"PIPE WALL THICKNESS CROSSING AND STABILITY ANALYSIS"

A thesis submitted in partial fulfilment of the requirements for the Degree of
Master of Technology
(Pipeline Engineering)

By

RAHUL PORWAL
R160207014

Under the guidance of

Mr.............................
College of Engineering
UPES, Dehradun

Mr. Anupam Das
General Manager
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College of Engineering
University of Petroleum & Energy Studies
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विद्यया शक्ति प्रदाम्

UNIVERSITY OF PETROLEUM & ENERGY STUDIES
(ISO 9001:2000 Certified)

CERTIFICATE

UPES Guide has ascertained quality of the project – II, Anti Plag certification etc for asserting this high quality academic activity.

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Pipeline Engineering

TO WHOM TO SOEVER IT MAY CONCERN

This is to certify that **Shri RAHUL PORWAL**, who was nominated by university of petroleum and energy studies, dehradun for summer internship project ,has completed the same at our campus during the period : 23/03/09 to 23/04/09.He has completed a project on "pipe wall thickness ,crossing and stability analysis "and his performance has been satisfactory.

I wish, all success to him in every walk of life

Hitesh Kumar

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ABSTRACT

Pipelines are increasingly being required to operate at high temperatures and pressures. Due to which the pipeline has to design to hold these pressure under high storm and tidal condition. The internal stresses are setup due to pressure both internal and external hydrostatic pressure, due to high temperature, and large bending stresses due to laying operation. The stress need to within the design stresses as specified by code & standards. While mechanical design of pipeline we check for equivalent stresses calculated by an specific criteria, pipe collapse due to external hydrostatic pressure, and buckling initiation and propagation due to external hydrostatic pressure

This project is concerned with the design of cross-country pipelines . It focuses on the fundamentals of pipe wall thickness calculation , high way ,road and rail crossing , and stability analysis of pipeline. It provides a general overview of the system approach of design, which integrates the hydraulic, mechanical, and operations and maintenance aspect in design of pipeline system.

PREFACE

Cairn India has proposed to lay two number of Pipelines for transportation of Crude oil (24") and gas (8"). Both are being laid in parallel to each other from Barmer (Rajasthan) to Salaya (Gujrat) .

The job of design of both pipelines is to be carried out by L&T GULF PVT LIMITED

We submit this report along with our sincere thanks to L&T GULF PVT LIMITED ,Faridabad for their guidance and co-operation throughout the project.

I also very thankful to our mentor **Mr. Anupam Das (General Manager)** for their guidance and co-operation throughout the project.

Sincerely

Rahul Porwal

M.Tech. (Pipeline Engineering 2007-09)

UPES, Dehradun.

ABBREVIATIONS

API	American Petroleum Institute
ANSI	American Nation Standard Institute
ASME	American Society of Mechanical Engineers
BS	British Standard
Bpd	Bareles Per Day
CS	Carbon Steel
CEIL	Crain Energy India limited
CPS	Central Processing Facilities
FBE	Fusion Bonded Epoxy
FEED	Front End Engineering Design
HDPE	High Density Poly Ethylene
MPT	Mangala process Terminal
OISD	Oil Industry Safety Derectorate of india
PE	Poly Ethylene
PUF	Poly Urethance Form
SAW	Submerged Arc Welding
SECT	Skin Effect Current Trace Heating System
SMYS	Specified Minimum Yield Stress
A	Corrosion Plus Any Other Allowances

A_m	Pipe Metal Area
A_s	Area of pipe Section
D_i	Internal Diameter Of Pipeline
D	External Diameter Of pipeline
E	Longitudinal Joint Factor
E_s	Modulus Of Elasticity Of Steel
F	Design Factor
F_i	Impact Factor
F_{As}	Anchor Force
F_s	Soil Resistance
G_{Hh}	Geometry Factor for cyclic circumference Stress From High way load
G_{Hr}	Geometry Factor for cyclic circumference Stress From rail load
G_{Lh}	Geometry Factor for cyclic Longitudinal Stress From High way load
G_{Lr}	Geometry Factor for cyclic Longitudinal Stress From rail load
H	Depth to top of pipe
L	High axle configuration factor
M	Bending Moment
MAOP	Maximum allowable Operating pressure for gases
MOP	Maximum Operating Pressure for liquid

Code and Standards

API 5L	Specification for line pipe
API 5L	Recommended practice for rail road transportation of line pipe
API RP 1102	Steel pipeline crossing railroad and highways.
API RP 1107	Movement in service pipeline
API RP 1109	Pressure testing of liquids petroleum pipeline
API RP 1111	Design ,construction and installation of offshore pipeline
ASME B31.3	Piping system
ASME B31.4	Pipeline Transportation system for liquid hydrocarbons.
ASME B31.8	Gas transmission and Distribution piping system
OISD 141	Cross country hydrocarbon pipeline
NACE	Pipeline coating

CONTENTS

LIST OF FIGURE

CHAPTER-1

COMPANY PROFILE

COMPANY PROFILE

L&T-GULF Private Limited is a Joint Venture of Larsen & Toubro Limited (L&T), one of Asia's leading engineering, construction & manufacturing major and US based Gulf Interstate Engineering Company, Houston, Texas (GULF), one of the world's top most engineering & project management companies for hydrocarbon pipelines. The joint venture, with its multi discipline engineering staff, provides creative, practical solutions with specific focus on Pipeline Engineering, from hydraulic modeling and conceptual design through detailed design, prourement, construction management, commissioning and start-up activities. This engineering set-up operates from L&T's modern engineering campus at Faridabad in India's National Capital Region (NCR). L&T-GULF complements L&T's capabilities in executing turnkey EPC contracts while augmenting GULF's engineering resource base to provide end-to-end engineering & project management services using State of the Art Technology to the hydrocarbon industry Worldwide.

L&T

L&T is one of Asia's leading engineering, construction and manufacturing company (www.larsentoubro.com). A strong, customer-focused approach to business, a culture of innovation, and the resource & ability to respond positively to challenging requirements have enabled the Company to sustain leadership in its major lines of business. L&T provides comprehensive engineering, procurement, construction and commissioning services for pipeline projects in India and overseas with operating centers across the Middle East and Malaysia. Among other achievements, L&T has built the world's longest LPG pipeline in India. L&T has manufacturing facilities in India, China and the Middle East.

Track Record

- Execution of cross country pipeline projects involving laying including OFC, Horizontal Directional Drilling, testing, pre-commissioning and commissioning of pipelines. Expertise includes design, engineering, procurement and construction of civil, mechanical, electrical and instrumentation for composite station works, catholic protection system for pipelines/stations.
- Construction of LNG terminals and LPG storage facilities
- Engineering, procurement, construction and commissioning of facilities for underground cavern storage system for LPG.
- Erection of high capacity gas compressors and associated facilities.
- Construction of 18" dia 517 km long product pipeline including catholic protection and

civil, mechanical, electrical and instrumentation works at stations en route for Sidhpur-Sanganer pipeline project of IOCL.

Gulf Interstate Engineering Company, Houston, Texas

Established in 1953, Gulf Interstate Engineering (GULF) is one of the world's leading international project management and engineering companies for hydrocarbon transportation systems from the wellhead to the export terminal and is top ranked among pipeline design companies worldwide(www.gie.com). GULF professionals are known for their extensive experience and are experts in engineering all aspects of oil and gas production facilities, transportation systems and storage facilities and have contributed to the success of some of the world's most complex oil and gas projects, many with demanding environmental requirements in some of the harshest natural conditions. GULF designs large diameter pipelines for extreme conditions and is currently active in the USA, Mexico, South America, Russia and the Middle East. It has so far engineered successfully over:

- One Hundred & Fifty Thousand kilometers of 'pipeline systems',
- Two million bpd 'production & processing' facilities,
- Four Hundred Thousand horsepower 'pumping stations',
- Five million horsepower 'compressor stations'.

The company prides itself on its commitment to quality. An ISO 9001 certified unit, it is committed to staying at the forefront of its business, investing in the technology that will make a difference in your projects

CHAPTER- 2

INTRODUCTION

2.1 GENERAL

Offshore/onshore pipelines for the transportation of oil and gas have become a safe and reliable part of the expanding infrastructure put in place for the development of the valuable resources below the world's seas and oceans. The design of these pipelines is a relatively young technology and involves a relatively small body of specialist engineers and researchers worldwide. An aspect of the pipeline industry, rarely understood by those engineers working in land based design and construction, is the more critical need for a 'right first time' approach in light of the expense and complexity of the materials and the installation facilities involved, and the inability to simply 'go back and fix it' after the fact when your pipeline is sitting in water depths well beyond diver depth and only accessible by robotic systems. Money spent on good engineering up front is money well spent indeed and again a specific fit for purpose modern approach is central to the best in class engineering practice requisite for this right first time philosophy.

It is well recognized that the natural gas resources in the worlds are gaining increasing importance as an energy source to help fuel world economic growth in the established and emerging economies alike. Pipelines carry a special role in the development and production of gas reserves since, at this point in time, they provide one of the most reliable means for transportation given that fewer options are available than for the movement of hydrocarbon liquids. Add to this the growing need to provide major transportation infrastructure between gas producing regions and countries wishing to import gas, and future oil transmission systems, then the requirement for new pipelines appears to be set for several years to come. Even today, plans for pipeline transportation infrastructure are in development for regions with more hostile environments and deeper waters than would have been thought achievable even ten years ago .

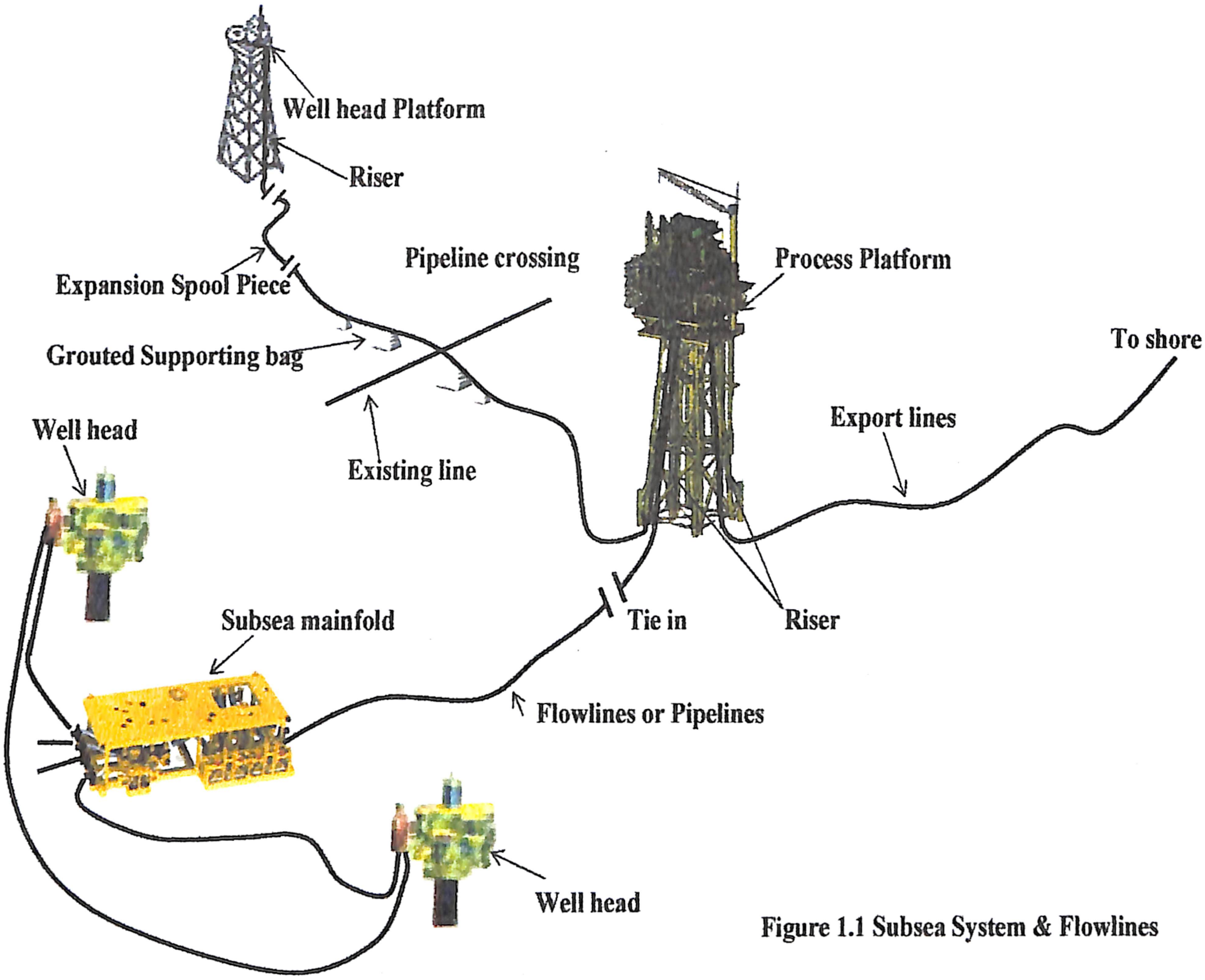


Figure 1.1 Subsea System & Flowlines

Pipelines are used for a number of purposes in the development of onshore /offshore hydrocarbon

resources (see Figure1.1). These include e.g.:

- Export (transportation) pipelines;
- Pipeline bundles.
- Flowlines to transfer product from a platform to export lines;
- Water injection or chemical injection Flowlines;
- Flowlines to transfer product between platforms,
- Subsea manifolds and satellite wells;

2.2. TECHNICAL TERMS:

1 Constructor or Contractor

A Constructor or Contractor is any person or organization having the responsibility to perform any or all of the following: analysis, design, fabrication, inspection, testing, load-out, transportation and installation.

2 Maximum Allowable Operating Pressures

The Maximum Allowable Operating Pressure is defined as the Design Pressure less the positive tolerance of the pressure regulation system.

3 Offshore

Offshore is the area seaward of the established coastline that is in direct contact with the open sea.

4 Operator

An Operator is any person or organization empowered to conduct commissioning and operations on behalf of the Owners of pipelines and risers.

5 Owner

An Owner is any person or organization who owns pipelines and risers/facilities.

6 Pipeline

A Pipeline is a primarily horizontal pipe lying on, near or beneath the seabed, normally used for the transportation of hydrocarbon products.

7 Pipeline System

A Pipeline System is an integrated set of sub-sea flowlines and pipelines including pertinent instrumentation, foundations, coatings, anchors, etc.

8 Risers

A Riser is a conducting pipe connecting sub-sea wellheads, templates or pipelines to equipment located on a buoyant or fixed offshore structure.

Types of riser

- Rigid riser - for shallow water
- Catenary steel riser - for deep water
- Flexible riser - for deep and shallow water

9. Riser clamp

Riser are supported/guided from the jacket members through clamps

Types of Clamp

- Hanger clamp
- Fixed clamp
- Adjustable clamp

10. Longitudinal stress

It is a normal stress acting parallel to pipe axis.

11. Hoop stress

Hoop stress id normal stress acting in the circumferential direction

12. Pipe bending moment

It is a bending moment in the pipe cross-section as the whole

13. Internal pressure

Pressure of the flowing fluid inside the pipe is called as internal pressure, may be gauge pressure or absolute pressure.

14. External pressure

Pressure (immediately) outside the pipe line is called as external pressure i.e., hydrostatic pressure of water column.

15. Over pressure

Difference between internal and external pressure is called as over pressure

16. Initiation pressure

External over pressure required to initiate a propagating buckle from an existing local buckle or dent is called as initiation pressure.

17. Propagation pressure

External over pressure required to propagate a buckle that has been initiated (at a higher pressure) is called as propagation pressure

18. Restrained lines

Pipelines which cannot expand or contract in the longitudinal direction due to fixed supports or friction between the pipe and soil

19. Unrestrained lines

Pipelines without substantial axial restraint. (Maximum one fixed support and no substantial friction).

20. Suspended length

Length of the pipeline without contact with sea bottom or other support is called as suspended length.

21. Nominal wall thickness

The pipe wall thickness that is specified for supply of pipes is called as nominal wall thickness.

22. Nominal pipe diameter

The outside pipe diameter to be used in design calculation is called as nominal pipe diameter.

23. Splash zone.

The splash zone for the riser is defined as zone between elevation – 2.0 m and upto the bottom of hanger clamp or + 5.5 m elevation, whichever is higher.

24. Submerged zone

Submerged zone is meant the region below the splash zone including sea water, sea bottom, and buried or mud zone.

25. Platform

Platform is a fixed or permanently anchored offshore installation on which the riser is mounted

26. Well head Platform

It is a platform constructed above a well. It is unmanned platform.

27. Process platform

It is platform where the initial process such as separation of oil water & gas (well fluid) is done. It is manned platform.

28. Well head

The structure above the well is called as well head.

29. Christmas tree.

It is a mechanical component above the well or on the platform to reduce the pressure of the well fluid. It consist of series of valve arrangements.

CHAPTER-3

PIPELINE DESIGN PROCESS

3.1 INTRODUCTION:

Mechanical design of pipeline mainly concerts with selection of appropriate wall thickness and check in conjunction with the hydrostatic collapse/propagation buckling. Wall thickness selection is one of the most important and fundamental tasks in design of pipelines. While this task involves many technical aspects related to different design scenarios, primary design loads relevant to the containment of the internal pressure are as follows:

- the differential pressure loads
- longitudinal functional loads
- external impact loads

The current design practice is to limit the hoop stress for design against the differential pressure, and to limit the equivalent stress for design against combined loads. This practice has proved to be very safe in general, except when external impact loads are critical to the integrity of the pipeline.

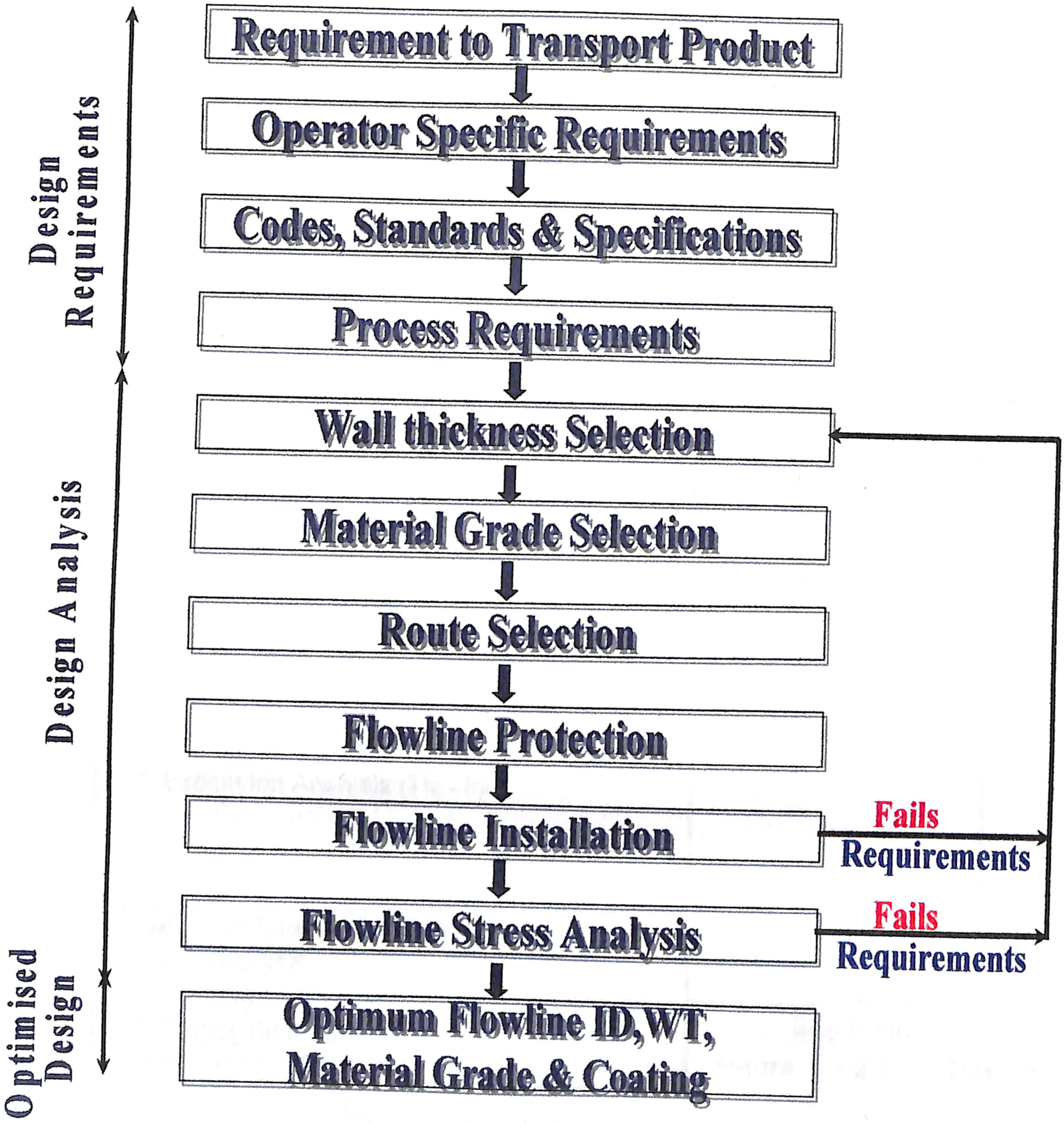
Considering the precise design and effective quality and operational control achieved by modern industry, and with the availability of new materials, it has been realized that there is a need to rationalize the wall thickness sizing practice for a safe and cost-effective design. New design codes provide guidance on application of high strength and new materials, as well as design of high pressure and high temperature pipelines.

2.2 Design Process

The object of the design process for a pipeline is to determine, based on given operating parameters, the optimum pipeline size parameters. These parameters include:

- Pipeline internal diameter;
- Pipeline wall thickness;
- Grade of pipeline material;
- Type of coating-corrosion and weight (if any);
- Coating wall thickness.

The design process required to optimize the pipeline size parameters is an iterative one and is summarize in Figure 2.1. The design analysis is illustrated in Figure 2.2.



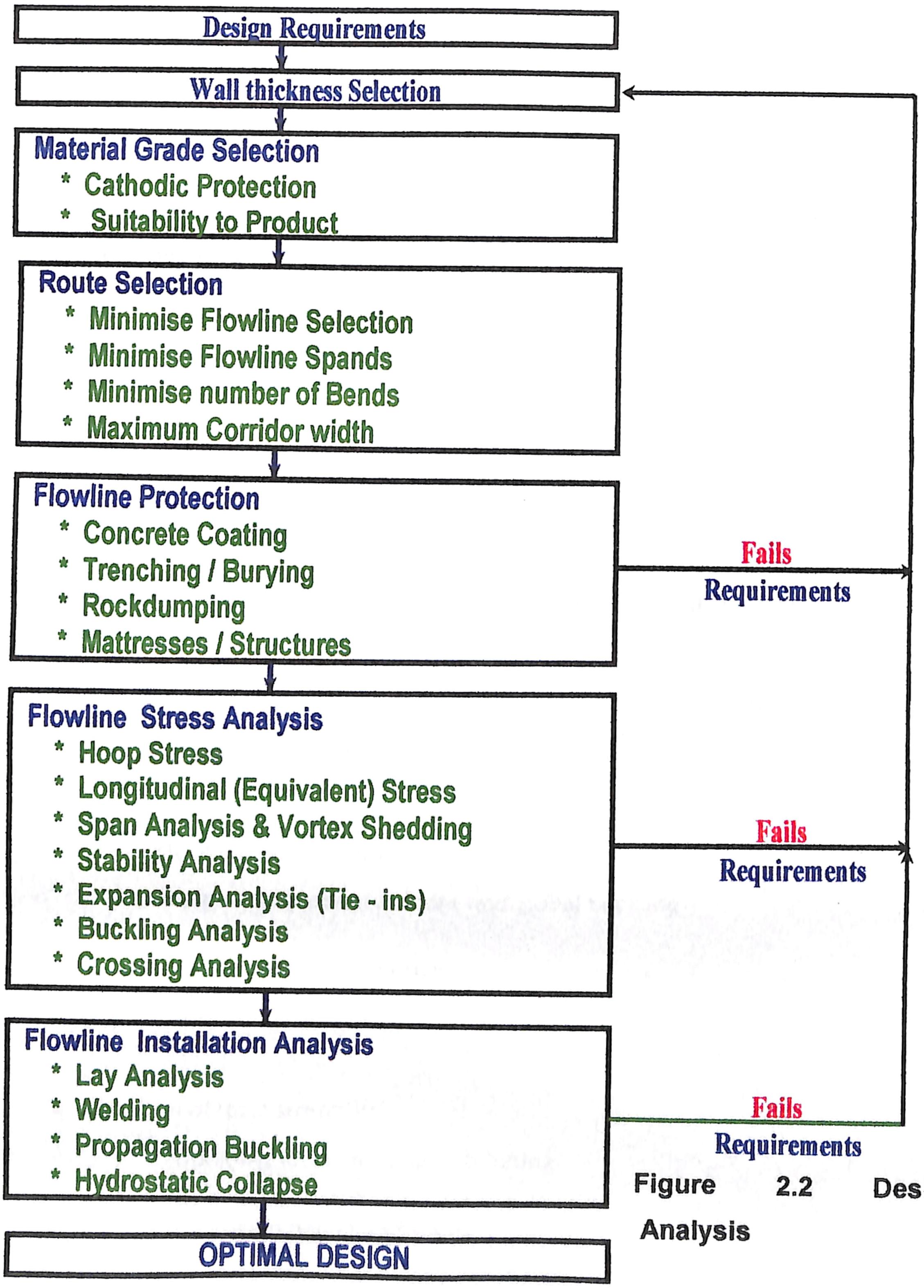


Figure 2.2 Design Analysis

Each stage in the design should be addressed whether it be conceptual, preliminary or detailed design. However, the level of analysis will vary depending on the required output. For instance, reviewing the objectives of the detailed design the design should be developed such that:

- Pipeline wall thickness, grade, coating and length are specified so that pipeline can be fabricated;
- Route is determined such that alignment sheets can be compiled;
- Pipeline stress analysis is performed to verify that the pipeline is within allowable stresses at all stages of installation, testing and operation. The results will also include pipeline allowable spans, tie-in details (including expansion spool pieces), allowable testing pressures and other input into the design drawings and specifications;
- Pipeline installation analysis is performed to verify that stresses in the pipeline at all stages of installation are within allowable values. This analysis should specifically confirm if the proposed method of pipeline installation would not result in pipeline damage. The analysis will have input into the installation specifications;
- Analysis of global response;

  Expansion, effective force and global buckling

  Hydrodynamic response

  Impact

- Analysis of local strength;

  Bursting, local buckling, ratcheting

  Corrosion defect and dents.

CHAPTER-4

PIPE WALL THICKNESS ANALYSIS

4.1. Pipe wall thickness section:

Pipeline wall thickness is selected on the following consideration

- Pressure confinement criteria
- Hydrostatic pressure criteria
- Collapse pressure criteria
- Longitudinal Stress

Flow chrt for design of pipe wall thickness calculation

4.1.1) Pressure Confinement criteria:

- **For Crude Pipeline** : The nominal wall thickness 't_n' for given design pressure for crude pipeline will be determine by

t_n = t+A **[as per ASME B 31.4 CL.404.1.2]**

Where

t = (Pi*D)/(2*S) **[as per ASME B 31.4 CL.404.1.2]**

P_I = Design internal Pressure

S= Allowable Stress (F*E*Specified minimum yield strength)

F= Design Factor

E= Weld joint Factor

A= Corrosion allowance plus any other allowance .

- **For Gas Pipeline** : The nominal wall thickness 't_n' for given design pressure for Gas pipeline will be determine by

t = (P*D)/(2*S*F*E*T) **[as per ASME B 31.8 CL.841.11]**

where

P_i= Design internal Pressure

D= Outside diameter of pipe

F=Design Factor

-Location Class 1 - 0.72

-Location Class 2 - 0.6

-Location Class 3 - 0.5

E= Weld joint factor [from table]

T=Temperature derating factor [from table]

4.1.2) **Hydro test Criteria**:

- For crude pipeline hydro test is carried out at **1.25 times** design pressure
- For Gas pipeline hydro test is carried out at **1.4 times** design pressure.

however the maximum pressure at the lower point of test section with least wall thickness shall be limited to hoop stress resulting 95% of specified minimum yield stress(SMYS).

4.1.3) Collapse Criteria :

A large external pressure tends to make a pipeline ovalize (take on an oval shape because the pipe loses it stiffness due to plastic hinge mechanism formation at the onset of local buckling) refer figure and collapse. A perfectly round pipeline loaded by a steadily increasing internal pressure would remain circular until the pressure reached the Elastic buckling pressure (Elastic critical pressure). And the pipeline would suddenly collapse. For most marine pipeline elastic buckling pressure is quite high. Circumferential pressure yield is possible, but elastic collapse occurs first expect for very tick pipeline.

Before the elastic critical pressure reached, the combination of hoop and circumferential bending stress reaches yield, beyond that the pressure can only increase slightly before collapse occurs.

➢ **For Crude and Gas pipeline**

Minimum wall thickness required to present the pipeline wall thickness collapse to be carried out **[as per API 1111].**

$$P_c = (P_y*P_c)/\sqrt{(P_y^2+P_c^2)}$$

Where

Py = Yield Stress at collapse =[2*S*(t/D)]

S= specific minimum yield stress

t = wall thickness

D= Nominal outer diameter

Pc= Elastic Collapse pressure =[2*Es*(t/D)]/[1-Vs²]

Where

Es = Young 's modulus of steel in Kpa

Vs=Possion ratio of steel

Pc = P_{cmax}/f_o

P_{cmax}= External pressure at maximum water depth

f_o =collapse factor **[as per API 1111]**

Pipe collapse is checked during installation and operation condition, and in both the cases P_{col}, as calculated above, should be not less than twice the maximum external hydrostatic pressure. Hydrostatic pressure in installation and operation condition will be the based on maximum water depth including astronomical tide, storm surge, and significant wave height respectively.

4.1.4) **Tensile Load Criteria**: the pipeline wall thickness will be designed for maximum installation pull load.

Pulling stress = (static friction co- efficient *length *weight)/(area of steel)

Bending stress = [Es*r]/[R]

Where

Es = young's modulus of elasticity , Mpa

r =pipe radius

R= Radius of curvature of pipeline

Combine longitudinal stress = pulling stress +bending stress

Check :

Combine stress < 90% of SMYS

5) **Longitudinal stress criteria:**

A pipeline in operation carries longitudinal stress as well as hoop stress. Longitudinal stresses arise primarily from two effects. The first is Poisson's effects: a bar of metal loaded in tension extends in the tension direction and contacts transversely. If transverse contraction is prevented, a transverse tensile stress will set up, and internal pressure will induces circumferential tensile stress. It there were only circumferential stress and no longitudinal stress, the pipe would extend circumferentially (so that its diameter increase) but would contract longitudinally (so that it would get shorter).

The second effect that tends to introduce longitudinal stress is temperature. If the temperatures of a pipeline is increased and if the pipeline is free to expand in all directions, it expands both circumferentially and axially. Circumferential expansion is usually completely unconstrained, but longitudinal expansion is constrained by friction and attachments. If follows that if expansion is prevented, a longitudinal compressive stress will be induced in the pipe.

- **For crude pipeline - [AS per ASME B31.4 CL 419.6.9]**

For restrained lines the net longitudinal stress due to combined effects of temperature rise and fluid pressure shall be determine by

Longitudinal stress $S_L = Es*\alpha*(T_2-T_1)-Vs*S_h$

Where

E = modulus of elasticity of Steel, MPa

S_h = hoop stress due to fluid pressure ,MPa

T_1= temperature at time of installation ,ºC

T_2= temperature at time of operation ,ºC

Vs= Poisson ratio =0.30 For steel

- **For Gas Pipeline** **[as per ASME B31.4 CL 833]**

a) Longitudinal stress due to internal pressure in restrained pipeline

$$S_p = 0.3 * SHE$$

Where S_H is the hoop stress ,MPa

b) The longitudinal stress due to internal pressure in unrestrained pipeline

$$Sp = 0.5\ S_H$$

c) The longitudinal stress due to thermal expansion in restrained pipe is

$$S_T = E*\alpha*(T_1-T_2)$$

Where

E =the elastic modulus

T_1 =the pipe temperature at the time of installation

T_2 =operating temperature

α = the Co-efficient of thermal Expansion

d) Nominal bending stress in straight pipe due to weight

$$S_B = M/Z$$

Where

M – bending moment

Z - pipe section modulus

e) The stress due to axial loading other than thermal expansion and pressure

$$S_x = R/A_m$$

Where

A= pipe area

R= external force axial component

Summation of longitudinal stress in restrained pipeline

1) The net longitudinal stress in restrained pipe

$$\mathbf{S_L = Sp + S_T + S_B + S_X \leq 0.9 * SMYS * T}$$

2) The net longitudinal stress in unrestrained pipe

$$\mathbf{S_L = Sp + S_B + S_X \leq 0.54 * SMYS * T}$$

T =temperature derating factor

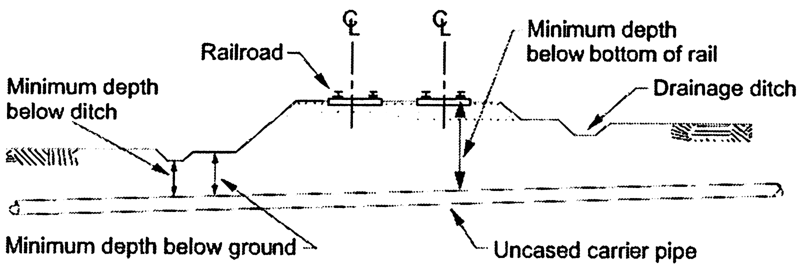
The nominal pipeline thickness of pipeline is selected from the standard API 5L line specification **TABLE 6 (C).**

CHAPTER-5

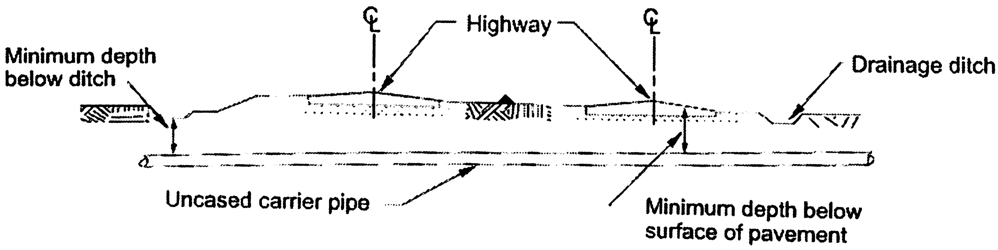
CROSSING ANALYSIS

5.1 ABOUT CROSSING

- To develop design provisions to evaluate the integrity of buried pipe for a range of applied loads.
- To maintain the integrity of buried pipeline from Impact load, surface live load and prevent the pipeline section from ovality, wall bending stress, crushing of side wall, Ring Buckling etc.
- It gives primary emphasis to provision for public safety.
- To protect the facility crossed by the pipeline , as well as provide adequate design for safe installation and operation of the pipeline.
- The carrier pipe should be as straight as practicable and should have uniform soil support for the entire length of the crossing.
- The carrier pipe should be installed so as to minimize the void between the pipe and the adjacent soil.
- The angle of intersection between a pipeline crossing and the railroad or highway to be crossed should be near to 90 degrees as practicable. In no case should it be less than 30 degrees.
- Crossing in wet or rock terrain and where deep cuts are required, should be avoided where practicable.



RAILROAD CROSSING



HIGHWAY CROSSING

—Examples of Uncased Crossing Installations

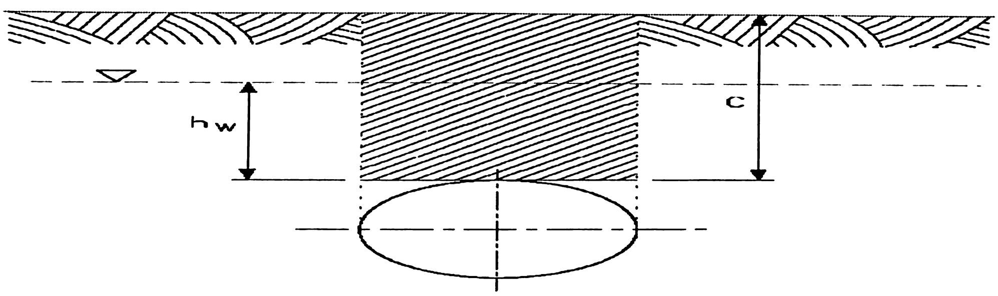
Fig 5.1 Uncased crossing installation

5.2 LOADS – GENERAL

- A carrier pipe at an uncased crossing will be subjected to both internal load from pressurization and external loads from earth forces (dead load) and train or highway traffic (live load).
- Other loads as a result of temperature fluctuations caused
- by changes in season: Longitudinal tension due to end effects, fluctuations associated with pipeline operating conditions, unusual surface loads associated with specialized equipment, and ground deformations arising from various sources such as shrinking & swelling soils, frost heave, local instability, nearby blasting and undermining by adjacent excavations. Pipeline stresses can be influenced by longitudinal bends & tees in the vicinity of the crossing.

External loads : It is the force resulting from the weight of the overlying soil that is conveyed to the top of pipe.

Earth dead load is the weight of a prism of soil with a width equal to that of the pipe and a height equal to depth of fill over the pipe

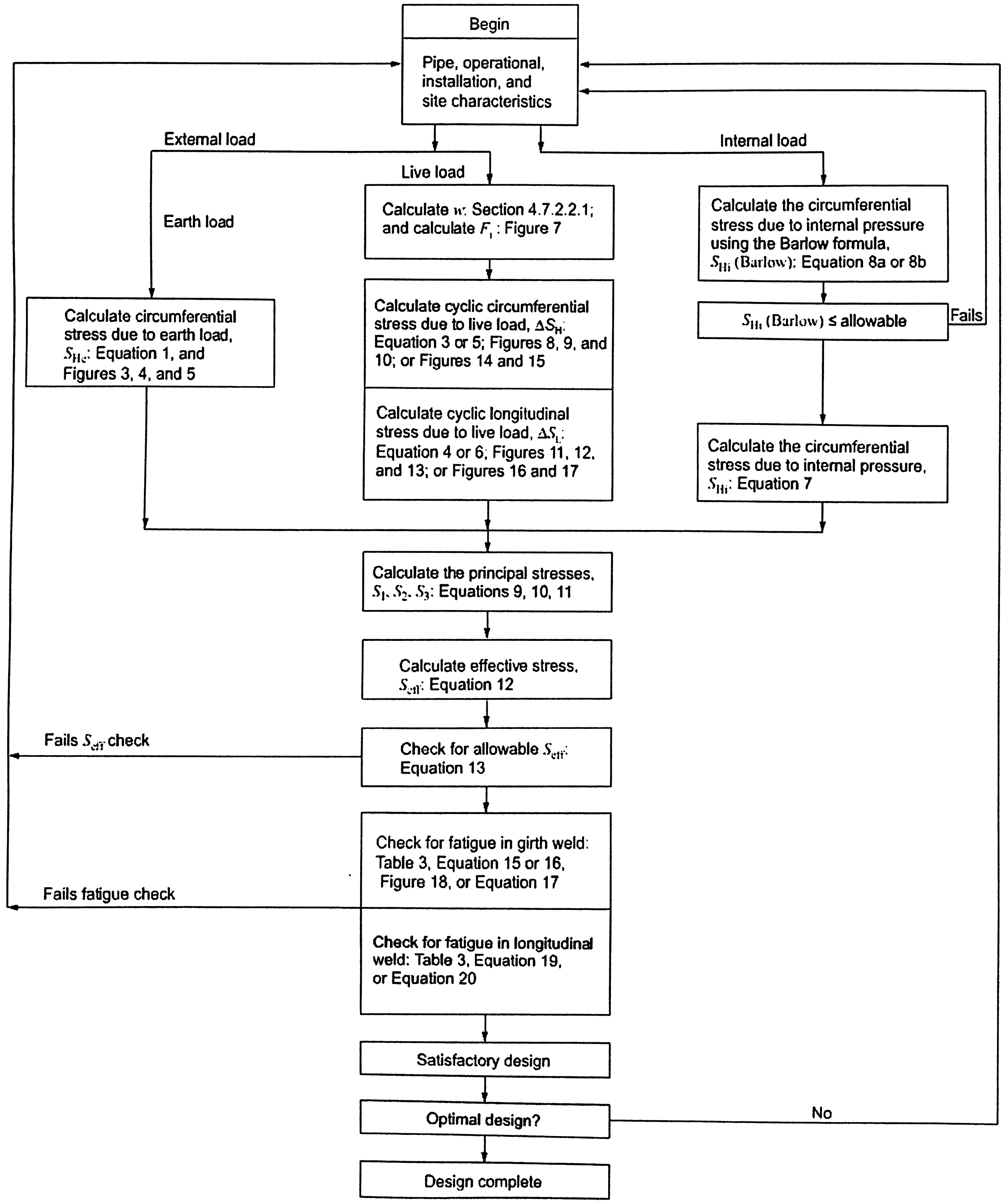


Surface Lives Load

In addition to supporting dead load imposed by earth cover , buried pipe can also be exposed to superimposed concentrated or distributed live loads due to truck wheel load, railway car .

Surface Impact Load :It is the force resulting from large weights falling from significant heights.

Internal Load :- The internal load is produced by internal pressure



–Flow Diagram of Design Procedure for Uncased Crossings of Railroads and Highways

Fig 5.2

5.3 Crossing Design :

1) Stress due to earth load **[API 1102 CL.4.7.2.2.3]**

Circumferential stress at pipeline invert covert by earth load

$$S_{He} = K_{He} * Be*Ee*y *D$$

Where

K_{He} = stiffness factor for circumfensial stress from earth load

D =pipe outside diameter in meter

Be =burial factor for earth load

Ee = excavation factor for earth load

K_{He} depend on the tw/D and E [from fig]

Be depend on the [from fig]

Ee depend on the Bd/D [from fig]

2)Stress Due to live load -

Cyclic Circumfensial stress

The cyclic circumfensial stress due to rail road , ΔS_{Hr}

$$\Delta S_{Hr} = KHr* GHr*NH*Fi*W$$

Where

KHr= rail stiffness for cyclic circumference stress

GHr= geometry factor

NH =rail load single or double track factor

Fi= impact factor

W=external load applied at surface of crossing =P/A

P=either single wheel load Ps ,or tandem wheel load Pt in KN

Ap =the contact area over which the wheel is applied taken as $0.093m^2$

Cyclic longitudinal stress **[API 1102 CL.4.7.2.2.3.2]**

$$\Delta SLr = KLr*GLr*N*Fi*w$$

Where

KLr= rail stiffness for cyclic Longitudinal stress

GLr= geometry factor

N =rail load single or double track factor

Fi= impact factor

W=external load applied at surface of crossing =P/A

P=either single wheel load Ps ,or tandem wheel load Pt in KN

Ap =the contact area over which the wheel is applied taken as $0.093m^2$

The railroad stiffness factor ,K_L ,is presented as a function of t /D and Er in fig

The railroad geometry factor ,G_L ,is presented as a function of D and H in fig

NL =for single track is 1.00 and for double track in shown in fig[ ]

B) **High cyclic stresses** **[as per API 1102 CL .4.7.2.2.4]**

The cyclic circumfensial stress due to high way vehicular load may be calculated from the following

$$\Delta S_{Hh} = KHh* GHh*R*L*Fi*W$$

Where

KHh= highway stiffness for cyclic circumference stress[from fig]

GHr= geometry factor [from fig]

R =high way pavement type factor

L=high way axle configuration factor

Fi= impact factor

W=external load applied at surface of crossing =P/A

P=either single wheel load Ps ,or tandem wheel load Pt in KN

Ap =the contact area over which the wheel is applied taken as $0.093m^2$

The cyclic longitudinal stress due to high way vehicular load ,may be calculated from following

Δ SLh =KLh*GLh*R*L*Fi*w

[as per API 1102 CL.4.7.2.24.2]

Where

KLh= highway stiffness for cyclic Longitudinal stress

GLh= geometry factor

R =pavement factor

L= axel configuration factor

Fi= impact factor

W=external load applied at surface of crossing =P/A

P=either single wheel load Ps ,or tandem wheel load Pt in KN

Ap =the contact area over which the wheel is applied taken as $0.093m^2$

The highway stiffness factor, KL, is presented as a function of t /D and Er in fig

The highway geometry factor ,G_L ,is presented as a function of D and H in fig

3) Stress due to internal load

Circumfensial stress

$$Shi = pi *(D-t)/(2*t)$$

Pi =internal pressure taken as MAOP [Kpa]

D=pipe outside diameter ,mm

t = wall thickness ,mm

CHECK FOR ALLOWABLE STRESS

Principle stress are

$$S_1 = S_{He} + \Delta S_H + S_{Hi}$$

S_1 =Maximum circumfensial stress

$$S_2 = \Delta S_L - Es*\alpha*(T_2-T_1) + Vs*(S_{He} + Sh_i)$$

S_2 = Maximum longitudinal stress

$$S_3 = -P = -MAOP \text{ or } -MOP$$

Total effective stress S_{eff} (KPa)

$$S_{eff} = \sqrt{½[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2}$$

Check

$$Seff \leq 0.9\ SMYS*F$$

Where

SMYS – specific minimum yield stress

F –temperature derating factor

CHAPTER-6

STABILITY ANALYSIS

6.1 Introduction :

Submarine pipelines are a convenient means to transport natural oil or gas from offshore oil wells to an onshore location. One of the main problems encountered with the use of the pipeline is the wave-induced instability. Under the wave loading, there exists a balance between wave forces, submerged weight of pipelines and soil resistance. To avoid swept sideways, the pipeline ought to be given a heavy enough concrete coating.

The aim of this calculation is to determine the stability of the pipeline through water course crossings.

6.2 Method : The method used to determine the stability of the pipeline through water courses is to calculate the total weight of the pipeline and compare it with the weight of the external fluid (water) it would displace. In order for the pipeline to be considered stable, the pipeline weight must be 10% greater than the weight of the water displaced.

The above method is overly conservative as it considers a pipeline free floating in water. In reality the pipeline lays in a trench covered by soil which will provide a hold down force to prevent floatation. This force is calculated by determining the submerged weight of soil above the pipeline.

Stability of pipeline with concrete coating we can check by considering a factor of safety 1.1 in installation condition and 1.25 in operating condition.

Concrete Coating

- **For Crude pipeline**

Concrete coating thickness will be calculated based on following by

$$W_p = W_1 + W_2 + W_3 + W_4 + W_5 + W_6$$

Where

W_p = Net downward pipe weight including coating ,N/m

W_1 =Steel Pipe Weight ,N/m

W_2 = FBE coating Weight ,N/m

W_3 = PUF coating Weight ,N/m

W_4=SHES Weight ,N/m

W_5 = HDPE coating Weight ,N/m

W_6 =concrete coating weight ,N/m

Above values can be calculate by

$$W_1 = \pi*(D_o - t)*t*\rho s*9.81/10^6 \text{ N/m}$$

$$W_2 = \pi*(D_o + t_{FBE})* t_{FBE} *\rho_{FBE}*9.81/10^6 \text{ N/m}$$

$$W_3 = \pi*(D_o + 2*t_{FBE} + 2* t_{PUF})* t_{PUF} *\rho_{FBE}*9.81/10^6 \text{ N/m}$$

$$W_4 = \pi*(D_o - 2*ts)* t_s *\rho_s*9.81/10^6 \text{ N/m}$$

$$W_5 = \pi*(D_o + 2*t_{FBE} + 2* t_{PUF} + t_{HDPE})* t_{HDPE} *\rho_{HDPE}*9.81/10^6$$

$$W_6 = \pi*(D_o + 2*t_{FBE} + 2* t_{PUF} + 2* t_{HDPE} + t_{cc})* t_{CC}*\rho_{cc}*9.81/10^6*(L-LC)/L \text{ N/m}$$

$$Wc = \pi*(D_o - + 2*t)^2 * t *\rho_c*9.81/4*10^6 \text{ N/m}$$

Thickness of concrete coating may be calculate by equating

Weight of steel + weight of content +weight of concrete coating = factor of safety *[buoyancy of pipe *density of liquefied soil]

DC1 is calculate from above equation and then calculate DC2 for considering length of pipe and cut back length

i.e.

$$\textbf{DC2} = \textbf{DC1}*\sqrt{[L/(L-Lc)]}$$

Then

Concrete coating thickness t = (DC2- diameter of HDPE)/2

Concrete Coating

- **For Gas pipeline**

Concrete coating thickness will be calculated based on following by

$$\mathbf{Wp = W_1 + W_6 + W_7 \quad N/m}$$

Wp = Net downward pipe weight including coating ,N/m

W_1 =Steel Pipe Weight ,N/m

W_6 =concrete coating weight ,N/m

W_7=weight of PE coating, N/m

Value of W_1 ,W_6, W_7 we can calculate by

$$W_1 = \pi*(D_o - t)*t*\rho s*9.81/10^6 \text{ N/m}$$

$$W_6 = \pi*(D_o + 2*t_{pe} + t_{cc})*t_{CC}*\rho_{cc}*9.81/10^6 \text{ N/m}$$

$$W_7 = \pi*(D_o + t_{pe})*t_{pe}*\rho_{pe}*9.81/10^6 \text{ N/m}$$

Thickness of concrete coating may be calculate by equating

Weight of steel + weight of content +weight of concrete coating = factor of safety *[buoyancy of pipe *density of liquefied soil]

DC1 is calculate from above equation and then calculate DC2 for considering length of pipe and cut back length

i.e.

$$DC2 = DC1*\sqrt{[L/(L-Lc)]}$$

Then

Concrete coating thickness t = (DC2- diameter of PE)/2

CHAPTER-7

INTRODUCTION TO BSPL PIPELINE

7.1 INTRODUCTION

Cairn Energy India Ltd (CEIL) is in the process of developing the Rajasthan Block RJ-ON-90/1 in the State of Rajasthan, India. Within the contracted area several discoveries have been made, the largest of which is Mangala in the north. Other fields in the north include Aishwarija and Bhagyam and there is potential for tie-ins to Saraswati and Raageshwari in the south. The Mangala Oil Field is located approximately 35 km North East of Barmer in Rajasthan. The field area is in a remote part of Rajasthan.

A Central Processing Facility (CPF) in the field area will comprise crude oil stabilisation, power generation, crude oil storage, heating to reduce viscosity, metering and crude oil export pumps.

The crude oil contain significant long chain paraffin components and that become a gel at temp 50 degree Celsius so heating system is provided to prevent the gelling and reduce the crude oil viscosity.

Pipeline heating system selected is skin effect current trace heating system. this consist of a small dia electric induction heat containing the power cable .and this heat tube transfer the heat to crude oil.

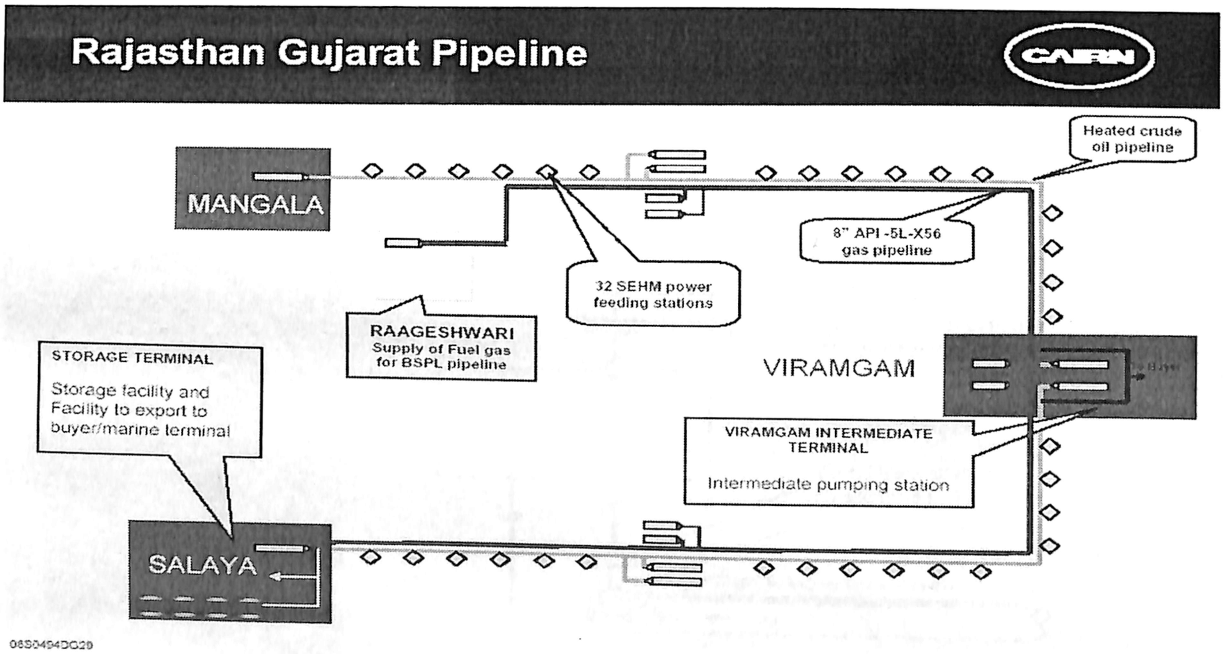


Fig 7.1 BSPL PIPELINE OVERVIEW

7.2 Skin effect heat current tracing

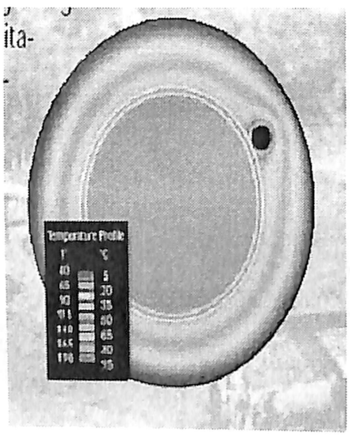
The Thermo Tracing system is ideally suited for long pipeline heating applications involving movement of materials to and from tank farms, process units and loading/unloading facilities. The versatility of the system makes it ideal for temperature maintenance, freeze protection and heat-up applications. Adaptable to varying site conditions both above and below ground, a Thermo Tracing system can traverse terrains with significant elevation changes.

A Thermo Tracing system provides a cost-effective alternative to conventional resistance heat tracing on long line piping by eliminating the need for an extensive power distribution system. it can be used in

• Chemical • Oil

• Power • Petrochemical

• Gas • Pulp/Paper



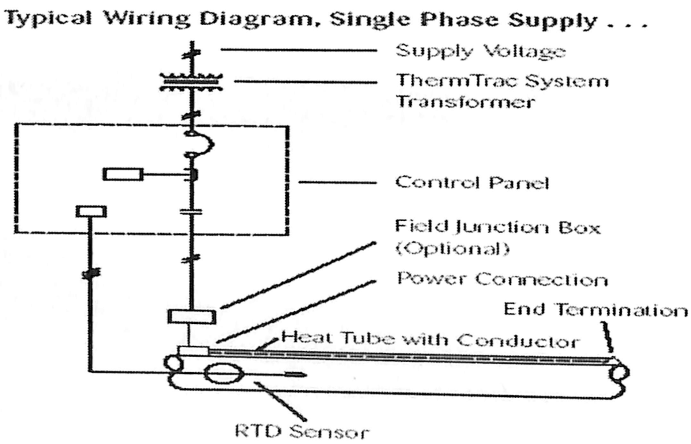


Fig 7.2 Wiring Diagram ,single phase supply

CHAPTER-8

DESIGN DATA AND CALCUTION

8.1 Design Data :

Design life	-	25 year

For Crud e Pipeline :

Grade	-	API 5L X65, PSL 2
Diameter	D -	24 inch (609.6mm)
Maximum flow rate	Q -	150000 bpd
Design pressure	P -	95 bar
Temperature – Operating	T1 -	93³C
Installation	T2 -	-15°C (minimum Design temperature for buried pipeline)
Pipeline length	L -	590 KM
Corrosion allowance	CA -	1.2 mm
Modulus of Elasticity of steel	Es-	207000 MPa
Density of steel	ρ -	7850 Kg/m³
linear co-efficent of thermal expansion	α -	0.0000117mm/mm ° C
possion ratio of steel	Vs-	0.3

For Gas Pipeline:

Grade - API 5L X56, PSL 2

Diameter - 8 inch (206.4mm)

Maximum flow rate - 18000mmscfd

Design pressure - 95 bar

Temperature – Operating - 60³C

Installation - 15°C (minimum Design temperature for buried pipeline)

Pipeline length - 515 KM

Corrosion allowance - 0.85 mm

Modulus of Elasticity of steel Es- 207000 MPa

Density of steel ρ - 7850 Kg/m³

linear co-efficent of thermal expansion α - 0.0000117mm/mm ° C

possion ratio of steel Vs- 0.3

8.2Pipeline Wall Thickness Calculation :

1) For crude Pipeline [for Class 1] **[as per ASME B31.4]**

Pipeline wall thickness $t = \frac{(P*D)}{(2*S)}$

where P =9.5 MPA

D =609.6mm

S = F*E*SMYS

F = 0.72

E =1

$t = \frac{(9.5*609.6)}{(2*322.56)}$

t = 8.98mm

Nominal wall thickness t_n = t + corrosion allowance

= 8.98+1.2

= 10.18mm

According to APi 5L line specification we take 10.6 mm

Thickness Check for :

a) Pressure criteria **[as per ASME B31.4]**

Hoop stress $S_h = \frac{(P*D)}{(2*t)}$ t =10.6-1.2=9.4mm

S_h = 308.04 MPa

Longitudinal stress $S_L = Es*\alpha*(T_1 - T_2) - Vs*S_h$

where Es=206000 MPa

S_L =207000*0.0000117*(93-15)-Vs*308.04

α=0.0000117mm/mm°C

S_L =95.58 MPa

T2=93°C

T1 =15 °C

Equivalent stress $Seq = S_L + S_h$ =308.04+95.58 =403.62 MPa

Safe Stress Seq < 0.9*SMYS

b) **Hydrostatic test criteria**

hydro test pressure Ph = 1.25* (design pressure+ 7barg)

=1.25*(9.5+.7) = 12.75 MPa

Pipeline wall thickness = t = (P*D) / (2*S) where P =12.75MPA

t =9.51 f=0.9

minimum wall thickness required for hydro test is 9.51 mm

Hoop stress Sh = $\frac{(Ph*D)}{(2*t)}$

Sh= 361.44 MPa

Longitudinal stress $S_L = Es*\alpha*(T_1 - T_2) - Vs*S_h$

S_L =206000*0.0000117*(50-15)-Vs*361.4

S_L =-24.093 MPa

Equivalent stress $Seq = S_L + S_h$ = 361.4 -24.093

Seq= 337.4 Mpa

Seq <0.9* SMYS

C) Tensile load

Radius of curvature R = $\frac{[Es*D]}{[2*S_b]}$

R =194.66 m

Area of steel A = 22.970 m^2

Weight per unit length wt =A* ρ =22.970*7850=10^{-6} kg/m

Static friction factor fs = 0.7

Bending stress Sb = (0.9*SMYS-Seq) =32.80MPa

Pulling Stress = (fs*L*wt)/A =0.000051 MPa

Combined stress $Sc = Sp+Sb$ =32.08MP

Safe criteria $Sc < 0.9*$ SMYS

D) **Collapse Criteria:** river crossing

Yield pressure at collapse $Py = (2*S*(t/D)$

$Py = 9.7067MPa$

Elastic collapse pressure $Pe =(2*Es*(t/D)^3)/(1-Vs^2)$

$Pe = 0.575MPa$

Collapse pressure $Pc = (Py *Pc)/(Py^2 +Pc^2)$

Collapse factor fo = 0.5746 MPa

External pressure at max water depth $Pcmax =\rho*g*dmax$

==0.402 Mpa

collaspe pressure Pc=Pmax/fo =0.5746 Mpa

For crude Pipeline [for Class 2] **[as per ASME B31.4]**

Pipeline wall thickness $t = \frac{(P*D)}{(2*S)}$

where P =9.5 MPA

D =609.6mm

S = F*E*SMYS

F = 0.6

E =1

$t = \frac{(9.5*609.6)}{(2*268.8)}$

t = 10.77 mm

Nominal wall thickness t_n = t + corrosion allowance

= 10.77 +1.2

= 11.97 mm

According to APi 5L line specification we take 12.70 mm

Thickness Check for :

a) Pressure criteria [as per ASME B31.4]

Hoop stress $S_h = \frac{(P*D)}{(2*t)}$ t =12.70 -1.2= 11.5 mm

S_h = 251.79 MPa

Longitudinal stress $S_L = Es*\alpha*(T_1 - T_2) - Vs*S_h$

where

Es=206000 MPa

α=0.0000117mm/mm°C

T2=93°C

T1 =15 °C

S_L =206000*0.0000117*(93-15)-Vs*251.79

S_L =112.45 MPa

Equivalent stress   Seq = $S_L + S_h$ =251.79+112.45 =364.29 MPa

Safe Stress   Seq < 0.9*SMYS

b) Hydrostatic test criteria

hydro test pressure Ph = 1.25* (design pressure+ 7barg)

=1.25*(9.5+.7) = 12.75 MPa

Pipeline wall thickness = t = (P*D) / (2*S)   where P =12.75MPA

t =9.51   f=0.9

minimum wall thickness required for hydro test is 9.51 mm

Hoop stress   Sh = (Ph*D) / (2*t)

Sh= 306.0 MPa

Longitudinal stress S_L =Es*α *(T_1 - T_2) – Vs* S_h

S_L =206000*0.0000117*(50-15)-Vs*306

S_L =--7.4434 MPa

Equivalent stress   Seq= $S_L + S_h$ = 306-7.4434

Seq= 298.55 Mpa

Seq <0.9* SMYS

C) Tensile load

Radius of curvature R = [Es*D] / [2*S_b]

R =

Area of steel A = (0.7853)*(.6096^2-0.58924^2) = 0.01916 m^2

Weight per unit length wt =A* ρ =0.01916*7850=150 kg/m

Static friction factor fs =

Bending stress Sb = (0.9*SMYS-Seq) =

Pulling Stress = (fs*L*wt)/A =

Combined stress Sc = Sp+Sb =

Safe criteria Sc < 0.9* SMYS

D) Collapse Criteria : river crossing

Yield pressure at collapse Py = (2*S*(t/D)

Py = 8.743MPa

Elastic collapse pressure $Pe = (2*Es*(t/D)^3)/(1-Vs^2)$

Pe = 0.4193MPa

Collapse pressure $Pc = (Py *Pc)/(Py^2 +Pc^2)$

Collapse factor fo = 0.4188 MPa

External pressure at max water depth Pcmax =ρ*g*dmax

Pcmax=1025*25*9.81

=0.251 Mpa

collaspe pressure Pc=Pmax/fo =0.4133

Calculation of Wall Thickness NPS 24

A	Pipe and opearting cond.	Symbol	Value	Units	formula used	References
1	Design Pressure	p	9.5	MPa		
2	Nominal Outside Diameter	D	0.6096	m		
3	Grade		X65			
4	SMYS	S	448	MPa		API 5L X-65 PSL2
5	Design factor	F	0.72			ASME B31.4
6	Weld joint factor	E	1			
7	Installation Temperature	T1	15	°C		
8	Operating Temperature	T2	75	°C		
9	Density of water	ρ_w	0.001025	kg/m³		
10	Max. water depth	d_{max}	40	m		
11	Acc. Due to gravity	g	9.81	m/s²		
12	Collapse factor(for ERW pipe)	f_o	0.7			API RP1111 Cl.4.3.2.1

B	Steel properties	Symbol	Value	Units	formula used	References
1	Young's modulus for steel	Es	206000	MPa		
2	Co efficient of Thermal Expansion	α	1.17E-05	m/m/°C		
3	Poisson's Ratio for Steel	v	0.3			

C	Pressure confinement criteria	Symbol	Value	Units	formula used	References
1	Wall Thickness	t	0.00898	m	P*D/2*S	ASME B31.4 Cl.404.1.2
2	CorrosionAllowance	CA	0.00085	m		
3	Minimun req. wall thickness	t_{nom}	0.00983	m	t+CA	ASME B31.4 Cl.404.1.1
4	Hoop stress	S_h	322.56	MPa	P*D/(2*(t)	
5	Longitudinal Stress	S_L	47.84	MPa	E_s*α*(T_2-T_1)-v*S_h	ASME B31.4 Cl.419.6.4(b)

6	Equivalent stress	S_{eq}	370.40	MPa	S_L+S_h	
7	Ratio of Equivalent stress and SMYS		0.83		S_{eq}/S	
8	Safe Stress		TRUE		$S_L<0.9*SMYS$	

D	Hydrotest criteria	Symbol	Value	Units	formula used	References
1	Hydro test Pressure	P_h	11.875	MPa	1.25*P	
2	Wall Thickness	t	0.01122	m	P*D/2*S	ASME B31.4 Cl.404.1.2
3	CorrosionAllowance	A	0.00000	m		
4	Hoop stress	Sh	322.56	MPa	P_h*D/(2*(t))	
5	Longitudinal Stress	SL	47.844	MPa	Es*α*(T2-T1)-v*Sh	ASME B31.4 Cl.419.6.4(b)
6	Equivalent stress	Seq	370.404	MPa	SL+Sh	
7	Ratio of Equivalent stress and SMYS		0.83		S_{eq}/S	
8	Safe Stress		TRUE		Seq<0.9*S	

D	TENSILE LOAD CRITERIA	Symbol	Value	Units	formula used	References
1	Young's modulus	E_s	206000	Mpa		
2	Pipe radius	r	0.3048	m	D/2	
3	Radius of curvature	R_r	194.66	m	E_s*D/2*S	
4	Length of pipeline	L	12	m		
5	Area of pipe	A	22.970	m^2	π*D*L	
6	Inside diameter	D_i	0.5899	m	D-(2*t_{nom})	
7	Weight per unit length	Wt.	0.000139	10^{-6}kg/m		
8	Static friction co-efficient	f_s	0.7			
9	Bending stress	S_b	32.80	MPa	.9*S-S_{eq}	
10	Pulling stress	S_p	0.000051	Mpa	(f_s*L*Wt.)/A	
12	Combined longitudnal stress	S_c	TRUE		$S_p+S_b<.9*SMYS$	

E	Collapse criteria	Symbol	Value	Units	formula used	Refrences
1	Selected pipeline wall thickness	t_{select}	0.00983	m		
2	External pressure at max. water depth	$P_{e-max.}$	0.402	MPa	$\rho_w * d_{max} * g$	
3	Collapse factor(for ERW pipe)	f_o	0.7			API RP1111 Cl.4.3.2.1
4	Collapse pressure due to water	P_{c1}	0.5746	MPa	P_{e-max}/f_o	
5	Thickness		0.0066			
6	Yeild pressure at collapse	P_y	9.7067	MPa	2*S*/(D/t)	API RP1111
7	Elastic collapse pressure	Pe	0.5756	MPa	$2*Es(t/D)^3/(1-v^2)$	API RP1111
8	Collapse pressure of pipe	P_{c2}	0.5746	MPa	$Py*Pe/(Py^2+Pe^2)½$	API RP1111

Wall Thickness Calculation NPS 8

Class 1

A	Pipe and opearting cond.	Symbol	Value	Units	formula used	References
1	Design Pressure	p	9.5	MPa		
2	Nominal Outside Diameter	D	0.2191	m		
3	Grade		X56			
4	SMYS	S	386	MPa		API 5L X-65 PSL2
5	Design factor	F	0.72			ASME B31.4
6	Weld joint factor	E	1			
7	Installation Temperature	T1	15	°C		
8	Operating Temperature	T2	60	°C		
9	Density of water	ρ_w	0.001025	kg/m^3		
10	Max. water depth	d_{max}	40	m		
11	Acc. Due to gravity	g	9.81	m/s^2		
12	Collapse factor(for ERW pipe)	f_o	0.7			API RP1111 Cl.4.3.2.1

B	Steel properties	Symbol	Value	Units	formula used	References
1	Young's modulus for steel	Es	206000	MPa		
2	Co efficient of Thermal Expansion	α	1.17E-05	m/m/°C		
3	Poisson's Ratio for Steel	v	0.3			

C	Pressure confinement criteria	Symbol	Value	Units	formula used	References
1	Wall Thickness	t	0.00374	m	P*D/2*S	ASME B31.4 Cl.404.1.2
2	CorrosionAllowance	CA	0.00085	m		
3	Available wall thickness	t_{nom}	0.00459	m	t+CA	ASME B31.4 Cl.404.1.1
4	Selected wall thickness	t'	0.00635	m		API 5L

5	Hoop stress	S_h	163.89	MPa	P*D/(2*(t'))	
6	Longitudinal Stress	SL	59.29	MPa	Es*α*(T2-T1)-v*S_h	ASME B31.4 Cl.419.6.4(b)
7	Equivalent stress	S_{eq}	223.18	MPa	SL+Sh	
8	Ratio of Equivalent stress and SMYS		0.58		S_{eq}/S	
9	Safe Stress		TRUE		S_{eq}<0.9*SMYS	

D	Hydrotest criteria	Symbol	Value	Units	formula used	References
1	Hydro test Pressure	P_h	11.875	MPa	1.25*P	
2	Wall Thickness	t	0.00468	m	P*D/2*S	ASME B31.4 Cl.404.1.2
3	CorrosionAllowance	A	0.00000	m		
4	Selected wall thickness	t''	0.00635	m		API 5L
5	Design temp for hydro test	T_2	50	°C		
6	Hoop stress	Sh	204.87	MPa	P_h*D/(2*(t''))	
7	Longitudinal Stress	SL	22.897	MPa	Es*α*(T2-T1)-v*Sh	ASME B31.4 Cl.419.6.4(b)
8	Equivalent stress	Seq	227.764	MPa	SL+Sh	
9	Ratio of Equivalent stress and SMYS		0.59		S_{eq}/S	
10	Safe Stress		TRUE		Seq<0.9*S	

E	Collapse criteria	Symbol	Value	Units	formula used	Refrences
1	Selected pipeline wall thickness	t_{select}	0.00983	m		
2	External pressure at max. water depth	$P_{e-max.}$	0.402	MPa	ρ_w*d_{max}*g	
3	Collapse factor(for ERW pipe)	f_o	0.7			API RP1111 Cl.4.3.2.1
4	Collapse pressure due to water	P_{c1}	0.5746	MPa	P_{e-max}/f_o	
5	Thickness		0.002374			
6	Yeild pressure at collapse	P_y	8.3648	MPa	2*S*/(D/t)	API RP1111
7	Elastic collapse pressure	Pe	0.5759	MPa	2*Es(t/D)^3/(1-v^2)	API RP1111

8	Collapse pressure of pipe	P_{c2}	0.5746	MPa	$Py*Pe/(Py^2+Pe^2)^{½}$	API RP1111

Pipeline crossing Railroad NPS 24

(Ref. Section 4 API RP 1102)

Pipe characterstics

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Design Pressure	p	0	MPa		
2	Nominal Outside Diameter	D	0.9144	m		
3	Grade		B			
4	SMYS	S	448.00	MPa		API 5L-X56-PSL2
5	Weld Joint factor (For ERW pipe)	E	1			ASME B31.8 Table 841.115A
6	Design factor	F	0.72			ASME B31.8 Table 841.114A,B
7	Temperatue Derating factor	T	1			ASME B31.8 Table 841.116A
8	Wall Thickness	t	0.01191	m		ASME B31.8 Cl.841.11
9	CorrosionAllowance	CA	0.00000	m		
10	Nominal wall thickness	t_{nom}	0.01191	m	t+CA	ASME 31.8
11	Pipe depth	H	1.7	m		
12	Bore diameter	B_d	0.96540	m	D+.051	API RP 1102 Cl. 4.7.2.1

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Soil Type		Clay/ Loose Sand			
2	Modulus of soil reaction	E'	3.4	Mpa		
3	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	
4	Stiffnes factor for circumferential stress	K_{He}	5000			API RP 1102 Cl. 4.7.2.1 Fig. 3

5	Ratio of Pipe depth to bore diameter		1.7609		H/B_d	
6	Burial factor for earth load	B_e	0.47			API RP 1102 Cl. 4.7.2.1 Fig.4
7	Ratio of bore diameter to Nominal OD		1.0558		B_d/D	
8	Excavation Factor for earth load	E_e	0.9			API RP 1102 Cl. 4.7.2.1 Fig.5
9	Soil unit weight	γ	0.0171	MN/m^3		API RP 1102 Cl. 4.7.2.1
10	Circumferential stress	S_{He}	33.07	Mpa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1

Live load calculation

Cyclic cicumferential stress

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Resilient Modulus	E_r	34	Mpa		API RP 1102 Annex A Table A-2
2	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	
3	Stiffness factor	K_{Hr}	475			API RP 1102 Cl.4.7.2.2.3.1 Fig.8
4	Depth to top of pipe	H	1.80	m		
5	Geometry factor	G_{Hr}	0.625			API RP 1102 Cl.4.7.2.2.3.1 Fig.9
6	Single or double track factor	N_H	1			API RP 1102 Cl.4.7.2.2.3.1 Fig.10
7	Impact factor	F_i	1.75			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
8	External load applied at surface of crossing	w	0.096	Mpa		API RP 1102 Cl.4.7.2.2.3.1
9	Cyclic circumferential stress	ΔS_{Hr}	49.875	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1

Cyclic longitudinal stresses

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Resilient Modulus	E_r	34	Mpa		API RP 1102 Annex A Table A-2
2	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	
3	Stiffness factor	K_{Lr}	520			API RP 1102 Cl.4.7.2.2.4.1 Fig.11
4	Depth to top of pipe	H	1.80	m		
5	Geometry factor	G_{Lr}	0.51			API RP 1102 Cl.4.7.2.2.4.1 Fig.12
6	Single or double track factor	N_L	1			API RP 1102 Cl.4.7.2.2.4.1 Fig.13
7	Impact factor	F_i	1.75			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
8	External load applied at surface of crossing	w	0.096	Mpa		API RP 1102 Cl.4.7.2.2.4.1
9	Cyclic longitudinal stress	ΔS_{Lr}	44.5536	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1

Internal load calculation

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Internal pressure	P_i	0	Mpa	p	API RP 1102 Cl.4.7.3
2	Nominal Outside Diameter	D	0.9144	m		
3	Nominal wall thickness	t_{nom}	0.01191	m	t+CA	ASME 31.8
4	Circumferential stress due to internal pressure	S_{Hi}	0.00	MPa	$Pi*((D-t_{nom})/t_{nom})$	API RP 1102 Cl.4.7.3
5	Allowable stress		322.56		F*T*E*S	
6	Stress check		TRUE		$S_{Hi}\leq F*T*E*S$	

Principal stress calculation

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Circumferential stress	S_{He}	33.07	Mpa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1
2	Circumferential stress due to internal pressure	S_{Hi}	0.00	MPa	$Pi*((D-t_{nom})/t_{nom})$	API RP 1102 Cl.4.7.3
3	Cyclic circumferential stress	ΔS_{Hr}	49.88	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1
4	Maximum circumferential stress	S_1	82.95	MPa	$S_{he}+\Delta S_{Hr}+S_{Hi}$	API RP 1102 CL.4.8.1.2
5	Young's modulus of steel	Es	206000	MPa		
6	Co-efficient of thermal expansion of	α	0.0000117	m/m/°C		
7	Installation temperature	T_1	15	°C		
8	Max. or min. operating Temp(Ambient temp)	T_2	93	°C		
9	Poisson's Ratio for Steel	v	0.3			
10	Cyclic longitudinal stress	ΔS_{Lr}	44.55	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1
11	Maximum longitudinal stress	S_2	-133.52	MPa	`$\Delta S_{Lr}-E_s*\alpha(T_2T_1)+v(S_{He}+S_{Hi})$	API RP 1102 CL.4.8.1.2
12	Maximum radial stress	S_3	0	MPa	P_i(negative)	API RP 1102 CL.4.8.1.2
13	Total effective stress	S_{eff}	189.16	MPa	$[.5\{(S_1-S_2)^2+(S_2-S_3)^2+(S_3-S_1)^2\}]½$	API RP 1102 CL.4.8.1.2
14	Allowable stress		322.56		S*F	
15	Stress check		TRUE		$S_{eff}\leq S*F$	

Fatigue calculation

Girth weld

Sr	Parameter's Used	Symbol	Value	Units	formula used	Refrences

no.						
1	Fatigue endurance limit	S_{FG}	82.74	Mpa		API RP 1102 CL.4.8.1.2.1.1.1
2	Cyclic longitudinal stress	ΔS_{Lr}	44.55	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1
3	Single or double track factor	N_L	1			API RP 1102 Cl.4.7.2.2.4.1
4	Longitudinal stress reduction factor	R_F	0.78			API RP 1102 Cl.4.8.1.1.2 Fig.18A
5	Allowable Fatigue		59.5728		SFG*F	
6	Fatigue check		TRUE		RF*ΔSLr/NL≤SFG*F	API RP 1102 Cl.4.8.1.1.2

Longitudinal weld

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Cyclic circumferential stress	ΔS_{Hr}	49.88	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1
2	Fatigue endurance limit of longitudinal weld	S_{FL}	158.58	MPa		API RP 1102 Table 3
3	Allowable Fatigue		114.1776		SFL*F	
4	Fatigue check		TRUE		$\Delta S_{Hr}/N_H \leq S_{FL}*F$	API RP 1102 Cl.4.8.2.2

Pipeline crossing Highway NPS 8

Class 1

Sr no.	**Pipe characterstics**	Symbol	Value	Units	formula used	Refrences
1	Design Pressure	p	9.5	MPa		
2	Nominal Outside Diameter	D	0.2191	m		
3	Grade		X56			
4	SMYS	S	386	MPa		API 5L-X56-PSL2
5	Weld Joint factor (For ERW pipe)	E	1			ASME B31.8 Table 841.115A
6	Design factor	F	0.72			ASME B31.8 Table 841.114A,B
7	Temperatue Derating factor	T	1			ASME B31.8 Table 841.116A
8	Wall Thickness	t	0.00374	m	P*D/2*S*F*E*T	ASME B31.8 Cl.841.11
9	CorrosionAllowance	CA	0.00085	m		
10	Minimun req. wall thickness	t_{nom}	0.00459	m	t+CA	ASME 31.8
11	Selected Wall Thickness	t'	0.00635	m		API 5L Table 9.
12	Depth to top of pipe	H	1.2	m		
13	Bore diameter of crossing	B_d	0.27010	m	D+.051	API RP 1102 Cl. 4.7.2.1

Sr no.	**Earth load calculation**	Symbol	Value	Units	formula used	Refrences
1	Depth to top of pipe	H	1.22	m		
2	Bored Diameter of crossing	Bd	0.2701	m		
3	Type of Longitudinal Weld		ERW			
4	Pavement Type		Flexible			
5	Modulus of Soil Reaction	E'	3.4	MPa		
6	Ratio of selected wall thickness to Nominal OD		0.028982		t'/D	
7	Stiffnes factor for circumferential stress	K_{He}	1600			

8	Ratio of Pipe depth to bore diameter		4.516846		H/B_d	API RP 1102 Cl. 4.7.2.1 Fig. 3
9	Burial factor for earth load	B_e	1			API RP 1102 Cl. 4.7.2.1 Fig.4
10	Ratio of bore diameter to Nominal OD		1.23277		B_d/D	
11	Excavation Factor for earth load	E_e	1.25			API RP 1102 Cl. 4.7.2.1 Fig.5
12	unit weight fo soil	γ	0.0171	MN/m^3		API RP 1102 Cl. 4.7.2.1
13	Circumferential stress for Earth load	S_{He}	7.49	MPa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1

Live load calculation

Sr no.	**Cyclic cicumferential stress**	Symbol	Value	Units	formula used	Refrences
1	Soil Type		Clay/ Loose Sand			
2	Resilient Modulus , Er	Er	34	Mpa		API RP 1102 Annex A Table A-2
3	Ratio of selected wall thickness to Nominal OD		0.028982		t'/D	
4	Stiffness factor	K_{Hh}	14			API RP 1102 Cl.4.7.2.2.4.2 Fig.14
5	Depth	H	1.22	m		
6	Geometry factor	G_{Hh}	1.15			API RP 1102 Cl.4.7.2.2.4.2 Fig.15
7	Pavement Type		Flexible			
8	Critical axle configuration for design wheel loads		Tandem axle			API RP 1102 Cl.4.7.2.2.1 Table1
9	Design wheel load	P_t	0.0445	MN		API RP 1102 Cl.4.7.2.2.1
10	Contact area over which wheel load is applied	A_p	0.093	m^2		API RP 1102 Cl.4.7.2.2.1
11	Impact factor	F_i	1.48			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
12	Highway Axle configuration factor	L	1			API RP 1102 Cl.4.7.2.2.4.2 Table2
13	Highway pavement type factor	R	1			API RP 1102 Cl.4.7.2.2.4.2 Table2

14	External load applied at surface of crossing	w	0.478	Mpa	P_t/A_p	API RP 1102 Cl.4.7.2.2.1 Table 1
15	Cyclic circumferential stress from highway vehicular load	ΔS_{Hh}	11.40	MPa	$K_{Hh}*G_{Hh}*R*F_i*L*w$	API RP 1102 Cl.4.7.2.2.4.2

Sr no.	**Cyclic longitudinal stresses**	Symbol	Value	Units	formula used	Refrences
1	Resilient Modulus , Er	Er	34	Mpa		API RP 1102 Annex A Table A-2
2	Ratio of selected wall thickness to Nominal OD		0.043529		t'/D	
3	Stiffness factor	K_{Lh}	12			API RP 1102 Cl.4.7.2.2.4.2 Fig.16
4	Depth	H	1.22	m		
5	Geometry factor	G_{Lh}	1.25			API RP 1102 Cl.4.7.2.2.4.2 Fig.17
6	Impact factor	F_i	1.5			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
7	Highway Axle configuration factor	L	1			API RP 1102 Cl.4.7.2.2.4.2 Table2
8	Highway pavement type factor	R	1.1			API RP 1102 Cl.4.7.2.2.4.2 Table2
9	External load applied at surface of crossing	w	0.478	Mpa		API RP 1102 Cl.4.7.2.2.1 Table 1
10	Cyclic longitudinal stress From highway vehicular load	ΔS_{Lh}	11.843	MPa	$K_{Lh}*G_{Lh}*R*l*F_i*w$	API RP 1102 Cl.4.7.2.2.4.2

Sr no.	**Internal load calculation**	Symbol	Value	Units	formula used	Refrences
1	Internal pressure	P_i	9.5	Mpa	p	API RP 1102 Cl.4.7.3
2	Circumferential stress due to internal pressure	S_{Hi}	0.0064	MPa	Pi*((D-t')/2*t')	API RP 1102 Cl.4.7.3
3	Allowable stress		277.92	MPa	F*T*E*S	
4	Stress check		TRUE		$S_{Hi} \leq F*T*E*S$	API RP 1102 Cl.4.8

Sr no.	**Principal stress calculation**	Symbol	Value	Units	formula used	Refrences
1	Circumferential stress From Earth load	S_{He}	0.01	Mpa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1
2	Circumferential stress due to internal pressure	S_{Hi}	0.0064	MPa	Pi*((D-t')/2*t')	API RP 1102 Cl.4.7.3
3	Cyclic circumferential stress from highway vehicular load	ΔS_{Hh}	11.40	MPa	$K_{Hh}*G_{Hh}*R*F_i*L*w$	API RP 1102 Cl.4.7.2.2.3.1
4	Maximum circumferential stress	S_1	11.42	MPa	$S_{he}+\Delta S_{Hr}+S_{Hi}$	API RP 1102 CL.4.8.1.2
5	Young's modulus of steel	Es	206000	MPa		
6	Co-efficient of thermal expansion	α	1.17E-05	/°C		
7	Installation temperature	T_1	15	°C		
8	Max. or min. operating Temp(Ambient temp)	T_2	60	°C		
9	Poisson's Ratio for Steel	v	0.3			
10	Cyclic longitudinal stress from highway vehicular load	ΔS_{Lh}	11.84	MPa	$K_{Lr}*G_{Lr}*R*L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.2
11	Maximum longitudinal stress	S_2	-96.61	MPa	$\Delta S_{Lr}-E_s*\alpha(T_2T_1)$ $+v(S_{He}+S_{Hi})$	API RP 1102 CL.4.8.1.2
12	Maximum radial stress	S_3	-9.5	MPa	P_i(negative)	API RP 1102 CL.4.8.1.2
13	Total effective stress	S_{eff}	99.24	MPa	$[.5\{(S_1-S_2)^2+(S_2-S_3)^2$ $+(S_3-S_1)^2\}]^{1/2}$	API RP 1102 CL.4.8.1.2
14	Allowable stress		277.92	MPa	S*F	
15	Stress check		TRUE		$S_{eff}\leq S*F$	

Fatigue calculation

Sr	**Girth weld**	Symbol	Value	Units	formula used	Refrences

no.						
1	Fatigue resistance of girth weld	S_{FG}	82.74	Mpa		API RP 1102 CL.4.8.1.2.1.1.1
2	Cyclic longitudinal stress from highway vehicular load	ΔS_{Lh}	11.843	MPa	$K_{Lr}*G_{Lr}*R*L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.2
3	Allowable stress		59.573	MPa	SFG*F	
4	Fatigue check		TRUE		$\Delta S_{Lh} \leq SFG*F$	API RP 1102 Cl.4.8.1.1.2

Sr no.	**Longitudinal weld**	Symbol	Value	Units	formula used	Refrences
1	Cyclic circumferential stress from highway vehicular load	ΔS_{Hh}	11.40	MPa	$K_{Hr}*G_{Hr}*R*L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.2
2	Fatigue endurance limit of longitudinal weld	S_{FL}	158.58	MPa		API RP 1102 Table 3
3	Allowable stress		114.1776	MPa	SFL*F	
4	Fatigue check		TRUE		$\Delta S_H \leq S_{FL}*F$	API RP 1102 Cl.4.8.2.2

Pipeline crossing Railroad NPS 24

(Ref. Section 4 API RP 1102)

Pipe characterstics

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Design Pressure	p	0	MPa		
2	Nominal Outside Diameter	D	0.9144	m		
3	Grade		B			
4	SMYS	S	448.00	MPa		API 5L-X56-PSL2
5	Weld Joint factor (For ERW pipe)	E	1			ASME B31.8 Table 841.115A
6	Design factor	F	0.72			ASME B31.8 Table 841.114A,B
7	Temperatue Derating factor	T	1			ASME B31.8 Table 841.116A
8	Wall Thickness	t	0.01191	m		ASME B31.8 Cl.841.11
9	CorrosionAllowance	CA	0.00000	m		
10	Nominal wall thickness	t_{nom}	0.01191	m	t+CA	ASME 31.8
11	Pipe depth	H	1.7	m		
12	Bore diameter	B_d	0.96540	m	D+.051	API RP 1102 Cl. 4.7.2.1

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Soil Type		Clay/ Loose Sand			
2	Modulus of soil reaction	E'	3.4	Mpa		
3	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	

4	Stiffnes factor for circumferential stress	K_{He}	5000			API RP 1102 Cl. 4.7.2.1 Fig. 3
5	Ratio of Pipe depth to bore diameter		1.7609		H/B_d	
6	Burial factor for earth load	B_e	0.47			API RP 1102 Cl. 4.7.2.1 Fig.4
7	Ratio of bore diameter to Nominal OD		1.0558		B_d/D	
8	Excavation Factor for earth load	E_e	0.9			API RP 1102 Cl. 4.7.2.1 Fig.5
9	Soil unit weight	γ	0.0171	MN/m^3		API RP 1102 Cl. 4.7.2.1
10	Circumferential stress	S_{He}	33.07	Mpa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1

Live load calculation

Cyclic cicumferential stress

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Resilient Modulus	E_r	34	Mpa		API RP 1102 Annex A Table A-2
2	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	
3	Stiffness factor	K_{Hr}	475			API RP 1102 Cl.4.7.2.2.3.1 Fig.8
4	Depth to top of pipe	H	1.80	m		
5	Geometry factor	G_{Hr}	0.625			API RP 1102 Cl.4.7.2.2.3.1 Fig.9
6	Single or double track factor	N_H	1			API RP 1102 Cl.4.7.2.2.3.1 Fig.10
7	Impact factor	F_i	1.75			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
8	External load applied at surface of crossing	w	0.096	Mpa		API RP 1102 Cl.4.7.2.2.3.1
9	Cyclic circumferential stress	ΔS_{Hr}	49.875	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1

Cyclic longitudinal stresses

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Resilient Modulus	E_r	34	Mpa		API RP 1102 Annex A Table A-2
2	Ratio of nominal wall thickness to Nominal OD		0.0130		t_{nom}/D	
3	Stiffness factor	K_{Lr}	520			API RP 1102 Cl.4.7.2.2.4.1 Fig.11
4	Depth to top of pipe	H	1.80	m		
5	Geometry factor	G_{Lr}	0.51			API RP 1102 Cl.4.7.2.2.4.1 Fig.12
6	Single or double track factor	N_L	1			API RP 1102 Cl.4.7.2.2.4.1 Fig.13
7	Impact factor	F_i	1.75			API RP 1102 Cl.4.7.2.2.3.1 Fig.7
8	External load applied at surface of crossing	w	0.096	Mpa		API RP 1102 Cl.4.7.2.2.4.1
9	Cyclic longitudinal stress	ΔS_{Lr}	44.5536	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1

Internal load calculation

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Internal pressure	P_i	0	Mpa	p	API RP 1102 Cl.4.7.3
2	Nominal Outside Diameter	D	0.9144	m		
3	Nominal wall thickness	t_{nom}	0.01191	m	t+CA	ASME 31.8
4	Circumferential stress due to internal pressure	S_{Hi}	0.00	MPa	$P_i*((D-t_{nom})/t_{nom})$	API RP 1102 Cl.4.7.3
5	Allowable stress		322.56		F*T*E*S	
6	Stress check		TRUE		$S_{Hi} \leq F*T*E*S$	

Principal stress calculation

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Circumferential stress	S_{He}	33.07	Mpa	$K_{He}*B_e*E_e*\gamma*D$	API RP 1102 Cl. 4.7.2.1
2	Circumferential stress due to internal pressure	S_{Hi}	0.00	MPa	$Pi*((D-t_{nom})/t_{nom})$	API RP 1102 Cl.4.7.3
3	Cyclic circumferential stress	ΔS_{Hr}	49.88	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1
4	Maximum circumferential stress	S_1	82.95	MPa	$S_{he}+\Delta S_{Hr}+S_{Hi}$	API RP 1102 CL.4.8.1.2
5	Young's modulus of steel	Es	206000	MPa		
6	Co-efficient of thermal expansion of	α	0.0000117	m/m/°C		
7	Installation temperature	T_1	15	°C		
8	Max. or min. operating Temp(Ambient temp)	T_2	93	°C		
9	Poisson's Ratio for Steel	v	0.3			
10	Cyclic longitudinal stress	ΔS_{Lr}	44.55	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1
11	Maximum longitudinal stress	S_2	-133.52	MPa	`$\Delta S_{Lr}-E_s*\alpha(T_2T_1)$ +$v(S_{He}+S_{Hi})$	API RP 1102 CL.4.8.1.2
12	Maximum radial stress	S_3	0	MPa	P_i(negative)	API RP 1102 CL.4.8.1.2
13	Total effective stress	S_{eff}	189.16	MPa	$[.5\{(S_1-S_2)^2+(S_2-S_3)^2+(S_3-S_1)^2\}]^{1/2}$	API RP 1102 CL.4.8.1.2
14	Allowable stress		322.56		S*F	
15	Stress check		TRUE		$S_{eff} \leq S*F$	

Fatigue calculation

Girth weld

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Fatigue endurance limit	S_{FG}	82.74	Mpa		API RP 1102 CL.4.8.1.2.1.1.1
2	Cyclic longitudinal stress	ΔS_{Lr}	44.55	MPa	$K_{Lr}*G_{Lr}*N_L*F_i*w$	API RP 1102 Cl.4.7.2.2.4.1
3	Single or double track factor	N_L	1			API RP 1102 Cl.4.7.2.2.4.1
4	Longitudinal stress reduction factor	R_F	0.78			API RP 1102 Cl.4.8.1.1.2 Fig.18A
5	Allowable Fatigue		59.5728		SFG*F	
6	Fatigue check		TRUE		RF*ΔSLr/NL≤SFG*F	API RP 1102 Cl.4.8.1.1.2

Longitudinal weld

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Cyclic circumferential stress	ΔS_{Hr}	49.88	MPa	$K_{Hr}*G_{Hr}*N_H*F_i*w$	API RP 1102 Cl.4.7.2.2.3.1
2	Fatigue endurance limit of longitudinal weld	S_{FL}	158.58	MPa		API RP 1102 Table 3
3	Allowable Fatigue		114.1776		SFL*F	
4	Fatigue check		TRUE		$\Delta S_{Hr}/N_H \le S_{FL}*F$	API RP 1102 Cl.4.8.2.2

Anti Buoyancy Calculation NPS 8 Pipeline

Class 1

Sr no.	Parameter's Used	Symbol	Value	Units	formula used	Refrences
1	Design Pressure	p	9.5	MPa		
2	Nominal Outside Diameter	D	0.2191	m		
3	Grade		X56			
4	SMYS	SMYS	386	MPa		API 5L-X56-PSL2
5	Weld Joint factor (For ERW pipe)	E	1			ASME B31.8 Table 841.115A
6	Design factor	F	0.72			ASME B31.8 Table 841.114A,B
7	Temperatue Derating factor	T	1			ASME B31.8 Table 841.116A
8	Density of steel	ρ_s	7850	kg/m^3		
9	Wall Thickness	t	0.00374	m	P*D/2*S*E*F*T	ASME B31.8 Cl.841.12
10	CorrosionAllowance	CA	0.00085	m		
11	Minimun req. wall thickness	t_{nom}	0.00459	m	t+CA	ASME 31.8
12	API thickness	t'	0.00635	m		
13	Pipe weight	$Wt._P$	16.898	kg/m	$\pi/4*((D)^2-(D-t')^2)*1*\rho_s$	
14	Corrosion coating Thickness	t_{cc}	0.0032	m		
15	Coating density	ρ_c	950	kg/m^3		
16	Coating weight	$Wt._c$	2.1220	kg/m	$\pi/4*[(D+2t_{cc})^2-D^2]*\rho_c$	
17	Concrete coating Thickness	t_{con}	0.06	m		
18	Concrete Density	ρ_{con}	2400	kg/m^3		
19	Concrete weight	$Wt._{con}$	129.09	kg/m	$\pi/4*[(D+2t_{cc}+2t_{con})^2-(D+2t_{cc})^2]*\rho_{con}$	
20	Density of water	ρ_w	1000	kg/m^3		
21	Buoyancy force	B	93.71	kg/m	$\pi/4*[(D+2t_{cc}+2t_{con})^2*\rho_w$	
22	Factor of safety	FOS	1.25			
23	Net buoyancy force	B_{net}	117.13		FOS*B	

24	Safety check		TRUE		$(Wt._{con}+Wt._{cc}+Wt._{p})>B_{net}$	

Note:- 1) As B_{net} of Class 1 is minimum hence it has been used for safety check.

2) Buoyancy check = Weight of pipe+weight of concrete+Weight of Coating>Buoyancy force* FOS

FOS-factor of safety

CHAPTER- 9

CONCLUSION

Conclusion

Today we know that the pipeline are the most safe ,economical and reliable mode of transpiration of hydrocarbon in both offshore and onshore but some defects are also occur during design ,construction ,operation and maintenance and that defects after some time is become a chance of failure of pipeline . But around 20-30 % failure is occur due to design failure .

So if we design pipeline according to specific code and standard and flow the standard design procedure and done all stress checks like for wall thickness of pipe we check the pressure criteria, Hydro test criteria, collapse pressure criteria after that we select the wall thickness of pipe .So less chances of failure is posible.along with less human error.

CHAPTER-10

REFERENCE

References

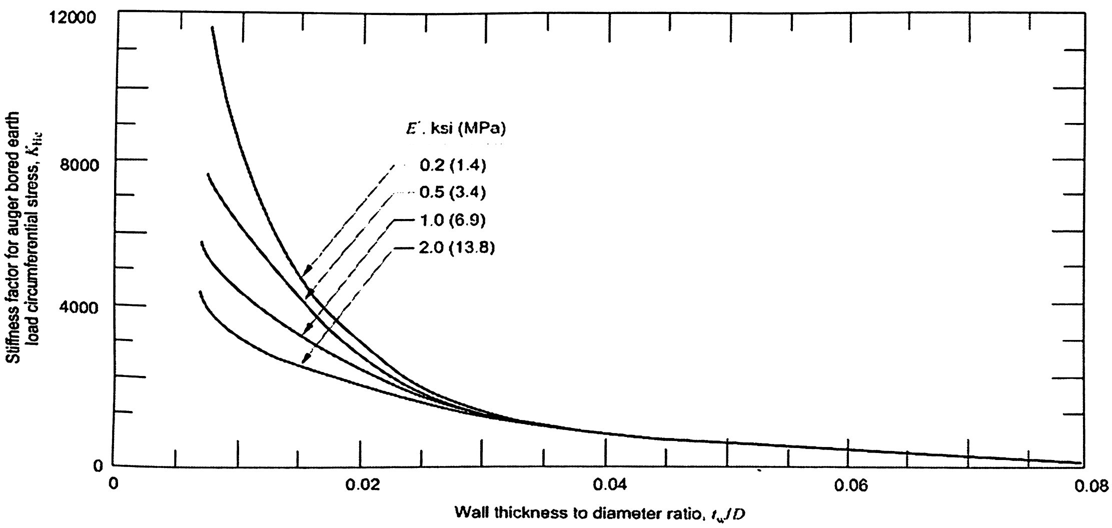
- Pipeline Rule Of Thumb (5th Ed.)
- Pipeline Engineering, Henry Liu
- Mohitpour, M., Golshan, H., and Murray, A., Pipeline Design and Construction, 2nd ed., ASME Press, New York, 2003
- L &T Design Standard
- L&T GULF online library
- www. lntgulf.com

CHAPTER- 11

APPENDIX

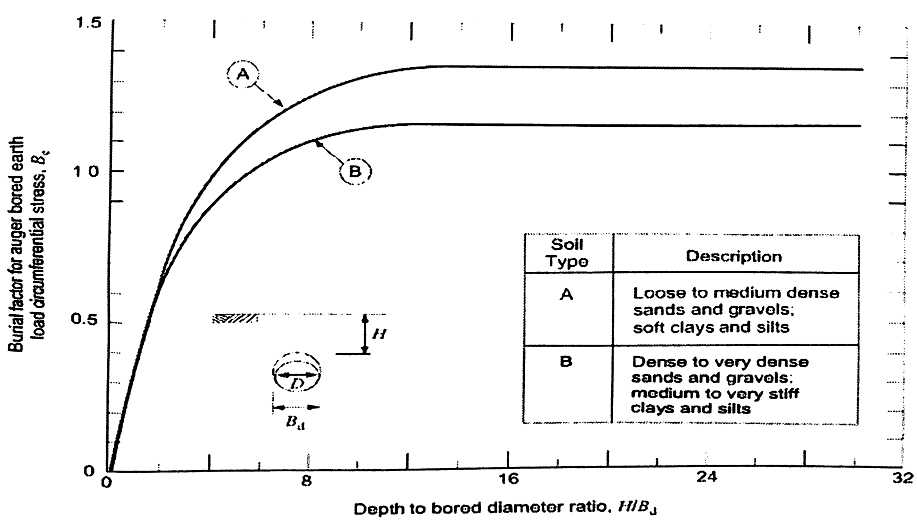
APPENDEX – A

LIST OF GRAPH



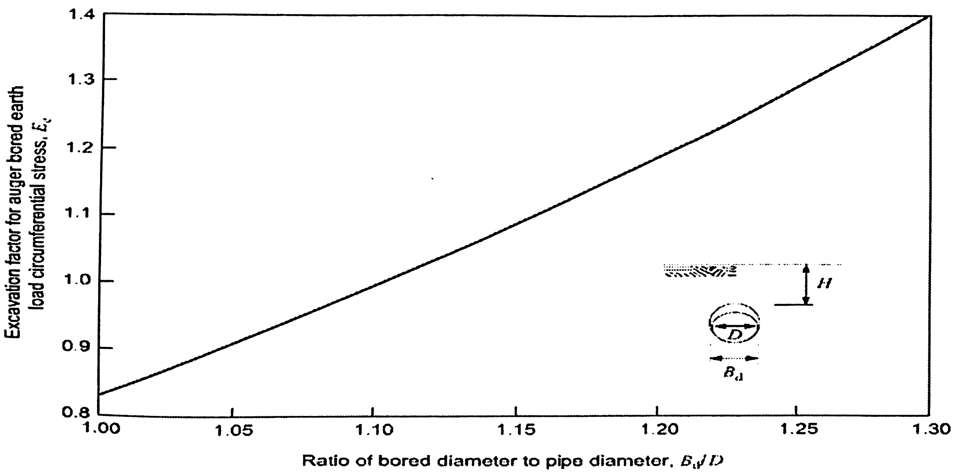
—Stiffness Factor for Earth Load Circumferential Stress, K_{He}

Fig stiffness factor for earth circumferential stress ,E_{He}



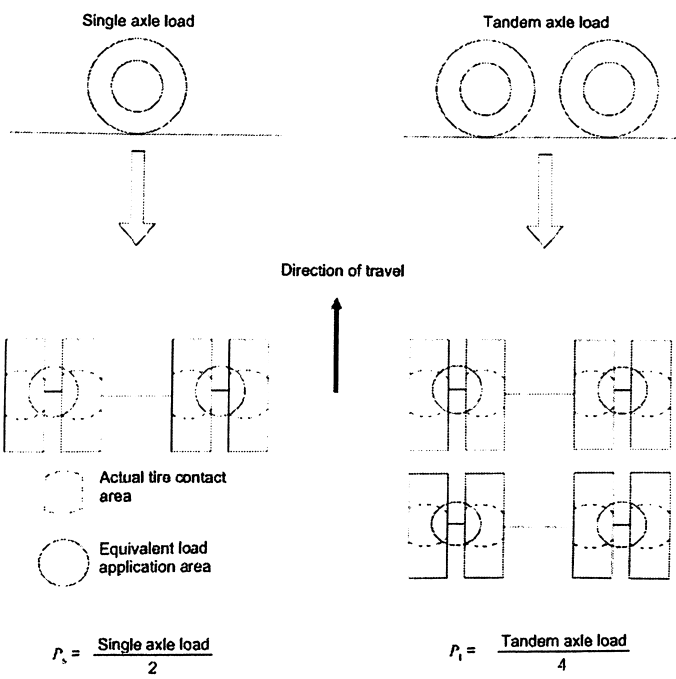
—Burial Factor for Earth Load Circumferential Stress, B_e

Fig –Burial factor for earth load circumferential Stress ,Ee



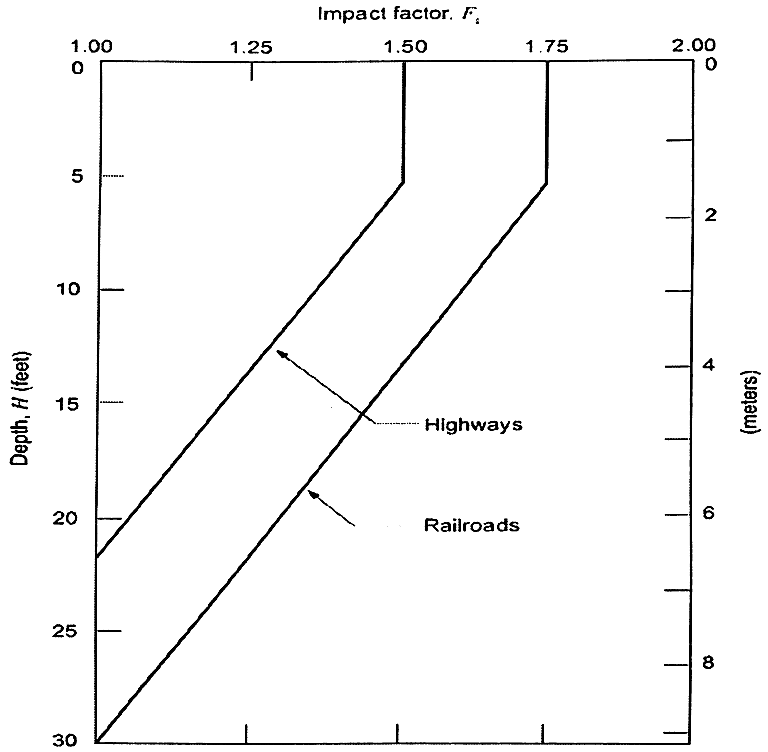
Excavation Factor for Earth Load Circumferential Stress, E_e

Fig Excavation factor for earth load circumferential stress ,Ee



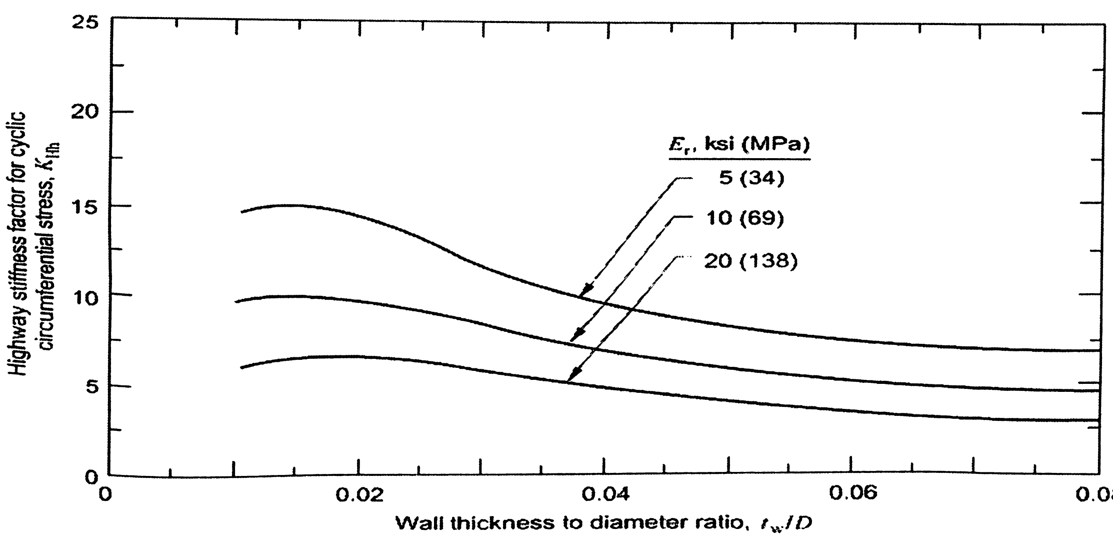
Single and Tandem Wheel Loads, P_s and P_t

Fig single and tandem wheel loads, Ps and Pc



—Recommended Impact Factor Versus Depth

Fig recommended impact factor versus depth



Appendix - B

Table 1

Design Factor [as per ASME B31.4 Cl 841.114 A]

Location Class	Design factor F
Location Class 1,division 1	0.80
Location Class 1,division 2	0.72
Location Class 2	0.60
Location Class 3	0.50
Location Class 4	0.40

Table 2

Temperature Derating Factor ,T [as per ASME B 31.4 CL. 841.116

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

Table 3

The minimum radius of field cold bends shall be as follows:

Pipe size, in Inches	Minimum Radius of Bend in Pipe Diameter
NPS 12 and smaller	18D
NPS 14	21D
NPS 16	24D
NPS 18	27D
NPS 20 and larger	30D

Table 4

Rail crossing

Location	Minimum Cover
a) Under track structure proper.	6 ft (1.8 m)
b) Under all other surfaces within the right-of-way or from the bottom of ditches.	3 ft (0.9 m)
c) For pipelines transporting HVL, from the bottom of ditches.	4 ft (1.2 m)

Table 5

Highway crossing

Location	Minimum Cover
a) Under highway surface proper.	4 ft (1.2 m)
b) Under all other surfaces within the right-of-way.	3 ft (0.9 m)
c) For pipelines transporting HVL, from the bottom of ditches.	4 ft (1.2 m)

Table 7

Table A-1—Typical Values for Modulus of Soil Reaction, E'

Soil Description	E', ksi (MPa)
Soft to medium clays and silts with high plasticities	0.2 (1.4)
Soft to medium clays and silts with low to medium plasticities; loose sands and gravels	0.5 (3.4)
Stiff to very stiff clays and silts; medium dense sands and gravels	1.0 (6.9)
Dense to very dense sands and gravels	2.0 (13.8)

Table A-2—Typical Values for Resilient Modulus, E_r

Soil Description	E_r, ksi (MPa)
Soft to medium clays and silts	5 (34)
Stiff to very stiff clays and silts; loose to medium dense sands and gravels	10 (69)
Dense to very dense sands and gravels	20 (138)

Table 8

Table A-3—Typical Steel Properties

Property	Typical Range
Young's modulus, E_s, psi (kPa)	$28 - 30 \times 10^6$ $(1.9 - 2.1 \times 10^8)$
Poisson's ratio, ν_s	0.25 – 0.30
Coefficient of thermal expansion, α_T, per °F (per °C)	$6 - 7 \times 10^{-6}$ $(1.6 - 1.9 \times 10^{-5})$

Table 9

Table 1—Critical Axle Configurations for Design Wheel Loads of P_s = 12 Kips (53.4 kN) and P_t = 10 Kips (44.5 kN)

Depth of burial, H, < 4 ft (1.2 m) and diameter, D, ≤ 12 in. (305 mm)	
Pavement Type	Critical Axle Configuration
Flexible pavement No pavement Rigid pavement	Tandem axles Single axle Tandem axles
Depth, H, < 4 ft (1.2 m) and diameter, D, > 12 in. (305 mm) Depth, H, ≥ 4 ft (1.2m) for all diameters	
Pavement Type	Critical Axle Configuration
Flexible pavement No pavement Rigid pavement	Tandem axles Tandem axles Tandem axles