Next, the pressure-flow profile is calculated based on measurements at the outlet. Third, the two profiles are overlapped and the location of the leak is identified as the point where these two profiles interest. If the measured characteristics deviate from the computer prediction, the RTTM system sends an alarm to the pipeline controller. The more instruments that are accurately transmitting data into the model, the higher the accuracy of and confidence in the model. Note that models rely on properly operating and calibrated instruments for optimum performance. Calibration errors can result in false alarms or missed leaks, and the loss of critical instrument could require system shutdown.

However, the chosen systems should include as many of the following desirable leak detection utilities as possible.

- Possesses accurate product release alarming;
- Possesses high sensitivity to product release;
- Allows for timely detection of product release;
- Offers efficient field and control center support;
- Is configurable to a complex pipeline network;
- Performs accurate imbalance calculations on flow meters;
- Accommodates product blending;

- Provides the pipeline system’s real time pressure profile;
- Identifies leak location;
- Identifies leak rate;
- Accommodates product measurement and inventory compensation for various corrections (i.e., temperature, pressure, and density).

CHAPTER 7

CONCLUSION

After conducting study of Execution of an EPC Project in which 10" pipeline carrying LPG from Mangalore Hassan Mysore Sollur following are the observation:

- Pipeline construction/ laying activities were performed as per the procedures and instructions given in the approved standard documents.
- Pipeline successfully passes a hydrostatic pressure test; it can be assumed that no hazardous defects are present in the tested pipe.

$$\mathbf{P = (P_1 - (P_2 + \Delta P))}$$

  Where

  P_1 = Initial Pressure and P_2 = Final Pressure

$$P = (160.0 - (159.63 + 0.780)) = -0.41$$

  The pressure value thus adjusted is compared with the initial value and the test is considered as acceptable with evaluated difference is less than or equal to 0.3bar.

- Horizontal Directional Drilling of 397.24 meters across Hemavathi river crossing was performed for 10" pipeline. Design calculations for various stresses, Overburden and collapse pressure, Buoyancy of pipe, Radius of curvature, Roller spacing during pull and pulling force were calculated.

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