Execution of Naphtha and High Speed Diesel Pipeline project from Kochi Refinery to BPCL Installation Irumpanam

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Execution of Naphtha and High Speed Diesel Pipeline project from Kochi Refinery to BPCL Installation Irumpanam

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Master of Technology

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BONAFIDE CERTIFICATE

This is to certify that the work contained in this thesis titled "Execution of Naphtha and High Speed Diesel Pipeline project from Kochi Refinery to BPCL Installation Irumpanam" has been carried out by Kevin Sibi under my/our supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

Kochi Refinery, BPCL is expanding their Crude Processing capacity from 9.5 MMTPA to 15.5 MMTPA. The Petroleum, Oil and Lubrication terminal at Irumpanam is being expanded to handle the approx. 165000 KL of extra petroleum products from Kochi Refinery. BPCL is laying two nos of Naphtha and High speed diesel pipeline from Kochi Refinery to BPCL installation Irumpanam. This project is about the execution work of Naphtha and High speed Diesel pipeline from Kochi refinery to BPCL installation Irumpanam.

In the first stage of the work a route feasibility study was conducted. Three possible routes have been analyzed and depending on the optimum route selection criteria the best possible route was selected for laying the product pipeline.

In the second stage basic design considerations and parameters of the Mainline Pipe , Dispatch and Terminal station pipe are studied from OISD 141, API 5L and ASME B 31.4 guidelines .

In the third stage the mainline and station piping construction activities are carried out as per the approved specified procedures. For river crossing, Horizontal Directional Drilling of 120 meters was conducted. Calculations needed for design of HDD crossing were performed including pulling load calculation, total pipe stress calculation and radius of curvature of the pipe.

During the laying of pipeline, to protect the pipeline from corrosion, as a temporary cathodic protection method sacrificial anode is applied. Mixed metal oxide is used as the sacrificing anode for the pipeline. The temporary cathodic protection prevents the corrosion activities that tend to happen to the pipeline during construction. Later Permanent cathodic protection using impressed current having a life span of 30 years is applied on the pipeline. Design parameters such as current requirement, number of anodes required, life of anode, ground bed resistance are calculated.

ACKNOWLEDGEMENT

Every project big or small is successful largely due to the effort of a number of wonderful people who have always given their valuable advice or lent a helping hand. I sincerely appreciate the inspiration; support and guidance of all those people who have been instrumental in making this project a success.

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Last but not the least I thank my family and friends who have been constant source of inspiration during the preparation of this project work.

Kevin Sibi

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

HSD	- High Speed Diesel
KRL	- Kochi Refinery Limited
BPCL	- Bharat Petroleum Corporation Limited
MMTPA	- Million Metric Tons per Annum
ATF	- Aviation Turbo Fuel
ANST	- American Society for Non Destructive Testing
API	- American Petroleum Institute
ASME	- American Society of Mechanical Engineers
DBBV	- Double Block and Bleed Value
OISD	- Oil Industry Safety Directorate
CISF	- Central Industrial Security Force
TP	- Turning Point
ALT	- Alternate
SMYS	- Specified Minimum Yield Strength
ROW/ ROU	- Right Of Way/ Right Of Use
SMAW	- Shield Metal Arc Welding
NDT	- Non Destructive Testing
PE	- Polyethylene
SDH	- Side Drill Hole
RT	- Radiographic Testing

DAC	- Distance Amplitude Correction
CP	- Cathodic Protection
MMO	- Mixed Metal Oxide
TPIA	- Third Party Inspection Agency
HDD	- Horizontal Directional Drilling
TOFD	- Time of Flight Distraction

CHAPTER - 1

INTRODUCTION

Bharat Petroleum Corporation Limited (BPCL) desires to augment the existing Infrastructure facilities at Irumpanam and lay two new product pipelines from Kochi Refinery at Ambalamughal to connect its existing oil installation at Irumpanam. The project envisages the construction of 3km pipeline 24” and 18”which includes the pig dispatch station inside the refinery and the pig receiver station in filling station.

Kochi Refinery, a unit of Bharat Petroleum Corporation Limited (BPCL), embarked on its journey in 1966 with a capacity of 50,000 barrels per day. Formerly known as Cochin Refineries Limited and later renamed as Kochi Refineries Limited, the refinery was originally established as a joint venture in collaboration with Phillips Petroleum Corporation, USA. Today it is a frontline entity as a unit of the Fortune 500 Company, BPCL.

The product portfolio of the 190,000 barrels per day refinery today includes petrochemical feed stocks and specialty products in addition to its range of quality fuels. Fuel products of this fuel based refinery include Liquefied Petroleum Gas, Naphtha, Motor Spirit, Kerosene, Aviation Turbine Fuel, High Speed Diesel, Fuel Oils and Asphalt. Specialty products for the domestic markets include Benzene, Toluene, Propylene, Special Boiling Point Spirit, Mineral Turpentine Oil, Sulphur and Hydrogen.

The refinery has facilities to evacuate products to the consuming centers through road, rail, ships and through pipelines. All the major industries in the area are connected to the refinery for product receipt. The BPCL installation at Irumpanam, to which the refinery is connected by pipelines, is the major product distribution center of the refinery. Petronet CCK, a joint venture company of BPCL looks after the 300 km long pipeline that connects the refinery to various consumption points in Tamil Nadu such as Coimbatore and Karur.

Kochi Refinery, BPCL is expanding their Crude Processing capacity from 9.5 MMTPA to 15.5 MMTPA. In order to handle the additional petroleum products from Kochi refinery, the POL terminal at Irumpanam is being expanded to handle the approx. 165000 KL of extra petroleum products including the associated facilities viz. full rake railway siding with loading gantry, two nos. pipeline from KR to Irumpanam Installation and re-allocation of existing facilities and associated works.

Presently products from Kochi Refinery are being transferred to Irumpanam Terminal through the terminal. There is also a provision to transfer products from Irumpanam Terminal to other marketing companies (IOCL & HPCL) directly. Tanker loading is being mostly done from the Irumpanam terminal but also a facility for pumping directly from KR is being used. The product to the Kochi Coimbatore Karur pipeline is being pumped from BPCL Terminal. Wagon loading and Tank Truck loading of Petroleum products are also being carried out from the Irumpanam BPCL Terminal.

It is therefore proposed to augment the existing Infrastructure facilities at Irumpanam, Installation and also lay 2 nos. of pipelines for Naphtha and HSD from KRL to Irumpanam. Earlier the naphtha and HSD were sent through the same line by turns, according to new rule proposed by PNRB (petroleum and natural gas regulatory board) no two crude oil by products could be sent through the same line. Hence by this project the byproducts are sent through 24" and 18" inch pipelines simultaneously.

The Laying of pipeline work was contracted to Inkal ventures private Limited. Inkal is a fast emerging Engineering, Procurement and Construction company with breadth and depth of expertise to respond to technically challenging and time bound projects in Oil & Gas, Petrochemical, Fertilizers & Chemical, Power.

CHAPTER-2

LITERATURE REVIEW

Jeffery E Hambrook presented a paper *on integration of pipeline Specifications, Material and Construction Data* at the 8th international pipeline conference (2010).The paper introduces the concept of pipe data log which is creating and populating the pipe log as construction proceeds. This can provide multiple benefits.

- Progress of all aspects of construction can be tracked.
- Anomalies in data received can be identified immediately and rectified before the project proceeds.
- Missing information can be captured before the project is completed and crews are demobilized.
- Field Engineer can compare with design to verify that the project is being constructed as it was designed.
- When construction is complete the pipe log will be as well.

Kenneth Y Lee, a pipeline Safety officer presented a paper on *Pipeline Construction Challenges* at the NAPCA workshop conducted in Houston, Texas (2010). In his work the author highlights past pipeline incidents and issues that took place year vice with pictures and charts. He also came up with pipeline defects and methods to mitigate it.

Mohammad Najafi Ph.D., P.E is an Assistant professor of construction Management and Director of Centre for underground Infrastructure Research and Education (CUIRE) at Michigan State University. In his book *Trenchless Technology: Pipeline and Utility Design, Construction and Renewal* (2005) he gives us a detailed reference covering construction details, design guidelines, environment concerns and the latest advances in equipment, methods and materials. Trenchless Technology allows for the installation or renewal of underground utility system with minimum disruption of the surface.

Da Ming Duan presented a paper on *Stress Check Procedure For Pipe Lowering-In Process during Pipeline Construction* at the 10th international pipeline conference (2014). The work points out that the quality of pipeline construction is determined by the effort of controlling the pipe stress level. Here are some of the constraints he brings out.

- Pipe size.
- Side booms lifting capacity.
- Number of side booms.
- Side boom spacing and the lifting height profile.

Author concludes that for normal pipe lowering in practice pipe stress can be effectively controlled by checking and controlling the lift height of just one or two points.

James B Bushman a Principal Corrosion engineer, Bushman & Associates Ohio USA presented a paper on *corrosion and cathodic protection Theory*. In his paper the author discuss about highly adaptable and effective means of preventing corrosion on a variety of underground or underwater structures. Cathodic protection designs can differ considerably depending upon the coating, the configuration of structure, the environment and the presence of neighboring structure. Author came up with the conclusion that when a system is designed, installed and maintained properly, cathodic protection is one of the most effective and economical methods of preventing corrosion.

Patrick J Garland who is a ASNT and ACCP LEVEL III presented a paper on the *topic The importance Of Non-destructive testing and inspection of Pipelines* at the10th European conference on non-destructive Testing in Moscow (2010).He emphasis on making use of the latest Non-destructive testing methods like digital radiography that can save time and consumable cost, Automated Ultrasonic testing that utilizes TOFD and phased array produces recordable results and a permanent record, which can be evaluated by third party inspectors at a later stage, intelligent pigging extensively used for the evaluation of corrosion in pipelines and can be used on all pipelines fitted with pig launching facilities, Three dimensional laser beam profile measurement of corrosion is an extremely accurate tool for the measurement of the corrosion depth and location.

CHAPTER-3

3. FEASIBILITY STUDY

Bharat Petroleum Corporation Limited proposes to identify a feasible route for possible new pipelines 18”and 24” .The study covers the reconnaissance survey with alternate routes for the pipeline route from the aforementioned route covering different lengths for different routes. The pipeline route traverses within the city area i.e. the refinery area village Thiruvankulam, Taluk Kanayannur, District Ernakulam Block no 10.

3.1 Scope of Work

- Map reconnaissance.
- Identification of pipeline corridor.
- Compilation of strip maps.
- Physical verification of the Pipeline route.
- General terrain configuration and administrative jurisdiction report.

3.2 About Thiruvankulam

Thiruvankulam is a suburb of the city of Kochi, in the state of Kerala, India. It is a part of Tripunithura Municipality and Kochi Metropolitan region. Though Thiruvankulam was an idyllic village, its proximity to the city as well as industrial areas comprising the Kochi refineries and allied industries have contributed to its growth. The village is home to large petroleum corporations as well as numerous small scale and cottage industries. Traco Cable Company, BPCL, IOC, and HPCL are major players having presence in the region. Most people living here are employed in the city of Kochi, major employees being Kochi Refinery, HOC, FACT and the government of Kerala.

3.3 Soil Strata and Administration

Soil in the Thiruvankulam area seems to be se sediments such as alluvium, Teri’s, brown sands, etc. Hydromorphic saline soils are also found in the area surrounding the backwaters.

Thiruvankulam was administrated by a special grade panchayat under the Kerala panchayat act, in 2010, as a result of the re-organisation of administrative divisions in Kerala. Thiruvankulam panchayat merged with the neighboring Tripunithura municipality. Thiruvankulam is still part of the Piravom assembly constituency.

3.4 Features of Pipeline

The Pipeline starting point is at the compound wall at BPCL Kochi refinery, at village Irumpanam, Kochi

Coordinates: 76 º, 21’51.9”E (longitude) & 9º, 58’15.3”N (latitude).

Terminal point of the pipeline is located at the compound wall of the BPCL installation compound wall across the railway lines.

Coordinates: 76º, 21’17.0”E (longitude) & 9º, 58’22.4”N (latitude).

3.5 Proposed Alternate routes

Macon MSC Pvt Ltd conducted reconnaissance and detailed route survey for the proposed pipeline and came up with three possible alternate paths for the construction

- ALT-1 Path- A-B-C-D-E-F-G-H-I-J-K Total Distance- 1519m

  From the start point A(BPCL refinery compound wall) the route traverses to the back side CISF gate through the path A-B-C and from there turning left towards D and encircling the CISF boundary wall towards old Irumpanam road(path E-F-G) and from there turning right towards the railway lines till it reaches the point H. Upon reaching the railway lines the route again deflects left towards behind the railway yard through the drain and reaches a point from where it turns right towards north and crosses the railway line straight and terminates at the BPCL installation compound wall at the terminal point (path H-I-J-K).

- ALT-2 Path-A-D-E-F-G-J-K Total Distance-1343m

  Start point A the route dissects part of the BPCL property and reaches to the corner of the CISF boundary at point D. There it encircles the CISF boundary traversing path D-E-F-G on the BPCL refinery road. From the point G, the route dissects through a private property, then under the bridge and again dissects another private property till it reaches the point J .From J the route turns north and crosses the railway lines and terminates at point k.

- ALT-3 Path-A-B-C-C1-C2-C3-C4-C5-K Total Distance-1167m

From start point A the route slightly deflects towards the north and reaches on the right side of the back side of CISF gate at point C1. From C1 the route traverses through the path C1-C2-C3-C4 to the railway quarters. From C4, the route deflects to the right towards the north and crosses the railway line to reach the point C5. From C5 the route again deflects towards the left (west direction) and traverses parallel to the railway line to reach the terminal point at K.

List of Major crossings on Proposed Route

Table 1 ALT- 1

SR No	Type of Crossing	Detail of crossing
1	**Creek**	**Creek near BPCL boundary.**
2	**Drain**	**Drain near CISF Facility.**
3	**Road**	**Old Irumpanam road- Not a crossing but the road will have to be opened up in order to lay the pipeline.**
4	**Bridge**	**Under bridge besides Old Irumpanam road.**
5	**Drain**	**Along the drain behind the Rail yard.**
6	**Railway**	**Multiple Railway line crossing.**

Table 2 ALT -2

SR No	Type of Crossing	Detail of crossing
1	Creek	Creek near BPCL boundary and dissecting through BPCL property to point D.
2	Road	Old Irumpanam road.
3	Railway	Multiple Railway line crossing.
4	Foreign Lines	Multiple foreign lines.

Table 3 ALT-3

SR No	Type of Crossing	Detail of crossing
1	Creek	Creek near BPCL boundary.
2	Railway	Multiple Railway line crossing.
3	Foreign Lines	Multiple foreign lines.

3.6 Factors for Selection of the Feasible Route

The final pipeline route selection is based on the following observations.

- Safety of public lives, property and also safety of pipelines.
- Shortest and Feasible pipeline length.
- Easy and favorable terrain conditions, avoidance or Minimization of crossings.
- Avoidance of sharp bends and turnings.

- Minimum up-rooting of tress.
- Consideration of Availability of infrastructure & access to pipeline route during and after construction.
- Avoidance or Minimization of crossings length of built up areas, places of worship, burial grounds or any reserved forest and industrial area.

Based on the above factors (as applicable), the pipeline route was selected including feasibilities of additional routes. The survey team moved into the proposed areas for the routes and marked the important turning points on the ground, with yellow paint on nearby tress or prominent places. The crossing points of major obstacles like roads etc. were painted yellow, on nearby tress and structures etc.

3.7 Recommendation

After accomplishing the survey for BPCL HSD/Naphtha Pipeline for BPCL, Kochi and carrying out in-depth study ,discussion and site visit with BPCL authorities as well as considering the pros and cons of the alternate routed (ALT-1,ALT-2 & ALT-3) especially avoiding private property area and foreign lines, the **ALT-1(A-B-C-D-E-F-G-H-I-J-K)** with **1519 Meters** length is the most feasible route and considered as **proposed route.** The other portion of the route comes inside the Refinery and the installation stations which could be totaled to 3 km pipeline.

ALT-3 Path- A-B-C-C1-C2-C3-C4-C5-K Total Distance-1167m

Really would have been the most desirable route. However in this route, after the point C-5, when the line crosses the railway track there are many other foreign lines like HPCL, IOCL, BPCL, GAIL etc., are found whose records are not easily available. And hence there is a risk of puncturing of foreign lines eventually leading to litigation or arbitration process.

ALT-2 Path-A-D-E-F-G-J-K Total Distance-1343m

Ideally would be the next desirable route. However, in this route, there are two limitations. Some part of BPCL property near the creek area between point A and D which is planned for BPCL facility in future, will have to be compromised and after the point G, the line enters the private property. In recent times according to local inquiry it is found that the land rates are very high and cost prohibitive and will later on cause complications in acquisition and hence private property also should be avoided as far as possible.

Hence Route ALT-1(Path- A-B-C-D-E-F-G-H-I-J-K) with length 1519 meters is finally selected and recommended as proposed route.

3.8 Detailed Feature of Proposed Route

Recommended route: (ALT-1 Path-A-B-C-D-E-F-G-H-I-J-K)

This route starts from BPCL refinery compound wall at TP-00 marked as point “A”. From there it traverses west towards TP-01 which is across the creek. The length of the crossing is 65.6239 meters. There is already a bridge constructed on the right side of the line standing from TP-00 which contains existing pipelines of water, petroleum and ATF.

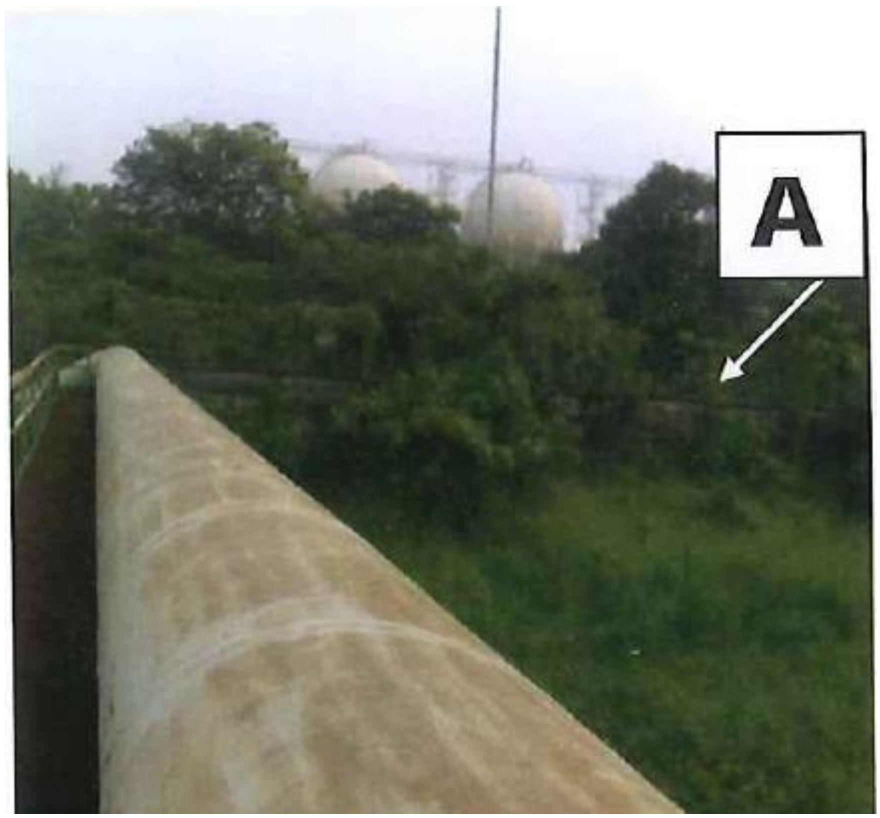

Figure 1 View from TP-01 to TP-00

In the above Picture A points out to the Refinery compound wall


(a)


(b)

(c)

Figure 2 (a),(b),(c)-TP-01 stone

From TP-01 the route climb up a little towards the left BPCL road to TP-02.

Figure 3 TP 02

TP-02 falls on the left side of the BPCL road that runs from the creek towards the CISF facility and traverses west towards TP-03 and TP-04 near the CISF back gate.

(a)Location of TP-03

Figure 4 (a), (b)(b) -View of CISF back gate from TP-03

(a)Location of TP-04

Figure 5 (a), (b)(b) View from TP-04 to TP-05

From TP-04, the route turns left southwards parallel to the CISF facility wall and traverses till it reaches the corner of the compound wall at TP-05.

(a)View from TP-05 towards TP-04

Location of TP-05

(b) TP-05 stone Figure 6 (a), (b), (c)(c) view from TP-05 towards TP-06

From TP-05, the route turns towards the right side (west direction) and encircles the CISF boundary wall till it reaches TP-06.As you can notice that there are quite a few number of coconut trees on the left side of the line.

(a)View from TP-06 to TP-05 (b) TP-06 stone

Figure 7 (a), (b)

From TP-06, the route turns again to right (towards north direction) and traverses to TP-07 near HT tower seen in the view below. An HT line of 110KV passes right above this route and hence in this location, it is strongly recommended to protect the pipe cover with appropriate cathodic protection.

(a) TP-07 stone and view from TP-07 to TP-08 **(b) view from TP-06 to TP-07**

(c) View from TP-08 to TP-07

Figure 8 (a), (b), (c)

From TP-07 the route traverses forward towards TP-08.

(a)TP-08 **(b) from TP-08 to TP-09**

Figure 9 (a), (b)

From TP-08 the route traverses forward towards TP-09 near the front CISF gate. There is cabin like structure falling in line. This cabin was a site office when the CISF facility was being developed and is in non-use at the moment. Hence it can be dismantled.

(a) TP-09 Stone **(b) CISF Facility Front gate**

From TP-09 the route traverses on the left side of the road which is BPCL owned road towards TP-10 to TP-14

(c) View from TP-09 to TP-10

Figure 10 (a), (b), (c)

(a) TP-14 Stone

From TP-14, the route slightly deflects towards the intersection of the BPCL road and the old Irumpanam road and reaches the center of the back top of the old Irumpanam road where TP-15 has been marked. There is a transformer fence that will have to be crossed from TP-14 to TP-15.

(b)View from TP-14 toTP-15

Figure 11 (a), (b)

From TP-15, the route traverses on the center of the road till it reaches TP-16 again on the road.The laying of pipeline on the road will be decided after opening the road for pipeline as there are two other lines passing underground. A water pipeline and one BPCL line. So based on the availability of the space, the Naphtha and HSD lines will be laid accordingly.

Figure 12 View from TP-16 towards TP-15 of old Irumpanam road

From TP-16 the route again deflects to the left (west direction) towards the underbridge as shown below and then falling in the drain on the back of the Railway property.

Figure 13 View from TP-16 towards TP-17 under the bridge.

From TP-17, the route follows the zig-zag alignment along the drain and reaches TP-21 from where it crosses the railway line.

From TP-21, the route crosses the railway line and terminates at TP-22 on the boundary wall of BPCL installation. The route passes through the two electric poles EP1085 and EP1087 near TP-21 and between EP1082 and EP1089 near TP-22 on the other end.

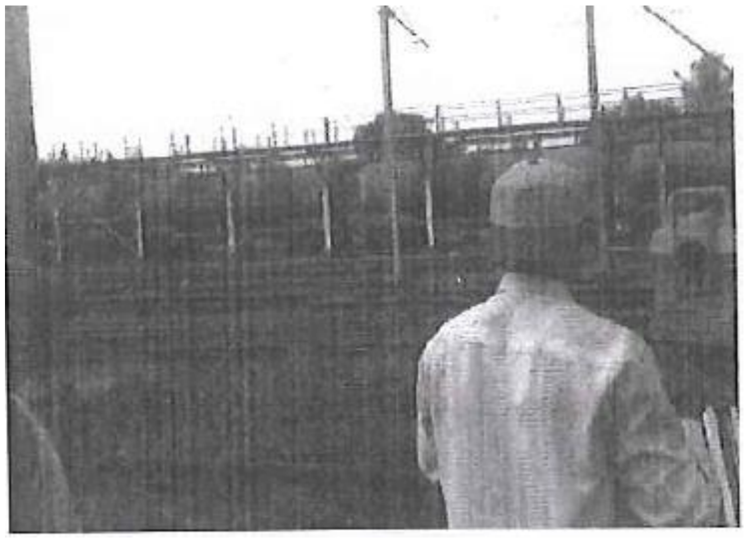

Figure 14 View from TP-21 to TP-22

There are multiple railway lines (9 tracks in all) to be crossed in order to reach the terminal point.There is also a Railway bridge depicted in the picture.

Below is the Table showing the detail survey data log.

Table 4 Survey Data log

List of TP/IP					
Sr No.	TP/IP	DEF ANGLE	PARTIAL DISTANCE	CUMM DIST	LEVELS
1	TP-00	00-00-00	0.000	0.000	100.334
2	TP-01	24-28-22-R	65.590	65.590	98.290
3	TP-02	24-48-41-R	17.560	83.150	99.395
4	TP-03	26-21-43-L	86.780	169.930	99.377
5	TP-04	91-55-12-L	46.840	216.770	99.587
6	TP-05	90-06-38-R	133.370	350.140	98.170
7	TP-06	30-27-17-R	109.510	459.650	98.144
8	TP-07	06-02-38-R	51.070	510.720	98.649
9	TP-08	41-43-31-R	140.160	650.880	99.399
10	TP-09	67-40-01-L	160.740	811.620	99.679
11	TP-10	11-06-06-L	98.030	909.650	99.601
12	TP-11	04-01-38-L	32.650	942.300	99.907
13	TP-12	03-53-37-L	60.530	1002.830	101.335
14	TP-13	11-24-04-L	68.190	1071.020	102.012
15	TP-14	20-36-48-R	43.690	1114.710	101.506
16	TP-15	85-14-16-R	73.150	1187.860	100.737
17	TP-16	11-23-40-L	43.910	1231.770	100.642
18	TP-17	87-37-54-L	35.470	1267.240	100.597
19	TP-18	15-11-20-R	30.070	1297.310	100.541
20	TP-19	77-40-38-R	69.820	1367.130	98.296
21	TP-20	74-43-54-L	20.520	1387.650	99.438
22	TP-21	80-51-04-R	42.070	1429.720	98.713
23	TP-22	00-00-00	88.810	1518.530	99.962

CHAPTER - 4

PIPELINE DESIGN BASIS

4.1 Project Scope of 2 nos pipeline from Kochi Refinery to Irumpanam

- Present scope for Pipeline of the project includes the following:
- Dispatch station at KRL battery limit including basket filter, metering assembly, provision of temporary scraper launcher, pipeline manifold, pressure flow valve, inlet NRV and MOVs and associated facilities.
- Receipt station at Irumpanam including basket filter, metering assembly, provision of temporary scraper receiver, pressure control valve, flow control valve and associated facilities.
- One 18” 1.52 km cross county pipeline from BPC- KR to Irumpanam for HSD.
- One 24” 1.52 km cross country pipeline from BPC-KR to Irumpanam for Naphtha.

4.2 Basic Parameters

Table 5 Parameters

Products to be transported	Euro- IV grades of High Speed Diesel (HSD) Naphtha (LAN & HAN)
Product properties/specifications	As per Annexure-I
Design Throughput	Naphtha: 2200 m^3/hr (as per existing pump at KRL, YP-65 A/B/C) HSD: 1136 m^3/hr (as per existing pump at KRL, YP-8B/D/E)
Turn Down	Nil
Permissible Contamination Level in products	Nil
Design codes	Latest Edition of ASME B31.4 and PESO/OISD-STD will be followed as applicable. However, in case of contradictory stipulations, the stringent conditions will prevail. To mention Latest Edition

Table 6 Battery Limits

KRL Dispatch Facility	Downstream of Existing Naphtha & HSD pumps at KRL. At west compound wall near ATF - Nedumbassary P/L scraper launcher.
Receipt station Irumpanam	Pipeline receipt facilities from downstream of scraper receiver to product manifold and piping connection to existing and new storage tanks and hook-up to existing jetty transfer line.
Cross Country Pipeline from KRL to Irumpanam	Two nos. of 18” & 24” 1.52 km long cross-country pipeline system for HSD and Naphtha respectively from KR to Irumpanam including temporary scraper launcher & receiver.

Table 7 Pipeline Parameters

Pipeline design throughput	Naphtha: 2200 m^3/hr (as per existing pump at KRL) HSD: 1136 m^3/hr (as per existing pump at KRL)
Pipeline Design life	25 Years
Pipeline Length	1.52 km - both Naphtha & HSD
Basis for hydraulic Calculation	Pipeline hydraulics shall be carried out based on HSD throughput of, HSD: 1136 m^3/hr. With specific gravity 0.825 at 15°C and kinematic viscosity of 2.5 cSt at 40°C & 5.0 cSt at 25°C and destination pressure of 2.5 kg/cm^2g at farthest storage tanks inlet at Irumpanam terminal. Pipeline hydraulics shall be carried out based on Naphtha throughput of, Naphtha: 2200 m^3/hr.With specific gravity 0.68 at 15°C and kinematic viscosity of 0.43 cSt at 38°C & 1.35 cSt at 20°C and destination pressure of 6 kg/cm^2g at hook-up point to jetty transfer line at Irumpanam terminal.
Main Pipeline Diameter	18” OD (HSD)

	24" OD (Naphtha)
Pipeline roughness	45 microns
Line pipe Material of Construction	Carbon Steel
Pipeline Corrosion Allowance	1.0 mm (to be reviewed)
Pigging Facilities	Provision of temporary pigging facilities. Pipeline would be designed for "Intelligent Pigging".
Subsoil temperature (1.2 m below ground)	25 °C throughout the entire length of the pipeline.
Maximum Operating Pressure (MOP)	10% below pipeline design pressure
Design Pressure	14 kg/cm^2g (HSD) 22 kg/cm^2g (Naphtha)
Design Temperature	45°C for Buried facilities 65°C for Aboveground facilities
Surge control	Suitable surge control/ surge relief system will be provided as per requirement. The surge analysis will be done during the progress of detailed engineering.
Pipeline laying	Buried
Pipeline corrosion protection system	Pipeline external protection – Three Layer Polyethylene coating shall be provided. Cathodic Protection by impressed current for buried portion of pipeline will be provided.
Corrosion Monitoring System	Corrosion monitoring system will be provided as required.
Ground elevation profile	Refer Annexure-II
Sectionalizing valves	Sectionalizing valves will be provided if required across river crossing as per ASME B 31.4. & OISD-STD 141 and as per elevation profile requirement.
DBBV	DBBV will be provided wherever positive segregation is required.
Design margin (for pipeline)	On length : 3% On flow : Nil
Power supply	Power supply to CPs/Telecom stations to be covered under engineering design.

Dispatch station parameters

The dispatch station is at Kochi Refinery.

Table 8 Design parameters

Source of Products	From outlet of Naphtha & HSD pumps.
Max / Min. Product Supply temperature, °C	38 / 20
Max./Min. ambient Temperature, °C	38 / 20

Table 9 Utility Specification

Instrument air	Not Required
Plant air	Not Required
Service Water	5 m^3/hr(Intermittent only for floor washing)
Power	From KR
Emergency Power (lighting/controls)	To be provided only for Control room facilities and critical valves and instrumentation and Yard lights.

Receipt Station parameters

The Receipt station is at Irumpanam

Table 10 Station Design parameters

Delivery of Products to be considered	HSD : To Atmospheric storage tanks Naphtha: To atmospheric storage tanks and at hook-up point to jetty transfer line.
Ambient Temperature (max/min)ºC	38 / 20
Pumping Temperature ºC	38 / 20

Length of piping inside Irumpanam terminal	HSD: 1km from Pipeline battery limit to storage tanks. Naphtha: 1km from Pipeline battery limit to storage tanks and 1km from naphtha storage tanks to hook-up point to jetty transfer line.

Table 11 Utility specification

Instrument air	Not Required
Plant air	Not Required
Service Water	5 m^3/hr (intermittent only for floor washing)
Power	From Irumpanam Marketing Terminal
Emergency Power (lighting/controls)	To be provided only for Control room facilities and critical valves and instrumentation and Yard lights.

Table 12 INSTRUMENTATION

General	
Type of control	Electronic
Final control element	Electro-Hydraulic at all locations.

Table 13 METERING SYSTEM

Flow meters	**MFM** for HSD & Naphtha with one spare run shall be considered at both despatch and receipt station.
Density Meters	**NO**
Type of flow meters	
Type of Meter prover	NIL
On line Sulphur Analyzer/ color analyzer	NO

GENERAL PROJECT SPECIFICATIONS

Table 14 Unit numbers to be considered

Unit Description	Unit numbers
Dispatch Station at KR	Would be checked during P&ID finalization
Receipt Station at Irumpanam	’’
Pipeline (HSD)	’’
Pipeline (Naphtha)	’’

Drawings/Documents: All drawings and other documents shall be prepared.

Measurement: Metric, unless otherwise specified.

Table 15 PROPERTIES OF HSD/ NAPHTHA TO BE TRANSPORTED

PRODUCTS	SPECIFIC GRAVITY @ 15 °C	VISCOSITY cSt	REID VAPOUR PRESSURE (RVP), @ 38 °C	FLASH POINT (°C) Abel, min
HSD Euro IV	0.82 – 0.86	2.5 @ 40°C 5.0 @ 25°C	0.5 mm Hg	35 - 66
Naphtha	0.68 – 0.75 (LAN) 0.68 – 0.77 (HAN)	0.43 @ 38°C 1.35 @ 20°C	< 12.1 psi (LAN) < 9.1 psi (HAN)	< -10

CHAPTER – 5

MAINLINE CONSTRUCTION

5.1 Route Survey

5.1.1 Equipment

- Theodolite.
- Dumpy level.
- 30 meters measuring tape.
- Ranging rod.
- 5 meters staff.

5.1.2 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 are fixed at turning points and at 250 Meters on either side of ROW.

- Centerline of pipeline is demarcated by stacking of wooden pegs at an interval of maximum 500 Meters for straight-line sections and maximum 10 Meters for horizontal bends and turning points.
- Markers on the reference line are at a distance of max 250 Meters and for straight line section maximum 10 Meters is allowed 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.

5.1.3 Staking of pipeline route

Install wooden markers at a regular interval of two hundred meters minimum duly marked for easy identification with name of pipeline, progressive pipeline Chainage with yellow paint on base color of red. The staking shall be on the edge of ROW.

The markers are also to be installed at every turning point, and on both sides of all road, river, rail and canal crossing etc.

5.1.4 Bench marks

A temporary bench mark shall be established at every Turning point preferably on some permanent structure. The bench mark should be painted and marked for easy identification as in the case of marker stone.

5.2 Clearing and Grading

The ROW boundary lines shall be staked so as to prepare the strip for laying the pipeline. All construction activities are performed within the prescribed width (limits) of the ROW. The variation in this width caused by local conditions or installation of associated pipeline facilities or any existing facilities of Owner will be informed. Prior to the start of the clearing operations the following will be taken care of.

5.2.1 Stacking

- Install benchmarks, Intersection points and other required survey monuments.
- Stake two ROW markers every 100 meters.
- Set out a reference line with respect to pipeline centerline at a convenient location. Marker on reference line shall be at a distance of maximum 100 meters for straight-line sections and maximum 10 meters for horizontal bends.
- Install distinct marks on the ref line locating and indicating special points, such as contract limits obstacle, crossings, change of wall thickness, including corresponding Chainage etc
- All markers shall be of suitable materiel and shall be colored red with numbers printed in white. Number shall be identical to centerline marker number with letter A (left site) B (right site) added, looking to flow direction for easy identification and shall be maintained till permanent markers are installed and as built drawings are submitted approved.

5.2.2 ROW clearing and grading

Any obstacle in ROW hindering installation of pipeline along the pipeline route is removed. Grading of ROW is done as required for proper installation of the pipeline. All grubbed stumps, timber, bush, undergrowth and roots and or removed from the Right of Way shall be disposed of in a manner and method satisfactory to BPCL / TPIA, land owner and / or tenant, and Government Authorities having jurisdiction and as soon as practical after the initial removal. In no case shall it be left to interfere with the grading and laying operations. Whenever stumps are grubbed and a hole is left in the ground, it is back-filled and compacted to prevent water from gathering and making a big hole.

Any sharp or low points seen should be graded to allow the pipe to be bent and laid within elastic bend radius limits and shall drill, blast or excavate any rock or other material which cannot be graded off with ordinary grading equipment in order to make an adequate working space along the pipeline.

No temporary or permanent deposit of any kind of material resulting from clearing and grading shall be permitted in the approach and any other position, which may hinder the passage and / or the natural water drainage.

In the case of natural or artificial deposit of loose soil, sand, heaps of earth or other fill 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.

In the case of Right-of-Way clearing and grading on the hillside or in steep slope areas, proper barriers or other structures shall be provided to prevent the removed materials from rolling downhill. The ROW/ROU cross fall shall not exceed 10%.

Wherever the pipeline Right-of-Way runs across, through or alongside farmyards, built-up areas, groups of trees, groves, horticultural spreads, gardens, grass-fields, ditches, dikes, roads, paths, railways or any other area with restrictions of some kind, in such cases we can grade only the width of the Right-of-Way necessary for digging the pipeline trench and constricting the pipeline. In the said places the works should be carried out in such a way that damages resulting from the pipeline construction is kept to a minimum.

5.3 Trenching

- Excavator is used for digging pipeline trench on cleared and graded ROW/ROU in most of the cases.
- In cultivable land and other areas specifically designated by the COMPANY, top 60mm of the arable soil on the pipeline trench top and 500mm on either side shall be excavated and stored separately to be replaced in original position after backfilling and compacting rest of the trench.
- It is required that fresh soil recovered from trenching operation, intended to use for backfilling over the laid pipe in the trench is not mixed with loose debris or foreign material.
- The excavated material shall never be deposited over against the strung pipe. Suitable crossing should be provided and maintained over the open ROU wherever necessary to permit general public, property owners or his tenants to cross or move stock or equipment from side of the trench to the main path.
- On slopes wherever there is danger of landslides, the pipeline trench shall be maintained open only for the time strictly necessary.
- In certain sloppy section before trench cuts through water table, proper drainage shall be ensured, both near the ditch and ROU in order to guarantee the soil stability.

- Unless otherwise mentioned in job standards/drawings and or as required by authorities having jurisdiction, whichever is the greatest, the minimum depth of cover shall be measured from top of coated pipe to the top of undisturbed surface of the soil or top of the graded working strip or top of road or top of rail, whichever is lower.
- Fill material in working strip shall not be considered to add to the depth of cover. However surface of fill material placed to fill hollows may be used to determine the depth of cover with information to BPCL.

The depth of the trench will be such as to provide minimum cover as stipulated below for reference:

Location	Minimum Cover in meters
a) Industrial, Commercial & Residential Area	- 1.00 meter
b) Rocky Terrain	- 1.00 meter
c) Minor Water Crossings/Canals/drain/nala/stream	- 1.50 meter
d) River crossing for which Scour depth is defined (below Scour)	- 1.50 meter
e) River crossing (Bank width < 50 below lowest bed level)	- 1.50 meter
f) River crossing (Bank width > 50 below lowest bed level)	- 2.50m (For normal soil)
(Below lowest bed level)	- 1.50 m (For rocky strata)
g) Water crossing by HDD (Below least bed level)	- 2.50 m
h) Uncased / Cased road crossing/ Station approach	-1.20 m
i) Railroads crossing	-1.70 m
j) Drainage ditches at road & railway Crossing	- 1.00 m
k) Marshy land and creek area	- 1.50 (for normal soil)

Note: In case pipeline is located within 1.5 meter from any dwelling unit, the cover shall be Increased 300 and above as specified.

5.4 Welding

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 for Mainline

Process & Type	SMAW & Manual
Material	API 5L Gr X52
Diameter and wall thickness of pipe	24” & 7.9 mm
	18” & 6.4mm
Qualified range for diameter & wall thickness	12.75”OD & 4.8mm-19.1mm
Joint Design	Single “V”
Filler material and no of passes	Root-E6010 (3.15mm)
	Hot &Cap-E7010 (2.5mm)
	Filling-E7010 (3.15mm)
Position	5G
Direction of welding	Root – downhill
	Other – uphill
Cleaning and grinding	Power brushing, grinding and chipping
Preheat/Type of heating	100 deg c by LPG Heating/LPG flame torch
Inter pass temperature	Min 150 deg Celsius to max 250 deg Celsius
Temperature checking	Crayon and pyrometer.

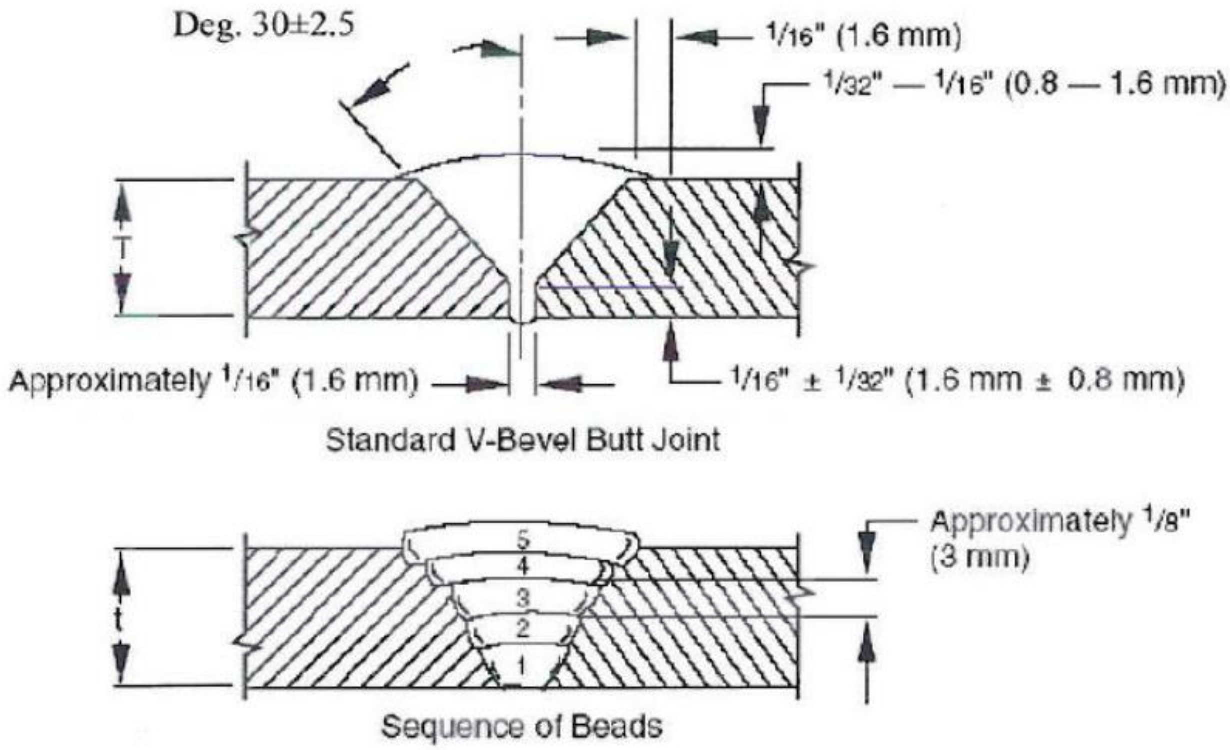

Figure 14: Welding

5.4.1 Preparation for Welding

Weld is made by the manual shield metal arc method. Before the welding procedure is begun all the foreign materials should be removed from the beveled ends. If any of the beveled edges of the pipe is 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 the pipe containing such defect shall be segregated, repaired or removed from the line.

5.4.2 Welding Procedure

Prior to start of production welding, a pipe welding procedure should be established, qualified and recorded for submission. All positions welds shall be made with the pipe resting on suitable and sufficient number of skids with the work clearance as specified. The number of beads required shall be governed by the wall thickness of the pipe, provided that the completed 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 built up with reinforcement at the root.

The hot pass should 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 from all scale. The minimum and maximum limits of reinforcement and the width of completed welds should be in accordance with relevant standards. After completing every pass, the same shall be cleaned and flattened by grinding and power brushing.

Interruption between first pass and second pass and to third pass should be as approved Welding procedure. After completion of the third pass the wielding can be suspended, 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 is done and all the surface defects are 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.

5.5 Non-Destructive Testing

5.5.1 Radiography Testing (RT)

Radiographic examination is done by using x-rays and Gamma rays. The acceptable limits of defects and removal of defects shall be as per the relevant codes of fabrication.

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 cannot 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.

5.5.1.1 Case 1 – By using Internal X-Ray Crawler (Single wall – Single Image 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.

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

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.

5.5.1.3 Case 3 - By Using Gamma-ray Equipment (Double wall, single image technique)

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 is positioned so that the radiation beam passes through the centre 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 source.

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.

5.5.1.4 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.

5.5.2 ULTRASONIC TESTING

This procedure intends to describe the ultrasonic test for detecting discontinuities in weldment and HAZ. All ultrasonic tests are performed manually by A scan pulse echo method employing contact through Couplant film.

5.5.2.1 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.

5.5.2.2 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 within the beam path shall be recorded in the report.

5.5.2.3DISTANCE AMPLITUDE CORRECTION (DAC) CURVE

The DAC curve are drawn for each variation in combination of nominal angle of reflection (probe angle) and frequency or when changing the probe or U.T. equipment or both.

5.5.2.4 Couplant

A couplant used will be of IOC or BP 2T oil mixed with white grease, and shall not be detrimental to material being inspected.

5.5.2.5 Methodology

- Place the probe on reference block to obtain a reflection from the required notch.
- Maximize the indication and adjust to approximately 80% of the full screen height using the gain control. Make a mark on the CRT at the peak of this indication using cursor setting. Note the gain in dB.
- Repeat the step 2, without disturbing the gain (dB) using reflection from the required reflector at different beam path length.
- In such a manner take at least three reflectors at three different path lengths and mark each. The gain (dB) noted in step 2 is DAC gain.
- Connect all points marked with a smooth curving line. This line is referred as DAC curve for that particular test system.
- Similarly plot 50% and 20% DAC by built in mechanism.
- Similarly, repeat steps 1 to 6 above for construction of DAC
- Curve from the Side Drill Hole (SDH).

5.5.2.6 EXAMINATION

Scanning for laminar reflection is permitted at the gain setting with 2nd BWE at 80% full screen height. Extent of scanning shall be 1.25x (longest skip distance to be used) Angle beam search unit to be scanned at perpendicular to the weld in orbital and swivel motions to obtain maximum amplitude. To final the transverse defect the angle beams search unit is scanned parallel to the weld. Probe additional to those given in above, can be used to supplement the technique or evaluation when deemed is necessary. The time base range can be either in terms of multiple of V path (normally 10/8 V) or a whole number on the upper side of 1.25 V path (for the angle used). All scanning will be done with minimum 10% overlap and not to exceed 150mm per seconds. Where suspected crack 'indication are observed transverse type scanning to be done on cap after flush grinding. Scanning sensitivity shall be at least 6dB more than-the normal sensitivity level for PRL.

5.5.2.7 Discontinuity location and size (defect valuation)

The 6 dB drop method is used to determine the length-and height. The maximum response from the defect is adjusted to 80% full screen height by adjusting the gain. Move the probe 'in forward direction so that the amplitude becomes half that is 40% FSH**.** Repeat the above method in backward direction and mark the position of echo on screen to detect the length of the discontinuity, above method to be used in left and right directions.

Depth and the location of the defect can be found by plotting the reflector indication size on the beam plotter, this chart can be made on a transparency and the profile of weld is made by manic, profile gauge or soldering wire. By sliding / overlapping the chart over the profile the location is known by distance calibration.

5.6 Joint Coating

5.6.1 Heat shrink sleeve

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.

5.6.2 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.

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

5.6.3 Application of heat shrink sleeve

Before installing the wraparound sleeve, the bare steel surface shall be pre heated over the surface to remove the moisture and checked using pyrometer. The solvent free the epoxy primer shall be mixed and applied prior to sleeve application. 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.

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 those 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.

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.

5.6.4 Inspection

5.6.4.1 Holiday Detection

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

5.6.4.2 Peel Test

Peel test is 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 is done as per coating 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

5.7 Lowering

Lowering shall follow as soon as possible, after the completion of joint coating of the pipeline after removal from ditch bottom all off cuts, pipe supports, stones, roots, debris, stakes, rock projections below underside of pipe and any other rigid materials which could lead to perforation or tearing of the coating. The thickness of the compacted padding shall not be less than 150mm. In those areas that are to be padded, the trench shall be at least 150mm deeper than otherwise required, and evenly and sufficiently padded to keep the pipe, when in place, at least 150mm above bottom of excavated trench.

All points on the pipeline where the coating has been in contact with either the skids or with the lifting equipment during laying shall be carefully inspected for damages, denting or other defects and shall be completely repaired.

The following works shall be completed before proceeding with the assembly and laying of overhead pipelines

- Construction of the pipe support structures or of mounts on supports.
- Paints and/or coating of the pipe work, as indicated in the engineering specification.

The pipe section should be placed on the trench bed without jerking, falling, impact or other similar stresses. In particular care must be taken that the deformations caused during the raising of pipeline from the support does not exceed the values for the minimum allowable radius of elastic curvature so as to keep stresses on steel & coating within safe limits.

Care shall be exercised while removing the belts from around the coated pipe after it has been lowered into the trench. Take precaution immediately after lowering to prevent the movement of pipe in the trench.

5.8 Backfilling

Backfilling is to be commenced only after post padding is done at least for 300 mm above the pipe. Backfilling shall not be done until the pipe and appurtenances have been properly fitted and the pipe is according to the ditch profile at the required depth that will provide the required cover and it is not riding upon any stone, hard core etc., and has a bed which is free of extraneous material and which allows the pipe to rest smoothly. Before start of backfilling the provision of anti-buoyancy measures must be ensured. De-watering if required will be carried out. The lowered section, if immediate backfilling is not possible a covering of at least 300mm of earth free of hard rock and hard lumps shall be placed over and above pipeline coating.

The backfill material shall be soil, sand, clay or other materials containing no materials, which could damage the pipe and/or coating or leave voids in the backfilled trench. Each completed layer of backfilling shall be carefully deposited. The surplus material shall be neatly crowned directly over the trench and the adjacent excavated areas on both sides of the trench to such a height, which will, provide for future settlement of the trench backfill during the maintenance period and thereafter.

When the trench has been dug through driveways or roads, all backfilling shall be executed which will be thoroughly compacted. Warning mat above 300mm padding shall be provided prior to backfilling above padding through over the trench. Back filling in steep areas where slope is 10% or more shall be provided with breakers. These breakers will consists of grout bags filled with 4:1 sand: Portland cement as per direction.

5.9 Tie in welding

Summary of proposed WPS for Tie in Welding

Process & Type	SMAW & Manual
Material	API 5L Gr X52
Diameter and wall thickness of pipe	24" & 7.9 mm 18" & 6.4mm
Qualified range for diameter & wall thickness	12.75"OD & 4.8mm-19.1mm
Joint Design	Single "V"
Filler material and no of passes	Root-E6010 (3.2mm) Hot &Cap-E7010 (4.0mm) Filling-E7010 (4.0mm)
Position	5G
Direction of welding	Root – Up hill Other – Down hill
Cleaning and grinding	Power brushing, grinding and chipping
Preheat/Type of heating	100 deg c by LPG Heating/LPG flame torch
Inter pass temperature	Min 150 deg Celsius to max 250 deg Celsius
Temperature checking	Crayon and pyrometer

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. When a welded section 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.
The tie-in operation includes necessary cutting, beveling, grinding of pipe weld seams, line-up, cleaning, welding, priming, coating and wrapping, lowering in, backfilling for the tie-portion as per standard practice and approved procedures. Necessary widening of the trench should be carried out as per requirement.

Field welding of pipeline Tie-In joints shall be done as per Qualified Welding Procedure Specification .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. An angle of repose of 100^0 at such area is preferred.

Alignment of the Tie-In joint shall be done using external clamp capable of removing offset and misalignment shall be minimized. Seam orientation of welded pipe shall be selected to ensure that the longitudinal welds shall be staggered in the top 90^o of the pipeline or ¼ th of the circumference of the pipe whichever is the less. In cases not meeting above requirement, at least a distance of 250 mm shall maintain between two welded seams. In case the seams come closer than as defined above, a pup piece of minimum 1.0 m shall be used. For pipes of same wall thickness the offset shall not exceed 1.6 mm.

All Tie-In joints shall be welded in one heat cycle. While welding is in progress, care shall be taken to avoid any kind of movement of the components / pipe, shocks vibration and stresses to prevent occurrence of weld cracks. Electrode starting and finishing points shall be staggered from pass to pass. All finished welds shall be visually inspected for parallel and axial alignment of the work, welds, surface porosity and other surface defects, etc. All tie-in welds shall be 100% radio graphed.

5.10 Hydrotest Inspection

Hydrostatic test is performed on the entire length of the pipe in accordance with approved Hydrostatic test diagrams for each test length which should be at the most 25 kms. The test will 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.

5.10.1 Test duration and pressure

The duration of hydrostatic test must be a minimum of 24 hours after stabilization and the test pressure as indicated. The maximum base pressure should be higher than the one resulting in a hoop stress corresponding to 90% of SMYS of pipe material which is based on the minimum wall thickness in the test section. Minimum test pressure should be lower than the one resulting in a hoop stress corresponding to 85% of SMYS of pipe material which is based on the minimum wall thickness in the test section.

5.10.2 Procedure

Equipment and/or parts which need not or must not be subjected to the test pressures are disconnected or separated from the pipeline to be tested. The long segments of line exposed to atmospheric conditions, viz. Aerial lengths on piers, suspension bridges, etc., are tested separately. Test medium should be soft non-aggressive water. The water is filtered, not contaminated and free from sand and silt. Temporary piping which may be necessary to connect from source of water to its pumps and manifolds/ tankage is installed.

Before the start of filling operation the pipeline is cleaned by air driven pigs provided with spring loaded bushes and chisels to remove all mill scale rust/ sand from the inside of pipe section. For this purpose, temporary headers are attached to the pipeline for air cleaning. The number of pig runs to be made is decided depending upon the cleaning results.

After cleaning the pipeline using air, gauging is carried out by using gauging pig. The gauge plate diameter should be equal to 95% of inside diameter of the heaviest wall pipe in the test section. While computing the ID of heaviest wall pipe, pipe manufacturing tolerance is not to be considered. A 10mm thick aluminium plate is used for making gauge plate.

At the receiving end the gauging pig is inspected for any deformation, bent or damage which is an evidence of gauging pig failure .In such cases the gauging plate is repaired and made to repeat the procedure.

After the acceptance of gauging operation, the air header is cut and removed. Pre-tested test headers loaded with 3 four cup batching pig is welded to the test Section. Now introduce Un-inhibited water equal to 10% of the volume of test section to the first pig. The first pig is launched by introducing about 1.5 km uninhibited water. Then the second pig can be launched by pumping the inhibited water till the second pig is received at the other end.

5.10.3 Thermal Stabilization

After a check has been made to confirm if the pressure has attained at least 1 bar (g) on the highest section, thermal stabilization can be started. Thermal equilibrium between the pipeline and environment is checked using the thermocouples installed on the pipeline. Temperature readings are taken at 4 hours-intervals. Thermal stabilization is considered to have been achieved when a difference not higher than 1°C is attained between the average values of the last two readings.

5.10.4 Pressurization

Pressurization is performed in such a way that the rate should be constant and moderate not exceeding 2 bars/ min. A pressure gauge is installed parallel with dead weight tester.

The pressurizing shall be cycled according to the following sequence:

a) Pressurize to 50% of test pressure, hold pressure for 1 hour.

b) Drop pressure to static head of test section at test head.

c) Pressurize to 75% of test pressure, hold pressure for 1 hour.

d) Drop pressure to static head of test section at the test head.

e) Pressurize to test pressure.

During the pressurization to each test pressure, two tests shall be carried out for the air volume calculation of air volume in the pipeline under test. If there is a drop in pressure during the pressure hold stage as indicated above then the operation need not be done twice the line will be considered not capable for test.

5.10.5 Air volume calculation

In order to check the presence of air in the pipeline, two separate consecutive pressure lowering of 0.5 bar should be carried out. For calculation of air in the pipeline the second pressure lowering can be used, and the relevant drained water shall be accurately measured (V1). This amount measured is compared with the theoretical amount (Vp) corresponding to the pressure lowering that has been carried out, by using the procedure listed above .

If no air is present in the length under test:

$$\frac{V1}{Vp} = 1$$

In order that the above ratio is acceptable, it shall not differ from 1 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 V1 / Vp exceeds 1.06, the hydrostatic testing cannot go on.

5.10.6 Test

During the test period the following data is recorded.

- every one hour pressure measurements form dead weight testers.
- every two hours the ambient temperature and the pipe temperature at the thermocouples.

Bleed-off water shall be accurately measured and recorded.

5.10.7 Acceptance

The hydrostatic test is considered passed if the pressure value 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 should be algebraically added to the pressure value as read on the meters. The pressure value thus adjusted is compared with the initial value and the test can be considered as acceptable if the difference is less than or equal to 0.3 bar

If test section fails to maintain the specified test pressure after isolation, the location of leakage or failure is determined. All leaks and failures within the pipe wall or weld seam is repaired by replacement of entire joint or joints in which leakage or failure occurs. After completion of repairs, the hydrostatic test can be repeated in full, as per specification. All cracks and splice resulting from failures should be coated with an application of grease to preserve the characteristics of failures from corrosion. Joint of failed pipes is marked with paint, with a tag indicating failure details, date and location of failure and pressure at which failure occurred.

5.11 Pre-commissioning checks

The pre-commissioning checks are carried out for the pipeline to verify that the Pipeline system has been mechanically completed in all respects.

- System Checks- the entire facility is checked with the latest P & IDs and other design specification codes.
- Checking of Field Instruments- All field instruments like control values, sectionalizing values, transmitters, solenoid values, shut down switches etc. should be checked physically and also for their intended application by simulating the operating conditions. This also include checking of different meters, gauges action of shutdown valves etc.
- Survey of the Pipelines- performed to confirm that proper fittings/ supports, route markets, Fencing around SV Stations etc. has been installed along the pipeline.
- Checking of Communications System- check that there is proper communications with adequate back-up power to ensure uninterrupted communication.
- Checking of Electrical Distribution System- to ensure safety and also to ensure an uninterrupted power supply during startup and normal pipeline operation.
- Checking of Instruments, Controls & Interlocks- check that instrument controls and interlocks are functional as per the normal operating conditions.
- Checking of Utilities- check that utilities like power, nitrogen, UPS system instrument air, etc. are available prior to startup.

5.12 Dewatering

The dewatering operation consists of number of dewatering pig runs when air is used as propellant for pig trains. Bi-directional cup pigs are used which will be suitable for traversing the entire length of the pipeline/ pipe segment being dewatered. The pig design should be such that it does not cause damage to the pipeline internal coating and continuous operation is performed. A suitable compressor for oil-free air with sufficient capacity and pressure is provided .No delay is made on removing the pig at the receiving end.

5.13 Swabbing

The swabbing operation reduces the remaining water in the pipeline to bring the pipeline into touch dry condition. Swabbing operation is carried out to ensure that there is no free water left inside the pipeline. This is done by driving number of swabbing pigs so that the weight increase in pig before and after the swabbing operation is not more than 25%. The swabbing operation is considered to be completed when it is established that there is no free water left in the pipeline and the pipeline has achieved a touch dry condition.

5.14 Inertisation

During the inertisation operation, the air left in the pipeline is replaced by nitrogen before admitting the product that the pipeline will ultimately carry. The inertisation operation will start as soon as possible after the swabbing operation has been completed. The maximum allowable oxygen content inside the pipeline shall be less than 1% by volume. Multiple separation pigs with nitrogen slugs in between are used for pipeline commissioning. At least three batches of nitrogen separated by four separation pigs are for inertisation of the pipeline during charging of gas in it. The combined nitrogen column length to be used for inertisation should be at least 5% of the total pipeline length.

5.15 Safety Review before start of commissioning

A pre-startup safety review is carried out of the pipeline system before permitting entry of product into the new facility.

5.16 Commissioning

Commissioning of pipeline is considered completed when the line is charged with product Naphtha and High speed diesel at operating pressure and the total system operated at normal operating parameters for a minimum period of 72 hours with all the instruments.

CHAPTER - 6

STATION PIPING

The Scope involves pipe fabrication and Erection of 24”and 18”pipe at the two stations i.e. Dispatch station inside Kochi Refinery and the Terminal station at BPCL installation Irumpanam.

6.1 Piping fabrication

The sequential activities and corresponding tasks are as follows:

6.1.1 Preparation of Isometrics

Isometric chart for both 24” and 18” are made based on which the Pipe fabrication and Erection is carried out. The isometric chart contains all details needed for the pipe fabrication including the pipe number, joint number, weld number. Makes it easy to find out where the T joints, Elbow joints and flanges would come in the Skid.

6.1.2 Materials

Pipe, pipe fittings, flanges, valves, gaskets, stud bolts etc. used in a given piping system shall be strictly followed as per “Piping material Specification”. Identification marks are provided on the pipe length fabricated/erected.

Where the ends of the piping components being welded have an internal surface misalignment exceeding 1.6mm, the wall of the component extending internally should be trimmed by machining so that the adjoining internal surface will approximately flush. All threaded joints must be aligned properly. The pipe entering union is true to centerlines so as to avoid forcing of union coupling during make up. Damaged threads are cut from the end of run and the pipe is re-threaded.

6.1.3 Cutting & edge Preparation

Cutting of pipes can be carried out by manual oxygen cutting machine, cutting machine and hacksaw cutting to suit type of material & site conditions. Pipe ends should be beveled by beveling machine & grinding. The bevel ends must be made smooth and uniform and dimension in accordance with the approved WPS. Surface must be free from tears, slag, rust and scale. Reinforcement pads for structural attachment are provided with an untapped hole of 6 mm diameter for venting and the hole is fuelled with grease on competition of testing and painting.

6.1.4 Pre-Fabrication

After receiving approved drawings for construction, pre-fabrication of spool can be started in accordance with the spool number of isometric drawings. The length of the particular spool may not exceed 12 Meter to ease the handling & erection.

6.1.5 Fabrication

All fabrication work is carried out in accordance with piping GAD, codes as specified in the Technical Specification .Fabrication must be done by an experienced fitter or fabricator. Bolt-holes of flanges shall straddle the normal centerline unless specified otherwise. Immediately before testing the piping, all threads of pipe & fittings should be thoroughly cleared of cutting, fuel oil or other foreign material. Seal welding of threaded connections when specified shall include the first block valve, cover all threads. Threaded connections which are frequently subjected to testing and maintenance should not be seal welded. Where socket weld fittings or valves are used, pipe shall be spaced approx. 1/16" to avoid bottoming. Trimming must be done on piping components having an internal surface misalignment exceeding 1.6mm after welding.

6.1.6 Marking

Marking on the pipe includes dimension (NPS, Schedule & Length) and spool as designed on the spool drawing. If the original material identification is cut or the material is divided into two or more pieces then the Heat No.is transferred to each of the pieces. The identification for each pipe shall be punched as well as painted with the Line No. Taking the entire cutting shall do the marking of the pipe for pre fabrication and shrinkage allowances into account minimum 100 mm. of pipe length shall be kept for field tolerance at the free end of pipe.

6.1.7 Dimensional Tolerances

Dimensional Tolerances for piping fabrication are considered as per Standard Specification and dimensions shown on the drawings.

6.1.8 Pipe Joints:

The pipe joint to be adopted is specified by the piping class of each line. However in general,

- Joining of lines 2" and above shall be done by butt weld.
- Joining of lines 1-1/2" and below shall be done by socket weld/butt weld/threaded joint as per MECON Piping Material Specification and approval of TPIA.

- Flanged joints shall be done for connection to valves and wherever required for ease of erection & maintenance.

6.1.9 Butt Welded & Socket Welded piping

Is carried out as per Specified procedure

Welding Procedure Specification for station Piping

Process & Type	SMAW & Manual
Material	API 5L Gr X52
Diameter and wall thickness of pipe	24” & 11.1 mm
	18” & 9.5mm
Qualified range for diameter & wall thickness	12.75”OD & 4.8mm-19.1mm
Joint Design	Single “V”
Filler material and no of passes	Root-E6010 (3.2mm)
	Hot &Cap-E7018 (2.5mm)
	Filling-E7018 (3.15mm)
Position	6G
Direction of welding	Root – Up Hill
	Other – Up Hill
Cleaning and grinding	Power brushing, grinding and chipping
Preheat/Type of heating	100 deg c by LPG Heating/LPG flame torch
Inter pass temperature	Min 150 deg Celsius to max 250 deg Celsius

6.1.10 Flange Connection

All flanges facings shall be true and perpendicular to the axis of pipe to which they are attached. Wherever a spectacle blind is provided and tapping for the jackscrews in flange shall be done prior to welding to pipe. Flange bolt holes shall straddle the normal centerlines into different orientation is shown in the drawing.

6.1.11 Branch Connection

Branch connections are made as indicated in Piping Material Specification and Reinforcement pads are provided wherever indicated as in the drawings/specifications.

6.1.12 Forging/Forming

Forging and forming of small bore fittings shall be as per ASME B 31.3.

6.1.13 Cutting/Trimming of Standard fittings & pipes

Fabrication components are cut/rimmed/edge prepared wherever required to meet the fabrication and erection requirements, as per drawing and instruction.

6.1.14 Shop Fabrication and Pre-Fabrication:

This is carried out to minimize work during erection to extent possible with proper identification marks and preservation.

6.1.15 Miscellaneous

Miscellaneous elements like elements, interlocking arrangements of valves, operating platforms etc. required for Station Piping works are fabricated as per instruction of Engineer-in-charge.

6.2 Piping Erection

6.2.1 Pre-fabrication & Field Assembly

Extent of pre-fabrication is decided by the site in charge depending upon the transportation and actual site condition.

6.2.2 Supports

Location and design of pipe supports should be as per approved drawings and support drawings. Temporary supports installed for alignment, erection and assembly are to be removed on completion of works.

6.2.3 Equipment Hook-up

Hook-up shall be carried out after ensuring that there is no undue stress that may be induced in the system.

6.2.4 Hook-up Methodology

Line should be flushed three times before the work starts. After which the insulation joints at the station is disconnected. Then the required pit is taken, the pit should be in such a way that dewatering could be done easily. Two pits are made one of which is a wide pit, that pit will take on the portion where the hoop up work carried on. Another pit is taken which is a deep pit after the hook up portion. The wide pit should have a slope such that the water in the pit could flow easily to the deep pit. From the deep pit dewatering is carried out.

6.3 Dewatering

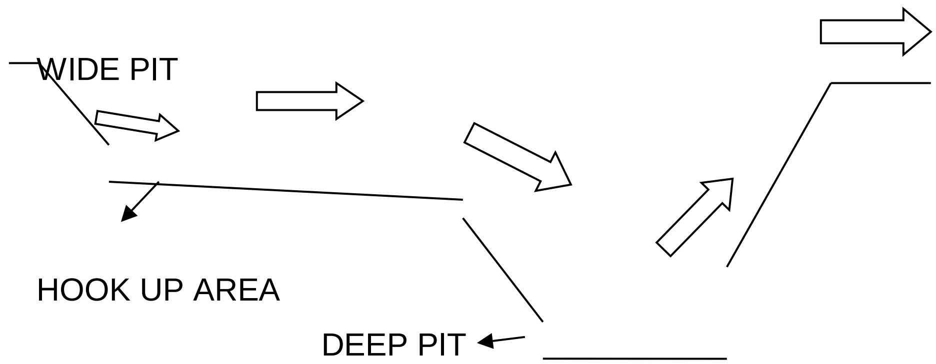

Figure 15 Dewatering

Provide screening in the working area using the fire resisting sheet. All the cutting activities are done by the cold cutting method that is cutting tool should be made up of brass. Four people will be paralleley engaged in cutting activity. Before the cutting works gets starts clean the existing pipe and Ultrasonic test should be taken.

6.4 Mud packing

Mud packing is the method used for diverting the gas vapours coming directly to welding area. At first make two round plates having almost the same diameter of the existing pipe. Make required holes on both plates for bolt insertion. Next weld nuts in that hole. Then make one more hole on the top position of plate, insert into it a small pipe and weld. After this push the plate nut side faced inside the existing pipe such that the other end of the pipe will be open to the atmosphere at some height from the existing pipe. Fill the pushed area with mud. Now place the next plate and push it, tight it with nut and bolt. After which some time is allowed for the curing of mud. When the setup is prepared and ready check whether any gas leak is there if not proceed the work

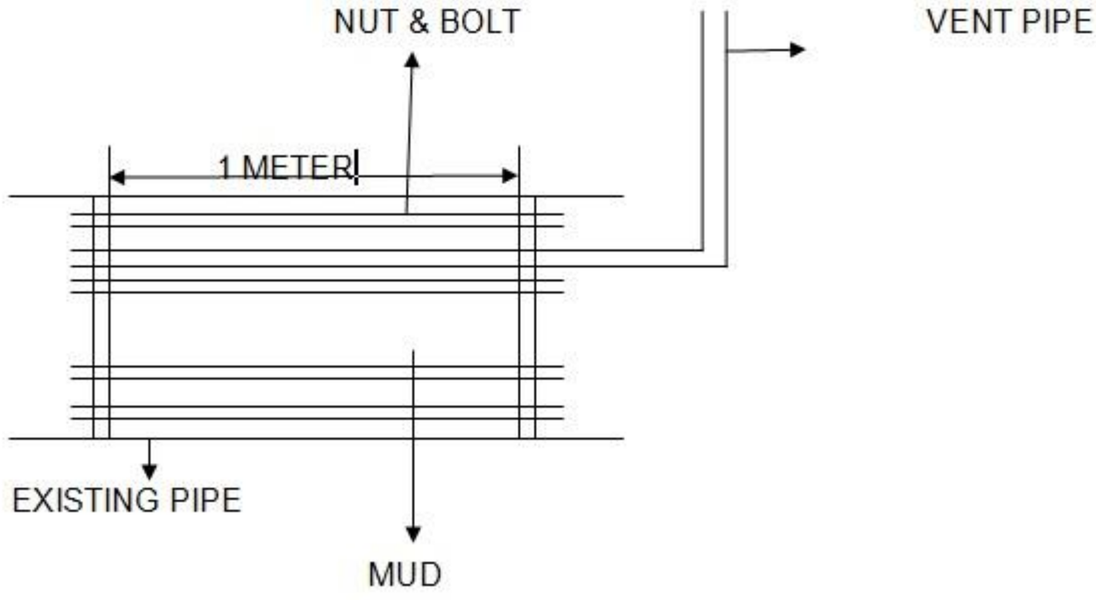

Figure 16 Mud Packing

In the second phase edge preparation of the existing pipe is done and fit-up is carried out. The root gap is accurately checked with the qualified welding procedure and confirmed after which the qualified welders will carry out welding. While welding is in progress, care is taken to avoid any kind of movement of the components / pipe, shocks vibration and stresses to prevent occurrence of weld cracks. Electrode starting and finishing points are staggered from pass to pass. All finished welds are visually inspected for parallel and axial alignment of the work, welds, surface porosity and other surface defects, etc. The pipe will be welded with slip-on flange, for the first pass DPT is required. If the DPT test gets passed then clean the weld surface and proceed on with welding, Header erection, Valve erection, Gasket erection.

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6.5 Erection

After radiography, clearance and shop priming for erection of pipe spool shall be done. Before the erection of pipe spool all the fitting and valves should be available at site with their respective fasteners and gaskets. The actual size is calculated after the erection of all material in accordance with isometrics drawing and/or P & I diagram. For proper pipe supporting the pipe supports are erected along with spool erection. The extra length of the pipe can be cut to suit the site requirement .The fabrication and welding procedures are as per the approved procedures for prefabrication & welding. The final tightening of the fasteners is done after erection welding. During the welding all valves must be in open mode. After the completion of welding, visual inspection and radiography of the welded field joints are perform.

Before erection all prefabricated spool pieces, fittings are cleaned inside and outside by suitable means. Pipe to pipe / structure / equipment distances / clearance shown in the drawings are followed as this clearance may be required for the free expansion of piping / equipment.

CHAPTER - 7

7. HORIZONTAL DIRECTIONAL 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.

7.1 Scope of Work

Bharat petroleum Corporation limited (BPCL) proposes to lay underground pipelines of Naphtha and HSD pipeline with Horizontal Directional Drilling of about 125 meters across the Chitrapuzha river. The site appears to be between the Kochi Refinery Dispatch station TP-00 and the Turning point TP-01.

Table 16 Carrier Pipe Details

Diameter (mm)	Thickness (mm)	Length (m)	Type of Coating	Location
457.2 OD (18")	9.5	125	3 Layer PE coated pipes	Chitrapuzha River crossing
609.6 OD (24")	11.1	125	3 Layer PE coated pipes	Chitrapuzha River crossing

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

7.2 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

- Preparation of hard standing area as to give suitable safe working conditions for all operations and personnel.
- Providing a security fenced enclosure for the rig side drilling area.

- Construction of Drilling Fluid Lagoons, bonded as required with pedestrian fenced perimeter.
- 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

- 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.
- 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.
- Before filling water in the pipe section, all NDT pipe log book (except joint coating) must be completed.
- 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.
- Pipeline section shall be gradually pressurized to the test pressure and intermediate check shall be done for any possible leakages.
- 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.
- After acceptance of test the section is depressurized and water is removed completely from the pipeline section.
- 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.

7.3 HDD Operations

An HDD operation normally falls into five major sections as:

- Mobilization and rig setup
- Pilot hole drilling
- Pre-reaming stages
- Pull back operation
- 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

- Transmitter
- Receiver (The walkover unit)
- 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

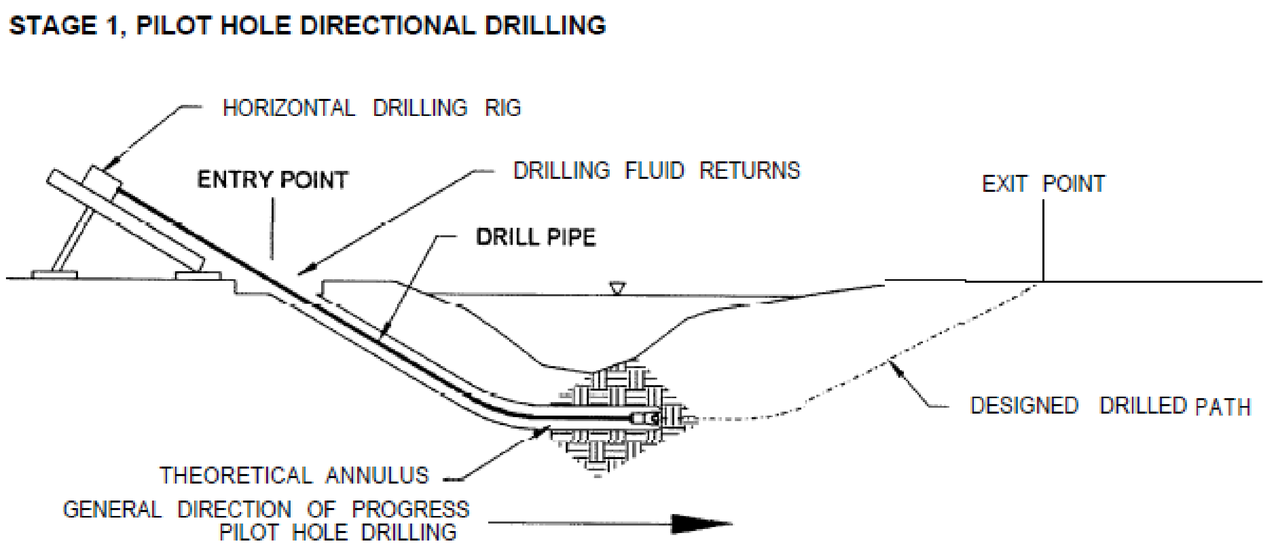

Figure 17Pilot hole Drilling

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.

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.

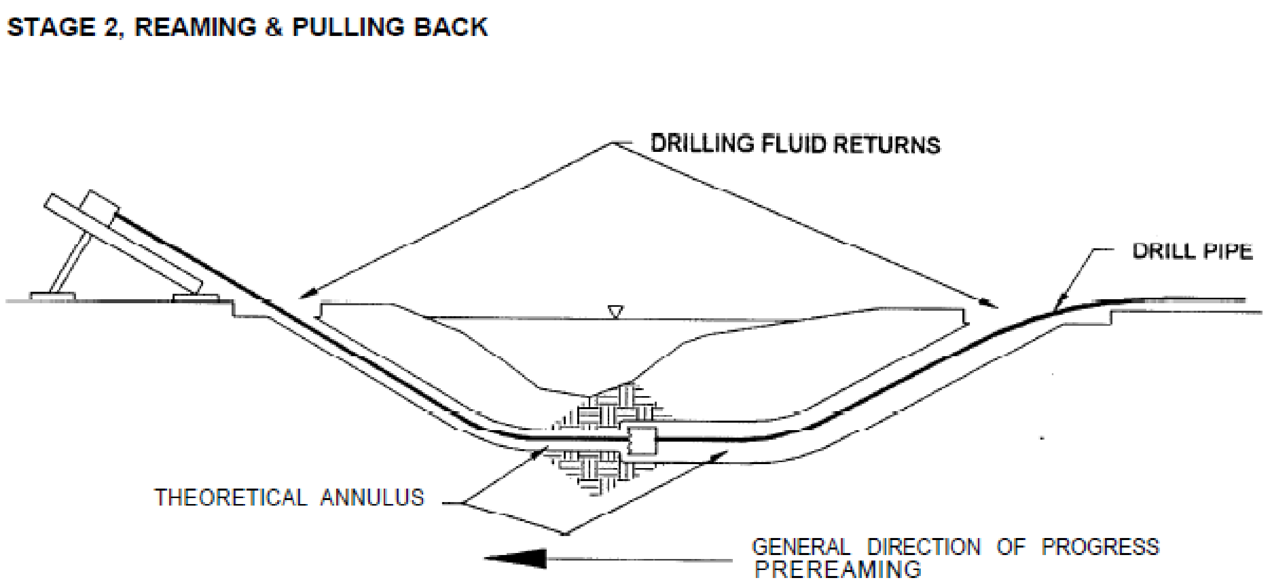

Figure 18 Reaming

Pulling force and time

The design of the drilling profile will support a relatively low pull force by avoiding any tight Curvature as well as getting support from the down hole weight of the pipe string. The estimated Pull time for the crossings will vary with the string length.

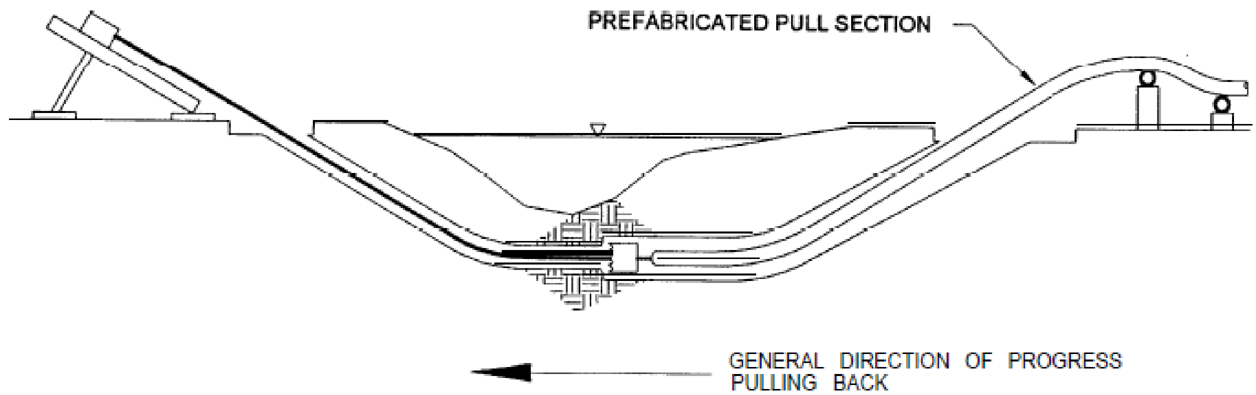

Figure 19 Pulling Back

Final Hydrostatic Test

The complete crossing section is tested after installation. The test pressure should be as 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.

7.4 Design Procedure for Uncased Pipeline crossing, of Highways and Railway Crossing by HDD method:

Design: To ensure safe construction and operation, the stresses affecting the Uncased pipeline must be accounted for comprehensively, including, both circumferential and longitudinal stresses. It consists of the following steps:

- Begin with the wall thickness for the pipeline of given diameter approaching the Crossing. Determine the pipe, soil, construction and operational characteristics.
- Use the Barlow formula to calculate the circumferential stress due to internal Pressure, SH (Barlow). Check SH, against the maximum allowable value.
- Calculate the circumferential stress due to earth load.
- Calculate the external live load, w and determine the appropriate impact factor.
- Calculate the cyclic circumferential stress and the longitudinal stress due to live Load.
- Calculate the circumferential stress due to internal pressure.
- Calculate the Radius of curvature.
- Calculate the bending stress.
- Calculate the total effective stress.

7.5 Design Criteria for 24" Pipeline

Outside Diameter	**Do**	**-**	**609.6 mm**
Inside Diameter	**Di**	**-**	**587.4 mm**
Wall Thickness	**T**	**-**	**11.1 mm**
Moment of Inertia	**I**	**-**	**0.0009 mm^4**
Weight of Pipe in Air	**Wt**	**-**	**163.90 kg/M**
Cross Section of Pipe	**As**	**-**	**0.3464 M^2**
Modulus of Elasticity	**E**	**-**	**2 x10^5 N/mm^2**
Radius of Curvature	**R (Assumed)**	**-**	**1250 M**
Co-efficient of Drag	**μd**	**-**	**239 N/M^2**
Mud density	**dm**	**-**	**1280 Kg/m^3**
Proposed length	**L**	**-**	**120 M**

Entry Angle			**5 degree**
Exit Angle			**4 degree**
Hydrotest pressure	**P**	**90 kg/cm²**	**8.81 N/mm²**
Design Pressure	**P**	**14 kg/cm²**	**1.37 N/mm²**
Weight of drill pipe	**-**	**35.00 kgs**	**35.00 Kgs**
Rig pull back capacity	**-**	**35.00 tons**	**35.00 tons**

Buoyancy of steel pipe in down hole

= $\pi/4 \times Do^2 \times$ Density of Drilling Fluid

Wb = $0.785714286 \times 0.6096^2 \times 1280 = 373.40$ kg/M

Total Weight of Steel Pipe in Down Hole

= (Wt. of Pipe) - (Buoyancy of Pipe in Down Hole)

= 163.90 – 373.40

= 209.49 kg/M

Buoyancy Force

= μ F x N

= μ (Buoyancy force x proposed length) x N

= 0.2 x (209.49 x 120) x 9.806

= 49303.38 N

Bending Moment

$$= \frac{EI}{R}$$

$$= \frac{\pi}{64}\left(Do^4 - Di^4 \right) = 0.0009$$

$$= \frac{2 \times 10^{11} \times 0.0009}{1250}$$

= 1496302.622 NM

Pulling Force calculation

Due to Buoyancy Force

F1 = μ F x N

= μ (Buoyancy force x proposed length) x N

= 0.2 x (209.49 x 120) x 9.806

= 49303.38 N

Due to Curvature

F2 = 4μ x Bending moment

½ x 2π /360 (Q enter R + Q exit R)

$$= \frac{4 \: x \: 0.36 \: x \: 1496302.6}{0.5 \: x \: 2 \: x \: 3.14/360 \: (5 \: x \: 1250 + 4 \: x \: 1250)}$$

= 21958.48 N

Due to Cohesion

F3 = μd x π/2 x Do x L

= 239 x 1.57 x 0.610 x 120

= 27448.82 N

Pulling Force

= **F1 + F2 + F3**

= 49303.38 + 21958.48 + 27448.82

= 98710.69 N

Considering Safety Factor & Drill pipes & Reamer Wt.

= 1.5 times x pulling force + Drilling force + Reamer Wt.

= 15099.53399+ 700 + 750

= 16.55 tons

35 Ton Rig Safe

The calculated value for pulling load is lower than the specified value

<u>**Stress Calculation**</u>

Allowable stress

S = 95 % of SMYS

= 95 x 52000

= 49400 PSI (conversion factor = 145.037)

= 340.60 N/mm²

Bending Stress

$$= \frac{ED}{2R}$$

$$= \frac{200000 \times 609.6}{2 \times 1250000}$$

= 48.77 N/mm²

Tensile stress

$$= \frac{\text{pulling force (N)}}{\text{Cross section area } (M^2)}$$

$$= \frac{98710.69}{0.346 \times 10^6}$$

= 0.28 N/mm²

Longitudinal stress during installation

Allowable stress > Tensile stress + bending stress

> 0.28 + 48.77

340.60 > 49.05 N/mm²

This is very much lower than allowable stress, thus safe

MAXIMUM EQUIVALENT STRESS DURING FINAL HYDROSTATIC TEST

Hydrotest Stress

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

$$= \frac{8.81 \times 609.6}{2 \times 11.1}$$

= 241.92 N/mm²

Bending stress = 48.77 N/mm²

Post Installation

Allowable stress > Bending stress + Hydrotest stress

> 48.77 + 241.92

340.60 > 290.69 N/mm²

This is lower than allowable stress, thus safe.

MAXIMUM EQUIVALENT STRESS DURING SERVICE

Minimum Allowable Radius of Curvature of Pipeline

$$= \frac{E \times Do/2}{(0.75\ x\ 95\%\ of\ SMYS\ ) - ((\Pi\ x\ Do^2\ x\ p)\ /\ 4\ x\ As)}$$

$$= \frac{2\times10^5\times609.6/2}{(0.75\times95\%\ of\ 52000) - (\frac{3.14\times609.6^2\times 1.370}{4}\times0.3464)}$$

= 60960000/ 258.1951148

= 236.1 M (radius of curvature for the pipe in full stressed condition)

= 236.1 x 1.85 times

= 436.785 M

This is lower than assumed Radius of Curvature of 1250 M

Therefore at this radius of curvature value the pipe could be easily bend to form the profile

7.6 Design Calculation for 18" pipeline

Outside Diameter	**Do**	**-**	**450.7 mm**
Inside Diameter	**Di**	**-**	**431.9 mm**
Wall Thickness	**T**	**-**	**9.4 mm**
Moment of Inertia	**I**	**-**	**0.0003mm^4**
Weight of Pipe in Air	**Wt**	**-**	**102.34 kg/M**
Cross Section of Pipe	**As**	**-**	**0.1852 M^2**
Modulus of Elasticity	**E**	**-**	**2 x10^5 N/mm²**
Radius of Curvature	**R (Assumed)**	**-**	**1250 M**
Co-efficient of Drag	**µd**	**-**	**239 N/M²**
Mud density	**dm**	**-**	**1280 Kg/m²**
Proposed length	**L**	**-**	**120 M**

Entry Angle		**-**	**5 degree**
Exit Angle		**-**	**4 degree**
Hydrotest pressure	**P**	**90kg/cm²**	**8.81 N/mm²**
Design Pressure	**P**	**9 kg/cm²**	**0.88 N/mm²**
Weight of drill pipe	**-**	**35.00 kgs**	**35.00 Kgs**
Rig pull back capacity	**-**	**35.00 tons**	**35.00 tons**

Buoyancy of steel pipe in down hole

= π/4 x Do^2 x Density of Drilling Fluid

Wb = 0.785714286 x 0.4507^2 x 1280 =204.11 kg/M

Total Weight of Steel Pipe in Down Hole

= (Wt. of Pipe) - (Buoyancy of Pipe in Down Hole)

= 102.34 – 204.11

= 101.76 kg/M

Buoyancy Force

= µ F x N

= µ (Buoyancy force x proposed length) x N

= 0.2 x (101.76 x 120) x 9.806

= 23949.31 N

Bending Moment

$$= \frac{EI}{R}$$

$$= \frac{\pi}{64} (Do^4 - Di^4) = 0.0003$$

$$= \frac{2 \times 10^{11} \times 0.0003}{1250}$$

= 48000 NM

Pulling Force calculation

Due to Buoyancy Force

F1 = µ F x N

= μ (Buoyancy factor x proposed length) x N

= 0.2 x (101.76 x 120) x 9.806 = 23949.31 N

Due to Curvature

F2 = 4μ x Bending moment

½ x 2π /360 (Q enter R + Q exit R)

$$= \frac{4 \ x \ 0.36 \ x \ 48000}{0.5 \ x \ 2 \ x \ 3.14/360 \ (6 \ x \ 1250 + 6 \ x \ 1250)}$$

= 528.30 N

Due to Cohesion

F3 = μd x π/2 x Do x L

= 239 x 1.57 x 0.4507 x 120

= 20293.93 N

Pulling Force

= **F1 + F2 + F3**

= 23949.31 + 528.30 + 20293.93

= 44771.54 N

Considering Safety Factor & Drill pipes & Reamer Wt.

= 1.5 times x pulling force + Drilling force + Reamer Wt.

= 6715.731 + 700 + 750

= 8.16 Tons

<u>Stress Calculation</u>

Allowable stress

S = 95 % of SMYS

= 95 x 52000

= 49400 PSI (conversion factor = 145.037)

= 340.60 N/mm²

Bending Stress

$$= \frac{\mathrm{ED}}{2\mathrm{R}}$$

$$= \frac{200000 \times 450.7}{2 \times 1250000}$$

$= 36.05\ N/mm^2$

Tensile stress

$$= \frac{\text{Pulling force (N)}}{\text{Cross sectional area}(M^2)}$$

$$= \frac{44771.54}{0.185 \times 10^6}$$

$= 0.24\ N/mm^2$

Longitudinal stress during installation

Allowable stress > Tensile stress + bending stress

$> 0.24 + 36.05$

$340.60 > 36.29$

This is very much lower than allowable stress, thus safe

MAXIMUM EQUIVALENT STRESS DURING FINAL HYDROSTATIC TEST

Hydrotest Stress

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

$$= \frac{8.81 \times 450.7}{2 \times 9.4}$$

$= 211.20\ N/mm^2$

Bending stress = $36.05\ N/mm^2$

Post Installation

Allowable stress > Bending stress + Hydrotest stress

$> 36.05 + 211.20$

$340.60 > 247.25\ N/mm^2$

This is lower than allowable stress, thus safe.

MAXIMUM EQUIVALENT STRESS DURING SERVICE

Minimum Allowable Radius of Curvature of Pipeline

$$= \frac{E \times Do/2}{(0.75\ x\ 95\%\ of\ SMYS\ ) - ((\ \Pi\ x\ Do^2\ x\ p)\ /\ 4\ x\ As)}$$

$$= \frac{2\times10^5\times450.7/2}{(0.75\times95\%\ of\ 52000)-(\frac{3.14\times450.7^2\times0.88}{4}\times0.4665)}$$

$$= \frac{45070000}{258.5909703}$$

= 174.29 M

= 174.29 x 1.85

= 322.43 M

This is lower than assumed Radius of Curvature of 1250 M

Hence the proposed 18inch pipe can easily make the profile at this value of curvature

CHAPTER - 8

CATHODIC PROTECTION SYSTEM

Cathodic protection is defined as the use of direct electric current to stop corrosion. The goal of cathodic protection is to make a cathode of the pipeline. This is done by impressing a direct electric current on the pipe and providing an anode which will corrode instead. This will not only reduce corrosion, it will stop it.

8.1 Scope of work

Table 17 Carrier pipe Details

Diameter (mm)	Thickness (mm)	Length (m)	Type of Coating	Chainage From (m)	Chainage To (m)
457.2 OD (18”)	6.4	2600	3 Layer PE coated pipes	0.00	2600.0
609.6 OD (24”)	7.9	2600	3 Layer PE coated pipes	0.00	2600.0

Table 18 Casing pipe and Crossing Details

Diameter (mm)	Thickness (mm)	Length (m)	Type of Coating	Location / Chainage
(a) Casing Pipe 24” for 18” carrier pipe	10	80	Uncoated/painted	Irumpanam Railway crossing
(b) Casing Pipe 32” for 24” carrier pipe	12	80	Uncoated/painted	Irumpanam Railway crossing

8.2 Cathodic Protection Design Criteria

The Temporary Cathodic Protection System (TCP) is designed and will be commissioned to meet the following criteria.

- The pipe to soil potential measurements will be between -0.95 volts and -1.5 volts with respect to saturated Copper / Copper Sulphate Reference Electrode.
- Alternatively the pipeline shall be considered protected when a minimum -300 mV shift will indicate adequate levels of cathodic protection for the pipeline.
- In rare circumstances a minimum polarization shift of (-) 100mV will indicate adequate levels of cathodic protection for the pipeline.

8.3 Soil Resistivity Survey

The corrosion of underground metallic structures is an electrochemical phenomenon accompanied by formation of corrosion cells. The number of corrosion cells formed and their severity depend on the conductivity of the soil surrounding the pipeline.

The measurement of soil resistivity is a fairly reliable means for assessment of soil corrosivity. When the corrosivity of the soil surrounding a pipeline has to be determined the soil resistivity readings are usually taken at the depth of the pipeline. A soil resistivity survey along the Right Of Way of pipeline when taken at a uniform spacing enables statistical analysis of the set readings to obtain a representative idea of corrosive conditions around the line

Soil resistivity values up to a depth of 10 meters at the proposed permanent ground bed location (three locations) which will be ideally suited for the proposed pipelines is obtained. All the three Locations were such a way selected that it will have a minimum 105m distance from the proposed pipelines for the uniform spread of CP System current during the entire design life.

The resistivity values obtained have been classified in 5 ranges according the corrosivity with them

Table 19 Resistivity and Corrosion

Sl.No	Range of Resistivity (ohm-m)	Degree of Corrosivity	Category Assigned
1.	0 to 10	Very Severely Corrosive	A
2.	> 10 and < 20	Severely Corrosive	B
3.	> 20 and < 50	Corrosive	C
4.	> 50 and < 100	Mildly Corrosive	D
5.	> 100	Progressively less Corrosive	E

8.4 Methodology

The soil resistivity readings were taken by a battery operated solid state null deflection type Soil Resistivity Meter using the 4 Pin Wenner Technique as described below

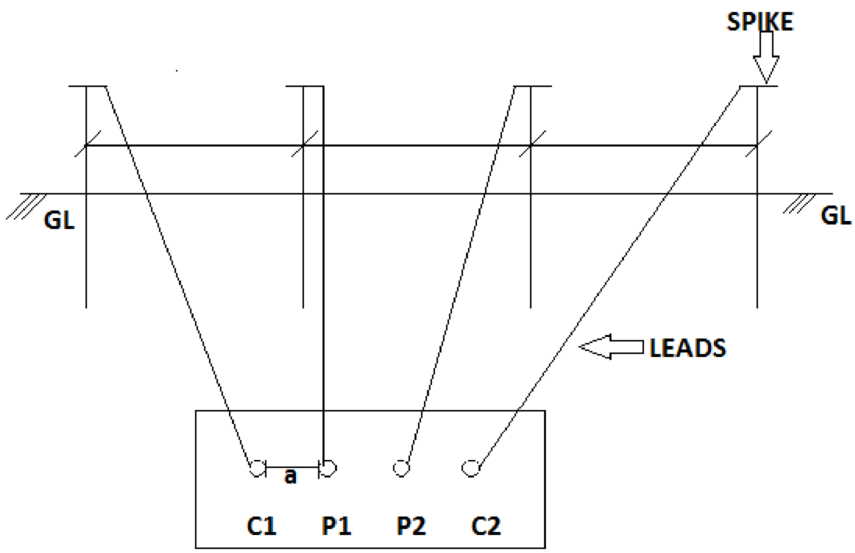

Figure 204 Pin Wenner

The 4 pin Wenner Technique of soil resistivity is the most commonly used technique for measuring soil resistivity at any depth in ‘situ’. Four E.C Grade Copper Non-Polarising spikes are driven into the soil at spacing of “a” as shown to measure the resistivity at a depth of “d”. The death of insertion shall not exceed d/20.

The outer spikes are connected to the current terminals C1 and C2 of the meter while the two inner Copper spikes are connected to the potential terminals P1 & P2. When the meter is in use a current circulates between C1 & C2 while the potential drop in the soil due to this current flow is picked up and received at terminals P1 & P2.

The average of soil resistivity up to depth “a” is then given by

$\rho = 2 \pi a R$

Where

ρ is Resistivity in Ohm-m.

2π is constant = 6.28.

A is the depth of measurement i.e. pin spacing in meters.

R is resistance in ohms measured in resistivity meter.

In order to get the true reading, the measurements are taken away from foreign metallic underground structures and earth current areas.

8.5 Permanent Cathodic Protection System

The readings were taken at three places at the proposed ground bed locations at pin spacing of 1.0m, 2.0m, 3.0m, 4.0m, 5.0m, 6.0m and 10m depth. Care was taken to ensure that measurement at a spot was not influenced by any foreign underground structures, presence of overhead lines and earth currents.

The proposed anode ground bed shall be installed at a depth of 1.5m and hence average of 1.0m and 2.0m was taken for calculating the soil resistivity of the proposed strata.

8.5.1 Design Calculation

For carrier pipe

Pipe length	**: 2.60 km (each).**
Outer diameter of pipelines	**: 457.2mm (18”) & 609.6mm (24”).**
Life of the C.P System	**: 30 Years.**
Type of C.P System	**: ICCP System with Titanium MMO Anodes.**

C.P Current Requirement

Surface Area

$S_a = (\pi) \times (d) \times (l)$

Where

S_a = Pipeline surface area (m^2)

d = Pipeline Diameter (m)

l = Pipeline length (m)

Total surface area of both the pipelines (S_a) = 8715 m^2

The soil resistivity data reveals that the proposed ROW is falling in corrosive Zone and the protective current Density of 0.125 micro ampere/ m^2 for PE coated pipeline is designed for the system. In addition we have also considered a safety factor of 30% in our design.

$I_t = (S_a)\ (I_{cd})\ (1.3)$

Where

I_t = CP current Requirement (Amp)

(S_a) = pipeline surface area (m^2)

I_{cd} = CP current density

1.3 = Safety Factor

Total requirement of C.P current for the pipeline (I_t) = 1.416 Amp

Anode Selection

Considering the latest trends in anode material, it is recommended to use Mixed Metal Oxide (MMO) coating on Titanium substrate as anodes**.**

Anode consumption Rate

The Anode consumption rate is extremely low and is not significant in determining the life of anode. MMO coating remains on the anode at the end of life and life is limited by the formation of a non-conductive oxide layer which is proportional to current density.

The titanium substrate of diameter 25.4mm (1.0”) and 500mm (19.685”) long coated with mixed metal oxide shall be used as anode. The current requirement for pipeline is calculated as 1.416 Amps. The consumption rate of anode is 2mg/A-Y and life is considered for 30 years.

Anode Required (Weight Basis)

The weight of the anode required for delivering current for 30 years is calculated as

W = C x t x I / F

Where

C = MMO Anode Consumption rate (2mg /A-Y)

t = time i.e. Life of anode (30 Years)

I = Total current (1.416 Amps)

F = Utilization factor

W = 2 x 30 x 1.416 / 0.8 = 106.20 mg

We use to have 6 micron coating of MMO over Titanium with the density of 2.77 gm/µm/m² or 2.77 x 6 = 16.62 gm/ m²

The surface area of the anode = 3.14 x 25.4 x 500 mm

= 0.039878 m²

Weight of MMO = 16.6 x 0.039878 x 1000

= 662.77 mg of MMO

Number of Anodes required = 106.20 / 662.7 = 0.16 No = 1 No of Anode

However as a design safety and to lower the ground bed resistance we have considered 15 numbers of Anodes.

Delivery current of each anode = 1.416 / 15 = 0.0944 Amps

= 2.367 A/ m²

The MMO anodes can withstand up to 538 A/ m² of anode surface.

Calculation of Anodes based on current density

CD = 59 x $t^{-0.36}$

Where

CD = Current density of anode surface area in A/ft²

t = Anode life in years

CD_{30} = 17.34 or 187 A/ m²

Based on this current limitation the No of Anodes is calculated as

$$N = \frac{I}{CD30 \times S}$$

$$= \frac{1.416}{187 \times 0.039878}$$

= 0.1898 Anode = 1 No of anode

However as a design safety we have considered 15 numbers of Anodes to bring down the ground bed Resistance.

Life of the Anode

The life of the Anode is calculated as

L = W x UF / I x CR

Where

L = Life of the Anode

W = Weight of the Anode (15 x 662.77 mg)

I = Total Current Required (1.416 Amps)

CR = Consumption Rate (2mg/A-Y)

UF = Utilization Factor (0.85)

L = (0.00994155 x 0.85)/ (1.416 x 0.0002) = 29.838 = 30 years

Ground Bed Resistance

The following formula is used for calculating the resistance of 15 Nos. of Anodes considered in Horizontal configuration Ground Bed.

$$Ra = \left(\frac{0.0052}{NL} \times \rho\right)\left(\ln\left(\frac{4L^2+4L\sqrt{(S^2+L^2)}}{ds}\right) + \frac{S}{L} - \frac{\sqrt{(S^2+L^2)}}{L} - 1\right)$$

Where

Ra = Resistance of ground bed

N = Number of anodes.

L = Length of anode including backfill in feet

S = Twice the depth of anode in feet

d = Anode diameter in feet

p = soil resistivity in Ohm.cm

ln = Natural Log function

$$Ra = \left(\frac{0.0052}{15 \times 7} \times 550\right)\left(\ln\left(\frac{4 \text{ x } 7^2 + 4 \times L\sqrt{(10^2+7^2)}}{0.666 \times 10}\right) + \frac{10}{7} - \frac{\sqrt{(10^2+7^2)}}{7} - 1\right)$$

Ra = 0.0272 × 3.085 Ω = 0.0839 Ω

Anode Tail Cable Resistance

Size of the Anode Tail Cable : 6Sq.mm

Length of the cable : 25 m

Resistance of the cable : $25 \text{ x } 1830 \text{ x } 10^{-6}$

= $45750 \text{ x } 10^{-6}$

Total resistance of 15 Nos anode cable = $\frac{45750 \text{ x } 10^{-6}}{15}$

= 0.003050 Ω

Resistance of Anode Tail Cable = 0.003050 Ω

Total Anode Ground bed Resistance including Anode Tail Cable Resistance = 0.0839 + 0.003050 = 0.08695 Ω

Resistance calculations for Header cables

a) Anode Header Cable

Type = 35Sq.mm XLPE insulated and PVC Sheathed single core copper Conductor

Length of the cable = 50m maximum

Anode header cable = 5.24 x 10^{-4} x 50

Resistance = 0.0262 Ω

b) Cathode Header Cable

Type = 35Sq.mm XLPE insulated and PVC Sheathed single core copper Conductor

Length of the cable = 100m maximum

Anode header cable = 5.24 x 10^{-4} x 100

Resistance = 0.0524 Ω

Total Circuit Resistance = 0.08695 + 0.0262 + 0.0524 Ω = 0.1655 Ω

Rating of Rectifier

D.C output current required = 1.416 Amps

Rectifier Voltage = Output current x Circuit Resistance x 150 % + 2 Volts (back emf)

= 1.416 x 0.1655 x 1.5 + 2

= 2.351 Volts

Considering the resistivity variations of soil from place to place a higher capacity rectifier of 50 Amps, 50 volts is recommended.

Installation Details of Anode

The system is designed with 15 Nos of MMO anodes. MMO anode will have a dimension of 25.4mm OD x 500mm long packaged in sheet steel canister together with coke breeze. The anode assembly shall be installed horizontally at a depth of 1500mm from the ground level.

The Anode is provided with 6mm² Single core XLPE/PVC Sheathed copper conductor. The anode tail cables shall be of adequate lengths for the direct termination at Anode Junction. The Anode Tail cables will be paralleley terminated in the anode junction box. The anodes shall be installed at a spacing of 15 feet (center to center of the anode) between them. Three locations for the ground bed installation were selected.

Permanent Copper Sulphate Electrode

Three Numbers of terracotta type $Cu/CuSO_4$ reference electrodes is installed near the pipeline current drain point and shall be connected with 4C X 2.5mm² copper conductor and terminated at Auto transformer unit for controlling the current flow in the pipeline and to maintain the required pipe to soil potential automatically.

T/R Unit Housing

The Auto controlled T/R unit having the output of 50V, 50 Amps single phase unit will be housed in a Non-hazardous area outdoor. The same can be housed near anode junction box in consultation with the concerned Authorities.

8.6 Temporary Cathodic Protection System

The readings were taken randomly at every 0.25 km i.e. at 14 locations for 2.6 km stretch along the proposed ROW at a pin spacing of 1.0m, 1.5m, 2.0m, 2.5m, 3.0m depth. Care was taken to ensure that measurement at a spot was not influenced by any foreign underground structure, presence of overhead lines and earth currents.

The pipeline is laid in such a way that there shall be top cover of 1.2 meter. Hence for calculating the average resistivity of the surrounding soil we have considered average resistivity at 1.50m, 2.0m, & 2.5m for TCP System Designing. While averaging the reading, location number-2 was not considered since the observed readings were relatively higher (because of rocky terrain) near chitrapuzha Soil resistivity survey revealed that the soil is of corrosive nature and observed pH values indicate that soil is moderately acidic in nature.

8.6.1 Design Calculations

The following calculations have been used to design the Temporary Cathodic Protection System.

Pipeline length : 2.60 Km (each)

Outer diameter of Pipelines : 457.2mm (18") & 609.6mm (24")

Life of the C.P System : 1 year

Type of C.P System : Sacrificial C.P System with Magnesium anode Material

C.P Current Requirement

Surface Area

$$S_a = (\pi) \times (d) \times (l)$$

Where

S_a = **Pipeline surface area** (m^2)

d = Pipeline Diameter (m)

l = Pipeline length (m)

Total surface area of both the pipelines (S_a) **= 8715** m^2

Current Requirement

The soil resistivity data reveals that the proposed ROW is falling in Corrosive Zone and the protective Current density of 0.15 micro ampere/ m^2 for PE coated pipeline is designed for the system. In addition we have also considered a safety factor of 30% in our design.

$$I_t = (S_a)\ (I_d)\ (1.3)$$

Where

I_t **= CP current Requirement (Amp)**

(S_a) **= pipeline surface area** (m^2)

I_d **= CP current density**

1.3 = Safety Factor

Total requirement of C.P current for the pipeline (I_t) = 0.170 Amp

Anode Weight Requirement (Based on weight)

The following formula has been used to calculate total anode weight requirement for the ground bed for Magnesium anode.

W = (I_t) x (THY) x (L)/ (Cr) x (Uf)

Where

W = Total Anode Weight (kg)

I_t = CP Current Requirement

THY = total Hours per Year (8760)

Cr = Anode Capacity for Magnesium anode (1100 Amp Hr/Kg)

L = Design Life (1 Year)

Uf = 0.5

W = (0.170) x (8760) x (1)/ (1100) x (0.5)

= 2.7 Kg

However in our design we have considered eight (8) Numbers of 4 kg Pre-packaged Standard Potential type and the same shall be connected one number each to all the proposed test stations excepting at Test station No.1 & 10 (end points) for the uniform distribution of current during the construction stage.

Cathodic Protection at cased crossings

Necessary care is taken in the design at the cased crossings for the carrier pipe inside the casing portion.

Details of cased crossings

Irumpanam Railway Crossing Chainage 1425 – 1530m (105m long)

- **Casing Pipe size for 18” = 24” (10mm thick)**
- **Casing Pipe size for 24” = 32” (12mm thick)**

The above casing pipes will not have external coating & wrapping similar to carrier pipe and have

Details of Additional Protection for the Carrier pipe inside casing

Extruded Zinc ribbon/ Arc anode is welded in between the insulators as per the drawing at 4 º clock – 8 º clock positions at the bottom of the pipeline.

Special provision at HT Crossing and pipelines running parallel to HT AC power transmission lines:

(a) The proposed ROW is running closely to HT power transmission line having rating of 110 KV between Chainage: 485.00m and Chainage: 668.00m and in the design we have considered two additional test points at the above mentioned chainages with “M” Type test station and will have provisions of Kirk cell and Zinc electrode to combat any fault current entering to our pipelines during transmission line fault.

(b) The C.P System will have the similar provision at 110 KV HT power line crossing at Chainage: 1025.0m

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Foreign Pipeline crossings

At the foreign pipeline crossing belonging to M/s IOC (near ROB) additional test point is considered and will have provision of link and variable resistor to regulate the discharge the current (if situation arises).

TCP Anode Installation

One number of Anode Shall be installed at all the Test stations excepting Test station No.1 & 10 vertically, in such a way that the top of the anode will correspond to the bottom of the pipeline.

The anode shall be installed 2.5m away from the pipeline. The anode tail cable shall be of XLPE/PVC 6Sq.mm unarmored type and shall be terminated inside the Test Station.

Cable to pipe connection

Cables from the pipeline will be connected by Thermite Welding method or any other approved exothermic process. Location for the joint will be identified and a square area of 25 x 25mm will be cleaned by removing coating and cleaning the surface with the help of a sharp Knife. The ends of the cable after removing the insulation will be placed above the surface. The welding is done as per the procedure. On completion of the welding the welding area is thoroughly checked any slack material (if any) removed and the jointed area will be epoxy encapsulated.

Regular Test Station & HT Crossing Test station

In order to check and monitor the effectiveness of the C.P system test stations will be installed at every 0.5 km interval and additionally at all major Road/Rail crossings and a HT Transmission line crossing.

8.7 C.P Commissioning Procedure

Pre Commissioning Test

Natural Pipe to soil Potentials will be taken before energizing the system. Before this is done the tests for the following will be recorded.

(a) Cables

    Cable No

    Voltage grade

    Conductor cross section

    Continuity check

(b) Insulation Test

    Checking of insulating joint for leakage, before and after energizing the system with insulation joint tester is carried out. Potentials at protected and unprotected side should be measured after energizing the system.

(c) Spark Gap Arrester

Location

Type

Rating

(d) Anode ground beds.

Location/ Test station number

Current output to the ground bed.

Commissioning

Natural pipe to soil potential shall be measured at each station location prior to connecting anodes to pipeline. The pipe to soil potential observation should be repeated after connecting in anodes and allowing sufficient time for polarization. The current output of the anode installation is measured to ensure that it does not exceed the output current capacity of the anodes. In case the anode output current exceeds the rated capacity the insertion of resistance element in the anode circuit inside test station must be controlled and the pipe to soil potential shall be rechecked for adequacy of protection. Additional anodes should be provided where required to achieve desired level of protection.

Interference Mitigation

Investigation should be made for stray current electrolysis of the pipelines, mutual interference between the pipeline and foreign pipelines/structures, interference on foreign pipelines/structures due to the CP of the pipeline and ground bed. There can be AC induction on pipeline due to 66KV and above overhead HV/EHV line, interference due to high voltage DC line, HVDC groundings, electric tractions etc.

Where transmission lines cross the pipeline or run parallel within or more than 25m from the pipeline, AC voltage measurements are made on the pipeline to find out continuous induction of voltage. In case of induced voltage beyond safe limit the pipeline should be grounded.

In case of fluctuating stray current, foreign pipelines (unprotected or protected by CP system) running parallel to the pipeline in same trench or very near to the pipeline and are not bonded to the pipeline ,investigations must be done on different locations to find out the stray current source and current discharge points on both pipelines.

Mitigation measures are provided depending upon the type of stray current electrolysis/interference. These include installation of bond with variable resistor, diodes, installation of galvanic anodes for auxiliary drainage of current, adjustment/relocation (if possible) of offending interference source, provision of electrical shield etc., depending on the type of interference.

Bonding with foreign pipeline/structure as a mitigation measure can be provided where the owner of the foreign pipeline/structure has no objection. Where bonding is used for mitigation, bonding resistor should be adjusted for optimum value for minimum/no interference. Galvanic anodes installed can be sized for the design life specified for Permanent CP system.

System Monitoring

The temporary C.P system is monitored at all test stations once in a month for healthiness/adequacy of protection for a period of three months from the date of commissioning. During the period if any deficiency/interference in protection system is noticed the same shall be rectified/augmented by additional anodes as required.

CONCLUSION

Following are the observations of the study on Execution work of laying 24" and 18" pipelines carrying Naphtha and High speed diesel from Kochi Refinery Ambalamugal to BPCL installation Irumpanam.

- The pipeline route feasibility study was conducted for which three alternate routes were suggested. Based on the pipeline route selection criteria the optimum route was selected for laying.

- Basic design considerations and parameters of the Mainline Pipe , Dispatch and Terminal station pipe were formulated from OISD 141, API 5L and ASME B 31.4 guidelines.

- Pipeline construction/ laying activities were performed as per the procedures and instructions given in the approved standard documents.

- For the Dispatch and Terminal stations, the pipe fabrication and erection activities as per ASME 31.3 specification were carried out. Isometric charts and drawings prepared gave clear guidance during pipe fitting and inspection.

- Horizontal Directional Drilling of 125 meters across chitrapuzha river crossing was performed for both 24" and 18" pipeline. Design calculations for various stresses, loads acting on the pipe, radius of curvature were worked upon. The values were compared with the standard allowable stress and radius of curvature values to come up with the feasible and proper profile for drilling.

- To safeguard the line from corrosion and other degradation causes cathodic protection was given to the pipeline initially by Temporary cathodic protection using sacrificial anode during the construction phase and later by Permanent cathodic protection using Impressed Current. Calculations for the Design package were made, the C.P current required, number of anodes required, life of anode, ground bed resistance.

RECOMMENDATIONS

Increase in the number of the domestic pipeline network used for the transportation of petroleum products has in turn resulted in more people living and working in closer proximity to the pipelines. Thus, it will be necessary for pipeline operators to carefully assess and plan the routes for new pipelines to reduce risk both to the public and the environment. The siting of the route comes under the state legislature and there is no governmental agency that functions to strategically route pipelines to minimize risk to the public or the environment. For this an organisation should be formed that will guide and recommend practices for local governments, property developers, pipeline operators, and real estate commissions to enhance awareness and develop risk-informed guidance for property development in the vicinity of pipelines.

Excavation damage is the main physical threat to the structural integrity and safe operation of the pipeline. This issue can be combated by equipping excavation equipment with contact-avoidance capabilities. Equipping excavation equipment uses onboard excavator technology and comprise of sensing equipment mounted on excavators that will detect metal objects near the bucket of the excavator and provide audio and/or visual alarms, as appropriate. The applicability of this new excavation machine can minimize the excavation damage to the pipeline.

Corrosion control is an essential tool to ensure the long-term integrity of pipeline systems. Both industry and regulators need to take aggressive steps to change the current mindset in which detection is considered to be the primary strategy for fighting pipeline corrosion. Although corrosion detection will always remain an important tool, focus needs to be shifted from corrosion detection to corrosion prevention. Asset preservation is necessary for the long term petroleum products utilization in the country.

Key to success in reducing pipeline integrity issues is a new commitment by the pipeline industry to emphasize prevention of incidents as a top priority not only for safety but for asset protection and stakeholder acceptance.

REFERENCES

1. Corrtech-Inkal Consortium (CIC)(2014)Standard Operating Procedure

2. Bharat Petroleum Corporation Ltd (2014) Basic Design Engineering basis report.

3. Bharat Petroleum Corporation Ltd.(2014)Feasibility study survey

4. Kenneth Y Lee (2010) Pipeline Construction challenges

5. Mohammad Najafi (2005) Trenchless Technology:: Pipeline and Utility Design, Construction And Renewal.

6. Patrick J Garland - ASNT level III, ACCP level III 9(2010) The Importance of Non-destructive testing and inspection of pipelines

7. Protech Anodes & Alloy Engineers (2014) Cathodic Protection Design Package

8. James B bushman- Principal Corrosion Engineer (2011) Corrosion and Cathodic Protection Theory

9. U.K Dhoot- IOCL General Manager, projects monitoring pipelines division Pipeline (2012) Design and construction Issues

10. T.C Pharris and R.L Kolpa (2007) Overview of the Design, Construction, and Operation of Interstate Liquid Petroleum Pipelines.