SIMULATION OF MAJOR PARAMETERS FOR LIQUID PIPELINES

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For the Degree of

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IN

PIPELINE ENGINEERING

Under the Guidance of

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ABSTRACT

M/s Bharath Oman Refinery Limited (BORL) proposes to lay crude oil pipeline from Vadinar a sea part to Bina, where a refinery is proposed to be built. The initial part in the report includes proposed pipeline design specification datas. The following part includes engineering and process design basis calculations. The major part is simulation of crude pipeline using Transient Liquid Net Analysis (TLNET), in which steady and transient state is made to simulate the pipeline surge relief, also to determine the maximum throughput, from the simulated results the operating costs can be reduced. TLNET calculates pressure, density and velocity at every knot. Spacing calculation for booster pump station and simulation of surge relief valve with respect to result obtained from the simulation and also suggestion for optimisation from the output is also carried out at the result.

CHAPTER 1

INTRODUCTION

1.1 About The Project:

M/s Bharath Oman Refinery Limited (BORL) propose to lay crude oil pipeline from Vadinar a sea part to Bina, where a refinery is proposed to be built. The initial part in the report includes proposed pipeline design specification datas. The following part includes engineering and process design basis calculations. The major part is simulation of crude pipeline using Transient Liquid Net Analysis (TLNET), in which steady and transient state is made to simulate the pipeline surge relief, also to determine the maximum throughput, by the simulated the operating costs results can be reduced. TLNET calculates pressure, density and velocity at every knot.

Input parameters such as equipment parameters, equipment set point ramp schedule for block valve at the terminals. Other input datas such as bulk modulus, coefficient of thermal expansion, heat capacity, kinematic viscosity and inlet fluid conditions. Forming of network is one of the major parts before simulation. Legs are formed for the whole section of the line, from that the initial and tail nodes are determined. Apart from this the valve physical characteristic data, external regulator data, number of single pumps, number of nodes, elevation profile data. Work carried out by myself is datas gathering and calculation for engineering and process design basis the input of simulation part. Suggestion for optimisation from the output is also carried out at the end.

The subsequent pages contain the details about M/s Bharat Oman Refinery Limited Pipeline Project from Vadinar to Bina pipe wall thickness calculation, basic process data for the project, spacing calculation for booster pump station and simulation of surge relief valve with respect to EIL data and project data.

CHAPTER: 2
PROPOSED PIPELINE DESIGN SPECIFICATION

Introduction:

M/s Bharath Oman Refinery Limited (BORL) propose to lay crude oil pipeline from Vadinar a sea part to Bina, where a refinery is proposed to be built. The pipeline is proposed to pass through Sidhasar, Thamina, Bewari and Sanadavata [6]. A geographical route map is shown in Figure: 1.

This project deals with the basic mechanical, process calculation and simulation for spacing the booster pump station.

2.1 Design Codes and Standards:

ASME B 31.4	Liquid Hydrocarbons Transmission Systems
ASME B 31.3	Process Piping
OISD Std. 138	Inspection of Cross Country Pipelines-Onshore
API Std. 1102	Steel Pipeline Crossing Railways & Highways
API Std. 1104	Standard for Welding Pipelines and Related Facilities

Pipelines and terminal facilities envisaged shall be designed and engineered primarily in accordance with the provisions of the latest edition of Code ASME B 31.4: Liquid Hydrocarbons Transmission Systems and OISD 141: Design and Construction Requirements for Cross Country Hydrocarbon Pipelines. In addition, requirements, as applicable to liquid service of following codes/standards shall be complied with Pipeline transportation systems. In case of conflict between the requirements of ASME B 31.4/OISD 141 and other codes/Standards referred above, requirement of ASME B 31.4/OISD 141 shall govern.

2.2 Pipeline Schematic Maps:

Taking the various factors essential for route selection, the route is selected. The route map is shown in Figure: 1.

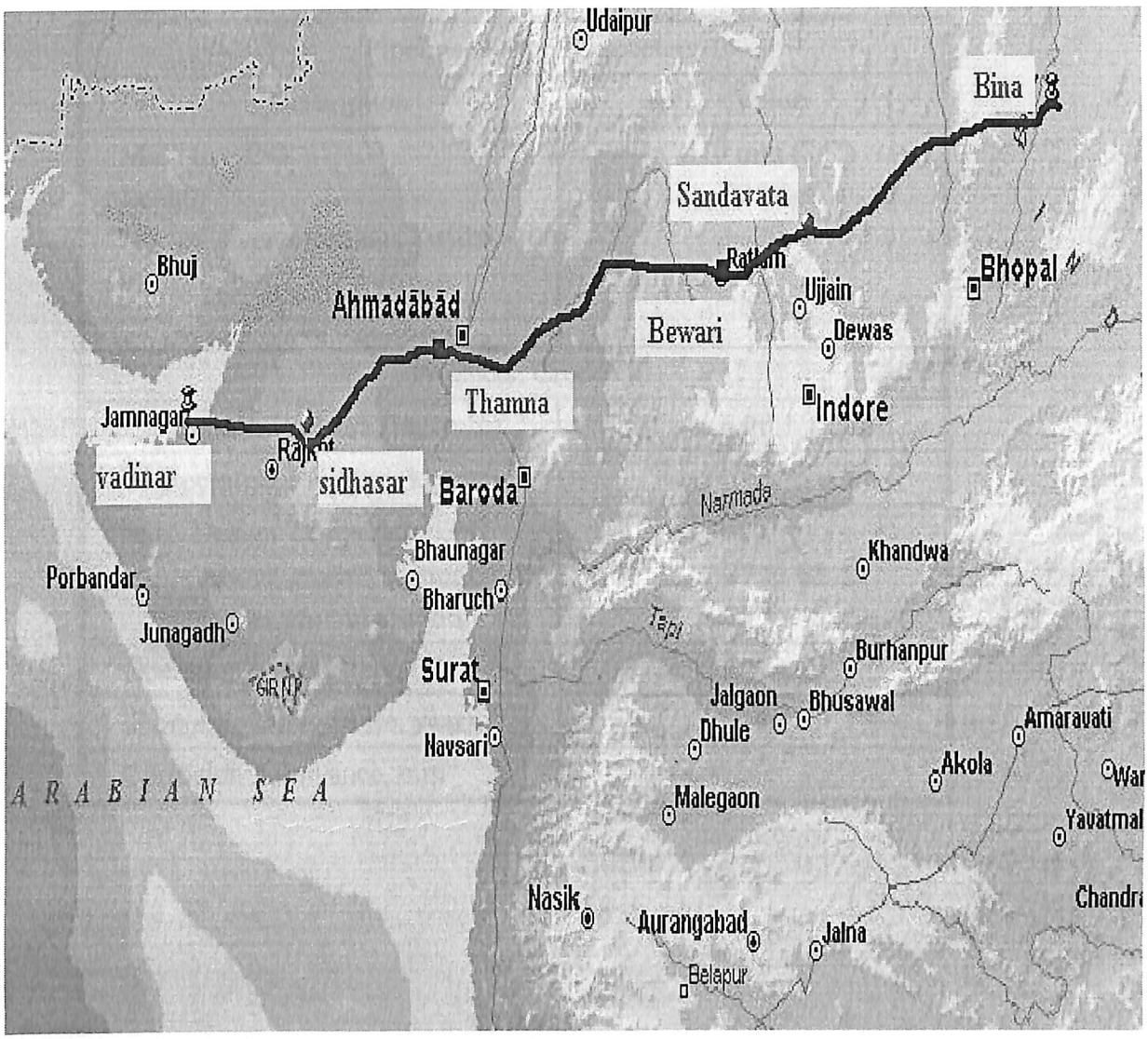

Figure: 1 Map showing pipeline route from Vadinar to Bina.

2.3 Design Data:

Pipeline design shall be designed for conditions as given in Table: 1.

Table: 1 Pipeline Design Parameters.

Pipeline Design Parameters	
Description	Value
Main line OD Length No. of river crossings (width>100 m)	610 mm (24") 935Km 30
Products: Crude Oil	
Design Pressure (kg/cm^2g)	70.1
Operating Pressure (kg/cm^2g)	63.7
Max. Design Temperature, °C 1. Above ground section 2. Under ground section	 -29 to 65 -29 to 45
Operating temperature, °C	22 – 25
Economic Design Life, years	35
Corrosion Allowance, mm	1

CHAPTER 3

ENGINEERING DESIGN BASIS

3.1 BORL PIPELINE [6]:

Pipeline shall be designed in accordance with requirements of ASME B 31.4 and OISD 141. The pipeline shall withstand all installation, testing and operating condition/ loads. All necessary calculations shall be carried out to verify structural integrity and stability of the pipeline for the combined effect of pressure, temperature, bending (elastic), soil/pipe interaction, external loads and other environmental parameters as applicable during all phases of work from installation to operation. Allowable stress limit shall be as per ASME B 31.4. Such calculations shall include, but are not limited to following:

Buoyancy control and stability analysis for pipeline section to be installed in areas subjected to flooding/submergence. Unless specified, specific gravity of installation in such area shall be at least 1.2.

- Stress analysis at crossing of major rivers, rail and highway etc.
- Crossing analysis of rivers by Horizontal Directional Drilling (HDD) as applicable.
- Pipeline expansion and its effect on station piping (above ground/below ground).

The area through which pipeline goes have been divided into different classes depending upon many factors such as the population density etc and thus a change in class changes the design factor for that particular area.

3.2 Pipeline Wall Thickness Analysis [1, 3]:

The calculation of pipeline wall thickness is as per ASME Code B 31.4 for the onshore liquid pipeline. As per ASME B 31.4 wall thickness for a straight pipe under internal pressure is given by the following expression:

$$t = \frac{PD}{2D.F.SYMS} \quad \text{----------> (1)}$$

where,

P = Pipeline design pressure in psi,

S = Specified Minimum Yield Strength (SMYS) in psi,

t = Nominal wall thickness in mm,

D = Pipe outside diameter in mm,

F = Design factor obtained from ASME B 31.4

E = Longitudinal joint factor obtained from Table: 2

Line pipe shall conform to API 5L and Company specifications. Type of line pipe to be used shall be LSAW/ HSAW. Line pipe size, material grade shall be 24" (610 mm) OD, API 5L Gr. X-70 and wall thickness shall be 7.1/7.9/11.9 mm for various places [2, 3, 4].

Table: 2 E Factor for Various Classes of Pipes.

Spec. No.	Pipe class	E factor
ASTM A 53	Seam Less	1.00
	Electric resistance welding	1.00
	Furnace Butt welded: continuous weld	0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric Fusion Arc Welded	0.8
ASTM A 135	Electric resistance welded	1.00
ASTM A	Electric Fusion welded	0.8

139		
ASTM A 211	Spiral welded steel pipe	0.8
ASTM A 333	Seamless Electric resistance welding	1.00 1.00
ASTM A 381	Double submerged arc welding	1.00
ASTM A 671	Electric fusion welded Classes 13,23,33,43,53 Classes 12,22,32,42,52	 0.80 1.00
ASTM A 672	Electric fusion welded Classes 13,23,33,43,53 Classes 12,22,32,42,52	 0.80 1.00
API 5L	Seamless Electric resistance welding Electric flash welded Submerged arc welded Furnace butt welded	1.00 1.00 1.00 1.00 0.60

Through the above process the optimum material and wall thickness combination is identified.

For this pipeline

P=70.1 kg/cm^2 g ,

D= 24" (610mm),

E=1,

S= 70000 psia (grade-X-70) or 4921.612 kg /cm^2,

So if we calculate thickness for class 1 i.e. F =. 72

t=(70.1*610/2*1*1*4921.612*.72)

t=7.1mm

For crossings having open cut, F =0.6 then

t= (70.1*610/2*1*1*4921.612*0.6)

t =7.9 mm

For crossings having Horizontal Directional Drilling (HDD) : F =0.5

t= (70.1*610/2*1*1*4921.612*0.5)

t =11.1 mm (seismic area)

The wall thickness selected for the proposed pipelines are summarized in Table: 3

Table: 3 Wall Thickness Summary.

Pipeline size (inch)	Area	Design factor	Line pipe material API 5L	Calculated wall thickness (mm)	Selected thickness (mm)
24"	In all places	0.72	Gr.X-70	7.03	7.1
24"	Open cut	0.6	Gr.X-70	7.2	7.9
24"	HDD	0.5	Gr.X-70	11.1	11.9

3.3 Horizontal Directional Drilling [1, 3]:

There are two stages to directional drilling; the first involves drilling a small diameter pilot hole along a designated path, while the second one involves enlarging the hole to accommodate the pipeline. A steering bias is created by the asymmetry of the leading edge. If a change in direction is required; the drill string is rolled so that the direction of bias is the same as the desired change in direction. Drilling progress is normally achieved by hydraulic cutting action with a jet nozzle. Mechanical cutting action, when required, is provided by a down hole positive displacement mud motor.

The actual path of the pilot hole is monitored during drilling by taking periodic readings of the inclination and azimuth of the leading edge. These readings, along with measurements of the distance drilled since the last survey, are, used to calculate the horizontal and vertical coordinates along the pilot hole, relative to the initial entry point on the surface.

The pilot hole is enlarged using a reaming process, which can either form part of the pullback process or be completed prior to it. Ordinarily the reaming tool is attached to the drill pipe at the exit point. The drill pipe is then drawn toward the drilling rig as the reamers rotate, thus enlarging the pilot hole. Sections of drill pipe are continuously added as progress is made, to ensure that there is always a string of pipe in the hole. The reaming tools consist of a circular set of cutters and drilling fluid jets. The pressurized drilling fluid serves three purposes: to cool the cutting tools, support the reamed hole, and lubricate the trailing drill pipe. In soft soils with small-diameter lines, pre-reaming is unnecessary and the final installation phase is undertaken when the pilot hole has been completed. In this circumstance the reaming assembly is attached to the actual pipeline pull section and sections of pipe are added as the reamer progresses towards the drilling rig. In order to minimize the torsion acting on the pipeline a swivel is used to attach the pull section to the leading reamer.

3.4 VALVES [Annexure]:

The entire length of the pipeline is divided into several sections by installing valves at certain intervals of length. This allows isolation of a section of pipeline in case of any emergency of a section of pipeline in case of any emergency such as bursting or leakage etc.

Application of various types of valves shall be as follows:

Valve type	Typical application
Ball	On/off, isolation (on main line)
Plug	On/off, isolation (in the terminals)
Check	Uni-directional flow

All pipeline valves shall comply with the requirements of API 6D/ relevant PMS. Ball valves shall have primary metal-seated design. In order to minimize potential leak sources, valves used in mainline shall be with butt-weld ends. Valve installed within the terminal to isolate the mainline/ pipeline shall also be provided with butt-welding ends. However terminal valves shall be flanged ends. Flanges may be used where frequent access or removal of equipment is required.

Wherever underground valves are provided, valves shall be provided with a stem extension in such a way that the centerline of the rim of the hand wheel on a horizontal shaft or center of power actuator is approximately 1.0 m above the finished ground level. Minimum size of any tapping from the underground pipeline shall be 2" NB and shall be provided with an isolation ball valve located at a minimum distance from the pipeline.

3.4.1 Required Spacing of Sectionalising Valves:

(a) When determining the sectionalizing valve spacing, primary consideration will be given to locations that provide continuous accessibility to the valves.

(b) The spacing between valves on a new transmission line should not exceed 30 miles in general location. However valves are required to be placed on either side of the water bodies crossings.

Valves on distribution mains, shall be spaced as follows:

(a) High pressure systems:

Valves installed in accessible location to reduce the time to shut down a section during emergency and due consideration given to size of mains, operating pressure, local physical conditions as well as number and type of human life's affected by the shutdown

3.4.2 Location of Valves (Transmission Valves)

(a) Sectionalizing block valves should be accessible and protected from damage and tempering.

(b) Sectionalizing valves should be installed above ground, in a vault or buried.

(c) Blow down valves should be provided such that each section of the pipeline between main line valves can be blown down.

3.5 PIPING [3]:

This section describes the design requirements of piping applicable for dispatch station, intermediate pigging stations, sectionalizing valve stations and receiving station. All piping and equipment shall be designed as per ASME B 31.4. All piping materials shall be as per Piping Material Specification (PMS). Utility piping to be provided shall be designed in accordance with the provisions of ASME B 31.3. Design shall provide consideration for all loadings like weight, temperature etc., significantly affecting the pipe material stresses in addition to fluid pressure.

3.5.1 Piping Flexibility/Stress Analysis:

All piping shall be designed for thermal expansion under start up, operating and shut down conditions without over stressing the piping, valves or equipment. Provisions for expansion shall normally be made with bends and offsets.

All piping shall be adequately supported, guided or anchored so as to prevent undue vibration, deflection or loads on connected equipments. Equipments/ valves requiring periodical maintenance shall be supported in such a way that the valves and equipment can be removed with minimum temporary pipe supports.

3.5.2 Piping layout

Piping will be located above ground wherever possible within the terminals.

- Piping shall be designed considering skin temperature of piping material under empty conditions as 65°C or design temperature of pipeline whichever is higher.
- Piping stress analysis shall be carried out to determine allowable pipe movement and support requirements wherever felt necessary.
- Buried piping inside the terminal area will have a minimum depth of cover of 1.2 m.
- Where buried pipes come out of the ground, the underground coating on the pipe will continue for a distance of 500 mm above ground.
- Platforms, crossovers shall be provided for ease of operation and maintenance.
- Platform for filters shall be provided for maintenance/ operational access.
- Painting above ground piping and structures shall be as per specifications enclosed in the Bid package. Painting suitability shall be as under:

  -Coastal and Marine environment for Vadinar terminal.

  -Normal industrial environment for all other stations and terminals.

3.6 Scraper Stations [1, 3]:

Scraper traps shall be provided at the dispatch terminal, intermediate pigging stations. The scraper traps shall be uni-directional capable of handling intelligent pigs and other cleaning pigs. The launching and receiving barrels shall be designed in accordance with the requirements of ASME B 31.4 and its end closure shall be designed and

fabricated according to ASME Section VIII, Div.1. Adequate arrangements for launching, retraction, handling and lifting of cleaning and instrumented pigs shall be provided at the scraper stations. Traps shall be accessible by walkway/road for movement of equipment, pigs etc. These stations shall be provided with access road from the nearest metalled road.

The diameter of barrel of the launcher cum receiver shall be three nominal sizes larger than the pipeline nominal size. Centerline elevation of scraper trap shall be at suitable height from grade level. Suitable arrangements shall be provided for handling & lifting of pigs. The piping system at the terminals and intermediate stations shall be designed to have sufficient flexibility to prevent pressure and thermal expansion or contraction from causing excessive stresses on the connected equipment. The piping shall be designed/fabricated as defined in clause 8.3.

3.7 Welding [Annexure]:

Welding shall be carried out in accordance with API 1104, specification for welding and welding charts. Butt welds shall be radio graphed / automatic UT for automatic welding, as applicable for all pipelines.

For gas service all butt welds for process piping shall be 100% radiographed and for utility piping NDT requirements shall be as per specification

3.8 Crossings [1, 2, 3]:

3.8.1 Water Crossings

All water crossing shall be installed by open cut. Wherever there is an evidence of bank erosion, the banks shall be protected by using gravel and boulders filled embankment mattresses of galvanized iron wire to be laid over the backfilled, compacted and graded banks.

3.8.2 Road Crossing

Road crossings shall comply with the requirements of API 1102 and the requirements of the concerned road authorities. Unless otherwise required by concerned Authorities, casing pipe shall not be used. However at national highway road crossings pipeline

shall be provided with casing pipe, which shall extend min. 600 mm beyond Road ROW on either side. The casing pipe shall be installed by trench less method like ramming/ boring/ jacking/ HDD /Micro Tunneling. Provision of casing at locations other than national highways shall be decided based on type of road crossing and as per requirements of local authorities if necessary. The casing pipe shall be three nominal pipe sizes larger than carrier pipe. The crossing angle shall be as close to 90° as possible. Casing insulators and end seals shall be provided to ensure electrical isolation of carrier pipe and casing pipe.

3.8.3 Rail Crossing

Pipeline at rail crossings shall be provided with casing pipe. The casing pipe shall be three nominal pipe sizes larger than carrier pipe (unless advised otherwise by concerned authorities) and shall be installed by boring/ jacking/ HDD/ ramming. The rail crossing shall comply with the requirements of API 1102 and Indian Railway Authorities. The crossing angle shall be as close to 90° as possible. It should be noted that the extent of casing pipe generally specified by Railways is 14.0 m beyond centerline of the outermost tracks on either side or 0.6 meter beyond the ROU limits of Railways on either side, whichever is more. Carrier pipe shall be electrically insulated from the casing pipe and casing ends shall be sealed using durable, electrically non-conducting materials. The crossing drawing shall be subject to approval of concerned Railway Authorities prior to implementation.

3.8.4 Existing Pipeline Crossing

The minimum clearance between the lines shall be 300 mm unless specified otherwise.

3.9 External/Internal Corrosion Coating [1, 2, 3]:

Pipeline to be installed below ground shall be protected against external corrosion by a combination of high integrity externally applied coatings and permanent impressed cathodic protection system. Externally applied coating shall be three layer side extruded polyethylene coating. In addition, pipeline shall be provided with internal roughness of 45-micron and corrosion allowance of 1mm.

All above ground piping and structures shall be painted to prevent atmospheric corrosion. Painting of above ground piping and structures shall be as per specifications. Painting shall be suitable for normal corrosive environment/corrosive environment, as applicable.

3.10 Hydrostatic Testing [Annexure]:

Hydrostatic test is essential for the pipeline to prove that the pipe has the strength required to meet the design conditions, and to verify that the pipe is leak free. It is a major operation and should be carefully planned. Estimating the hydrostatic test pressure before the construction work have finished is done by the following method [2, 3, 4].

1. We draw the ground profile of the pipeline, marking on the profile the rivers wherever existing.
2. Then we examine the elevation gradient, the gradient along with the location of the water source and the pipe design data, it will be used to determine the length and the number of test sections.
3. Where the pipe traverses hilly terrain, the elevation gradient must be carefully studied in selecting the pipeline test segments.

In this particular pipeline the range of allowable percentages is 90% of SMYS. And the hydrostatic test pressure is 1.25 times the design pressure

The design pressure =70.1 kg/cm^2

D= 610mm

T=7.1, 7.9, 11.9mm according to the classes

SMYS= 70000

Thus $P_H = 1.25 * 70.1 = 87.63\ kg/cm^2$

CHAPTER: 4

PROCESS DESIGN BASIS

4.1 Battery Limits [6]:

Battery limits is the name given for dispatch and receiving terminals. Bharat Oman Refineries Limited (BORL) is setting up a grass root refinery complex at Bina, M.P for which following facilities are visualized:

(a) Single Point Mooring (SPM) of CALM type near Vadinar, Gujarat and associated offshore/onshore pipelines up to Crude Oil Terminal (COT).

(b) Onshore Crude Oil Terminal (COT).

(c) Approx. 935 km Vadinar-Bina pipeline (VBPL) from COT to Refinery.

This document covers the design basis for approximately 935 km long Vadinar-Bina pipeline from COT outlet header at Vadinar to inlet header of crude oil tanks in the refinery at Bina.

Battery Limit Conditions

1.At Vadinar

Inlet flow, MMTPA (m^3/hr)	:	6.0 (862)
Battery Limit Pressure, kg/cm^2 g	:	42
Battery Limit Temp, ^{0}C (max/min)	:	35/10

2.At Bina refinery receipt terminals

Inlet flow, MMTPA (m^3/hr)	:	6.0 (862)
Battery Limit Pressure, kg/cm^2 g	:	5
Battery Limit Temp, ^{0}C (max/min)	:	35/10

4.2 Pipeline Parameters [6]:

Trunk line (Vadinar to Bina):

i) Pipeline OD	:	24" (API 5L Gr X 70)
ii) Pipeline length, km	:	935

iii) Pipe thickness, mm

for various considerations : 7.1/7.9/11.9

v) Design temperature above ground/buried, ^{0}C : 35 ^{0}C/10^{0}C

vi) Pipe internal roughness : 45 microns

vii) Pipe corrosion allowance : 1.0 mm

viii) Sub-soil temperature, ^{0}C : 25

ix) Pipeline laying : Buried

x) Ground profile : Elevation is considered.

xi) Pipeline external protection: : Suitable coating and impressed current cathodic protection shall be provided.

xii) Pigging facilities : suitable for intelligent pigging shall be provided as required.

xiii) Operating hours : 8000/Annum

xv) Design Life : 30 Years

4.3 Elevations [6]:

COT tank bottom elevation, m (above MSL)	:	10 (max)
Height (maximum) of COT tanks , m	:	20
Refinery tank bottom elevation, m (above MSL)	:	400-420
Height (maximum) of refinery tanks, m	:	20

4.4 Utilities [6]:

BORL shall make following utilities required at consumer terminals available.

- For effective maintenance of pipeline, pig launching / receiving facilities (for intelligent pigs) will be provided at the crude despatch, crude receipt in the refinery and intermediate locations along the pipeline.

-The arrangements for all the utilities required for the total system comprising of booster and mainline pump station at COT, intermediate pump stations, sectionalising valve stations and intermediate pigging stations are within the scope of this project.

- Tapping and distribution for fire water and drinking water is outside the scope of this part of the project.

4.5 Instrumentation and Control [6]:

Adequate instrumentation and control system shall be provided for safe and efficient operation. Pipeline is envisaged to be monitored and controlled from SCADA (Supervisory Control & Data Acquisition) monitoring & control station (SMCS), which will be located at the crude oil terminal at Vadinar. The SMCS shall be interlinked through pipeline communication system with Remote Terminal Units (RTU) located at each pumping, pigging, SV stations, receipt terminal and other locations along the pipeline.

4.5.1 Method of communication:

Optical fiber cable (data, voice & video communication). The telecommunication system shall be based on STM4 (minimum) with 12-fibre optical fibre cable. Back-up data & voice communication through lease line /VSAT shall be provided.

4.5.2 Electric power

Electric power shall be made available at all the stations through state electricity board grids. Emergency power generator shall meet emergency power requirement. For details, refer the relevant electrical design basis.

4.6 Metering [6]:

Metering facilities shall be provided at crude despatch facility in the crude oil terminal (COT) at Vadinar, at intermediate pumping stations and at crude receipt terminal in the refinery. Metering shall be through Turbine meters. One standby meter run shall be provided. Flow meters shall be provided at each metering point.

Density cum viscosity meter shall be provided at despatch and receipt terminals for density and viscosity measurement of crude oil and leak detection purpose.

Pressure and temperature monitoring shall be provided at each pumping, intermediate pigging and sectionalising valve (SV) stations.

4.7 Temperatures [6]:

4.7.1	Average sub-soil temperature, deg C	:	20
4.7.2	Ambient Temperature (max/min), deg C	:	42.9 / 0.7
4.7.3	Pumping Temperature (max/min), deg C	:	35 / 10
4.7.4	Design temperature		
Buried, deg C		:	45
Above ground, deg C		:	65

4.8 Pumps [6]:

4.8.1 Sparing and Operation Philosophy for Pumps:

- Two (2) working & one (1) stand by for booster and mainline crude oil pumps.
- One (1) working & one (1) stand by for corrosion inhibitors injection pumps.
- One (1) working & zero (0) stand by for sump pumps.
- One (2) working & zero (0) stand by for slop transfer pumps.

4.8.2 Choice Of Drives For Pumps:

At COT/ Intermediate pumping stations: All pumps will be electrically driven. Booster pumps at COT will be having fixed speed drive.

Mainline crude oil pumps at COT as well as at intermediate pump stations will have variable speed drive.

4.9 Crude Characteristics [6]:

Table: 4 Properties of Crude Oil

Property	Design Case	Check Case	
	Case-I (ARAB MIX)	Case-II (OMAN)	Case-III (KUWAIT)
Specific. Gravity (15.56/15.56 °C)	0.8722	0.8503	0.8739
Viscosity, cst	1.5 @ 129 deg.C 6.0 @ 30 deg.C	16.7 @ 20 deg C 8.5 @ 40 deg C	2.7 @ 100 deg.C 2.8 10 @37.8deg.C
Pour Point, deg C	< (-)5	(-) 42	(-) 21
RVP, kg/cm2a	0.3-0.7	0.3-0.7	0.3-0.7
Sulphur content, wt.%	2.42	0.95	2.6
Water content, vol %	2	2	2

4. 10. Sectionalizing Valve Stations [Annexure]:

Sectionalizing valve station shall be provided along pipeline route for isolating sections of pipeline as per ASME B 31.4 for:

- Limiting the hazard and damage from accidental discharge from pipeline system.
- Facilitating maintenance of pipeline system and

- Complying with the requirements of applicable codes.

The location of sectionalising valves shall be as per the requirements of applicable codes taking consideration of terrain features, requirement of safety and operation etc. Sectionalising valve on the main pipeline shall be ball valves of full bore type, to allow smooth passage of pigs.

All valves installed at Intermediate facilities, block valve stations, scraper stations and pipeline sectionalising valve stations shall be gas actuated/ hand operated and with butt-welded ends. Sectionalising and Station block valves shall be installed buried and provided with a stem extension in such a way that the centerline of rim of the hand wheel on a horizontal shaft or center of actuator is at approximately 1.0 m above the finished ground level. Valve surface shall be provided with corrosion protection coating. Valve body vent and drain lines shall be extended and terminated above ground.

The valve stations are normally located at a readily accessible location such as near road and shall be provided with an access road from the nearest all weather metalled road. The facilities within valve station shall be secured by a chain link fence enclosure with gate. The location of valve station shall be clear of overhead power lines.

The provisions of remote operated feature shall be as per the operation and control philosophy to be adopted for the project. At locations, where valve stations are combined with CP/Repeater stations, the safe distance and statutory clearance as per standard shall be followed.

CHAPTER: 5
SIMULATION

5.1 Steady State Vs Transient Simulation [5]:

Transient Liquid Net (TLNET) performs two types of simulation runs. A steady state run calculates time invariant pressure, temperature and flow profiles throughput the pipeline system, which results from specified boundary conditions and equipment set points entered by the user. In other words, the steady state run calculates the hydraulic state of a pipeline system operating at equilibrium. This type of simulation may be done just to obtain steady state data or to provide the initial condition (i.e. initial state/initial profiles) from which to start a transient run.

A transient run models the dynamic response of the pipeline system to changes in one or more system variables such as source/delivery rates or equipment set points. Transient calculations are more complex and require more computer time than steady state calculations. Useful results can be obtained from a transient simulation only if changes occur in or more of the parameters governing the system. Thus, the transient portion of the program should be run only if one or more ramp schedule with time-varying quantities is entered or if a batch tracking simulation is needed.

Naturally, then first time a model is run with a new network, there will have been no previous simulation. Thus, at least one steady state simulation will have to be run to calculate initial profiles. However, each time the same data are reused for subsequent transient runs with or without a limited set of changes), the steady state run can be bypassed by using the initial state or final state of the previous transient simulation. If this is done, the user may only change constraints, set points, schedules, or report/trend options. The user cannot strip the steady state run if changes are made to then physical pipeline configuration.

5.2 Choosing The Simulation Timetable [7]:

The simulation can be divided into any number of predefined ramp intervals for calculation and reporting purposes. The user should determine the length of the transient simulation. This depends on the phenomenon being simulated.

Example: to simulate a daily delivery cycle, simulation length would be 24hours (1440mts/86400seconds- depend upon time unit).

If a system upset were being modeled, the simulation length would be the amount of time the user thinks it might take for the transient conditions to propagate through the pipeline network system.

The simulation period is divided into ramp intervals, which should correspond to the beginnings and endings of all changes, which occur during the transient simulation. Each interval is used to set up a time increment for ramping. Changes in flow, pressure or other set point/constraints in the system. The value being changed is ramped linearly over the specified time interval, beginning with the value specified or calculated) for the present interval.

5.3 TLNET Applications [5]:

It is used for two general types of studies, they are as follows:

Simulating normal operation of various pipeline configurations to determine the most efficient design or mode of operation. Simulating transient conditions caused by events such as leaks or equipment failures to predetermine the most effective corrective action.

To study an existing system, for example the base case would logically be a simulation of the system under normal. Steady state operating conditions followed by a simulation of any normally occurring time varying phenomena. Subsequent runs would simulate changes in pipeline operation due too design modifications or dynamic condition, depending on which is being analysed. By comparing the results of these

test runs to the base case, the user can determine the most effective design change (if required) or modification of operational procedures.

From this (TLNET), we can able to determine maximum pipeline throughput in proposed/existing systems, simulate pipeline surge, simulate pipeline leak and study transient response, predict environmental impact of pipeline leakage, analyse pipeline deliverability, and reduce operating cost.

5.3.1 To determine maximum pipeline throughput:

The increase in flow that is possible without violating the minimum line pressure at a delivery point.

5.3.2 To simulate pipeline surge:

Leaks, valve closure, pump startup/shutdown and other factors can cause pressure surge in the pipeline, which could be potentially damaging. We can design to simulate upset conditions and determine if pressure surge will exceed design criteria anywhere within the network.

5.3.3 To Analyse pipeline deliverability:

The deliverability of a pipeline system operating during peak season can be analysed to determine whether the system can meet increasing future demands or whether additional equipment is needed. Strategies such as production to and from tankage and scheduling (startup/shutdown) of key pump units can be investigated.

5.3.4 To reduce operating costs:

Pumps can be optimally scheduled so as to minimize power costs. In addition, individual pumps or pump stations can be accurately modeled by input of manufacturer provided pump had and efficiency curves. Thus fuel/electrical use associated with a given operating scenario can be evaluated and based on case studies an optimum mode of operation can be selected.

Before simulating the operation of a pipeline network, many decisions must be made:

- How will the network be configured?
- What factors should be analysed?
- What time period should the simulation cover?
- Which system variables are to be ramped and on what kind of schedule?
- A schematic should be drawn and each of the elements to be modeled should be assigned identification?

The user should also determine the constraint for the pipeline system to be modeled and whether a steady state/transient run is required. The components must be defined before drawing the schematic. A pipeline system is viewed as a network of interconnecting components including legs, nodes, equipment and external regulators which are joined together in a specific configuration. Components are defined as follows:

5.4 Legs [5]:

Leg is any segment of pipe that has uniform characteristics along its entire length. These characteristics include inside diameter, wall thickness, and absolute roughness and for temperature tracking purposes only, ambient temperature and overall heat transfer coefficient. A pipeline is broken into leg segments at any point were any of these parameters change. A leg is always connected to nodes at both the head (upstream) and tail (downstream) ends. Leg is further divided into knots (as smaller intervals). TLNET calculates pressure, density and velocity at every knot.

5.5 Transient Analysis Has Been Cited For Application Of [3]:

Pipeline construction economics (use of surge control system vs. higher wall thickness pipe). Pipeline pumps station design and operation.

-Station control valve design for pressure overrides logic to protect pipeline from over pressurization.

-Effect of rapid valve closures.

-Effect of rapid flow (supply/demand) fluctuations.

-Pressure surge relief system design.

-Lines break control.

-Waxy crude transportation.

5.6 Steps Involved in Simulation [5]:

The following equations are involved in TLNET simulator.

5.6.1 Hydraulic Equations:

Equations needed are mass, momentum and energy balance equations.

5.6.2 Friction Factor:

From the calculation of Reynolds Number (NRe), the flow can be differentiated as laminar or turbulent.

5.6.3 Drag Reduction:

In general, equations involved are Burger Correlation or Conoco correlation.

5.6.4 Equipment and External Regulator Equations:

- Leak simulation external regulator.
- Resistance equipment.
- Block valves.
- Pumps details (head, performance curve, break power and shaft power).

5.6.5 Physical Properties of Liquid:

Properties such as density, bulk modulus, coefficient of thermal expansion, heat capacity and viscosity.

By Cole Brook white Equation [4]:

$$Q=C_4 \text{ Sq. Root of } (1/f).\ D^{2.5}\ [(p_1-p_2-\Delta PE)/L.G]^{0.5}\ (bpd)$$

Pressure Drop [4]:

$$\Delta P = p_1 - p_2 - \Delta PE$$

$$= (f.L.G.Q2) / (C_4^2.D^5)$$

where,

Q= flow of liquid (bpd).

C_4= 19.8072E –6

D=inside dia (inches).

f=friction factor.

p_1= upstream pressure (psia).

p_2= downstream pressure (psia).

ΔPE= elevation changes (psia).

L= pipeline length (miles).

G= specific gravity of liquid.

5.7 Simulation Input and Output:

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MAR 25, 2007                                                    12:52 PM

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              º                         º
              º      T L N E T  5.1      º
              º  FREE-FORMAT INPUT PROCESSOR  º
              º                         º
              ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

    --------------------------- COLUMN NUMBER ----------------------------
 CARD        1       2       3       4       5       6       7
  NO.
1234567890123456789012345678901234567890123456789012345678908904567890 12

   1:    *TITLE
   2:     INPUT FILE FOR VADINAR-BINA CRUDE OIL PIPELINE
   3:     PH-1 CONDITION WITH ARAB MIX 50:50 (SRVFINAL.DAT)
   4:     (WITH SURGE VALVE SURGE ANALYSIS BEFORE COT  VALVE)
   5:     25/03/2007
   6:
;=======================================================================
   7:
   8:    *OPTIONS
   9:                          I/O      USERDEF
  10:                          PRESS    GAUGE
  11:                          TIME     MINUTES
  12:                          TIMESTEP  AUTO
  13:                            TEMP     OFF
  14:                            RUN      SS
  15:
  16:
;=======================================================================
  17:
  18:    *CONST
  19:       TEMP    20
  20:                            TBASE   15.56
  21:                            ROUGH   45
  22:                            ATEMP   20.0
```

```
  23:                                KNOT   4.0
  24:
  25:
;=================================================================
  26:  *CONTROL
  27:
  28:                                  SCREEN
  29:                                  PROFILE
  30:                                  ICNS = 50
  31:                                  ITMX = 100
  32:
  33:
;=================================================================
  34:
  35:  *CONFIG
  36:
  37:   XREG=VADINAR  AT=N01  SUPPLY   FLMX=862  MODE=FLMX
  38:   PUMP=PUMPVAD  UP=N01  DN=N02   PUPMN=2   MODE = PUPMN
  39:   PIPE=L1       UP=N02  DN=N03   L=182.731  ID=23.44
  40:
  41:;  BLKV=BLKVIP1  UP=N03  DN=N03A  CV=110000 VSIZE=24
PCTOP=100
  42:   PIPE=L2       UP=N03  DN=N05   L=168.119  ID=23.44
  43:
  44:   PUMP=PUMPIP2  UP=N05  DN=N06   PUPMN=5.0   MODE = PUPMN


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     ------------------------- COLUMN NUMBER ---------------------------
 CARD       1      2      3      4      5      6      7
  NO.
12345678901234567890123456789012345678901234567890123456789089045678901 2

  45:   PIPE=L3       UP=N06  DN=N07   L=125.852  ID=23.44
  46:
  47:;   PUMP=PUMPIP3  UP=N07  DN=N08   PUPMN=5.0   MODE = PUPMN
  48:   PIPE=L4       UP=N07  DN=N09   L=79.347   ID=23.44
  49:
  50:   PUMP=PUMPIP4  UP=N09  DN=N10   PUPMN=5.0   MODE = PUPMN
  51:   PIPE=L5       UP=N10  DN=N11   L=198.029  ID=23.44
  52:
  53:;   PUMP=PUMPIP5  UP=N11  DN=N12   PUPMN=5.0   MODE = PUPMN
  54:   PIPE=L6       UP=N11  DN=N13   L=180.922  ID=23.44
```

```
   55:   BLKV=BLKVST  UP=N13  DN=N13A  CV=53500 VSIZE=24
PCTOP=100
   56:   PIPE=L7     UP=N13A DN=N13B  L=0.05  ID=23.0
   57:   RESI=CVBINA  UP=N13B DN=N13C  F=1  L=790  D=24
   58:   XREG=SRV     AT=N13C  DELIV PMIN=12.0  MODE=PMIN CHECK
   59:   RESI=METERBINA UP=N13C  DN=N13D  F=1  L=404  D=24
   60:   PIPE=L8     UP=N13D DN=N13E  L=0.95  ID=23.0
   61:   BLKV=BLKVCOT  UP=N13E  DN=N13F  CV=53500 VSIZE=24
PCTOP=100
   62:   XREG=BINA     AT=N13F  DELIV PMIN=2.00  MODE=PMIN CHECK
   63:
   64:
;=============================================================================
   65:*USRLINE
   66:
   67:   USERLINE=MAIN  HEADPOST= 0.0
   68:
   69:      HEAD XREG  = VADINAR
   70:                          COMP NODE  = N01
   71:      COMP EQUIP = PUMPVAD
   72:      COMP NODE  = N02
   73:      COMP LEG   = L1
   74:                          COMP NODE  = N03
   75:;     COMP EQUIP = BLKVIP1
   76:;     COMP NODE  = N03A
   77:                          COMP LEG   = L2
   78:                          COMP NODE  = N05
   79:      COMP EQUIP = PUMPIP2
   80:      COMP NODE  = N06
   81:                          COMP LEG   = L3
   82:                          COMP NODE  = N07
   83:;     COMP EQUIP = PUMPIP3
   84:;     COMP NODE  = N08
   85:                          COMP LEG   = L4
   86:                          COMP NODE  = N09
   87:      COMP EQUIP = PUMPIP4
   88:      COMP NODE  = N10
   89:                          COMP LEG   = L5
   90:                          COMP NODE  = N11
   91:;     COMP EQUIP = PUMPIP5
   92:;     COMP NODE  = N12
   93:                          COMP LEG   = L6
   94:                          COMP NODE  = N13
   95:      COMP EQUIP = BLKVST
```

```
 96:        COMP NODE  = N13A
 97:        COMP LEG   = L7

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     ---------------------------- COLUMN NUMBER ----------------------------
 CARD        1       2       3       4       5       6       7
  NO.
12345678901234567890123456789012345678901234567890123456789012345678908904567890 12

 98:                              COMP NODE  = N13B
 99:       COMP EQUIP  = CVBINA
100:        COMP NODE  = N13C
101:                   COMP EQUIP  = METERBINA
102:        COMP NODE  = N13D
103:        COMP LEG   = L8
104:                              COMP NODE  = N13E
105:        COMP EQUIP  = BLKVCOT
106:        COMP NODE  = N13F
107:                               TAIL XREG  = BINA
108:
109:
110:LINEPOST =  0.00    LINEELEV =  10.0
111:LINEPOST =  100.0   LINEELEV =  60.0
112:LINEPOST =  125.0   LINEELEV =  130.0
113:LINEPOST =  150.0   LINEELEV =  100.0
114:LINEPOST =  160.0   LINEELEV =  160.0
115:LINEPOST =  180.0   LINEELEV =  160.0
116:LINEPOST =  250.0   LINEELEV =   10.0
117:LINEPOST =  320.0   LINEELEV =   10.0
118:LINEPOST =  385.0   LINEELEV =   30.0
119:LINEPOST =  400.0   LINEELEV =   90.0
120:LINEPOST =  405.0   LINEELEV =   70.0
121:LINEPOST =  460.0   LINEELEV =  280.0
122:LINEPOST =  475.0   LINEELEV =  410.0
123:LINEPOST =  490.0   LINEELEV =  290.0
124:LINEPOST =  500.0   LINEELEV =  330.0
125:LINEPOST =  510.0   LINEELEV =  370.0
126:LINEPOST =  515.0   LINEELEV =  290.0
127:LINEPOST =  525.0   LINEELEV =  370.0
128:LINEPOST =  530.0   LINEELEV =  310.0
129:LINEPOST =  550.0   LINEELEV =  410.0
130:LINEPOST =  570.0   LINEELEV =  430.0
131:LINEPOST =  580.0   LINEELEV =  390.0
```

```
    PUMP HYD  = DET
                          XREG HYD  = DET
   DTIME = 5


;=====================================================================

 *TRANS
   RAMP EQUIP BLKVST  PCTOP VALUE=100  100   100   0   0
                   TIME =0    2.0   4.5   6.5 15.0

     RAMP EQUIP BLKVCOT PCTOP VALUE=100  100   0     0
                   TIME =0    2.0   4.0   15.0

;=====================================================================

 *LIQUID
  TYPE    = CRUDE
  CLASS   = CRUDE  GRAVL=30.0  GRAVU=35.0
  PRESL= 1.0
  PRESU= 100.0
  TEMPL= 5.0
  TEMPU= 25.0
  VSTEMP=   129     30
  VISC=     1.5     6.0

;=====================================================================
 *FILL

   DEFBAT     CRUDE
   DEFLT      CRUDE
   DEFAPI     30.73
   DEFXRG     VADINAR

;=====================================================================
 *END
```

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º                                          º
º          T L N E T                       º
º  TRANSIENT LIQUID NETWORK MODEL          º
º       STEADY STATE MODULE                º
```

º RELEASE 5.1 LEVEL 0
º SCIENTIFIC SOFTWARE - INTERCOMP º
º º
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INPUT FILE FOR VADINAR-BINA CRUDE OIL PIPELINE

TLNET EXECUTION OPTIONS REPORT
****

INPUT UNITS: USER-DEFINED
OUTPUT UNITS: USER-DEFINED
PRESSURE UNITS: GAUGE
TIME UNITS: MINUTES

TEMPERATURE TRACKING PERFORMED: NO
BATCH TRACKING PERFORMED: NO

INITIAL STATE FOR TRANSIENT SIMULATION:
NEW STEADY STATE

METHOD OF TIME STEP SELECTION FOR TRANSIENT SIMULATION:
AUTOMATIC TIME STEP SELECTION

VISCOSITY BLENDING RULE: STANDARD

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EQUIPMENT PARAMETERS REPORT
****

TOTAL NUMBER OF PUMP PERFORMANCE TYPES: 0

*** CENTRIFUGAL PUMP PERFORMANCE TYPE DATA

NUMBER OF CENTRIFUGAL PUMP PERFORMANCE TYPES: 0

*** TURBINE PERFORMANCE TYPE DATA

NUMBER OF TURBINE PERFORMANCE TYPES: 0

*** TURBINE DATA

NUMBER OF TURBINE TYPES: 0

TLNET INITIAL STATE OUTPUT OPTIONS REPORT

****

REPORT TYPES:

---

0 = NO REPORT
1 = SUMMARY REPORT
2 = DETAIL REPORT

*** LEG REPORT OPTIONS

LEG HYDRAULIC REPORT: 2

REPORTING ALL LEGS

*** PUMP REPORT OPTIONS

PUMP HYDRAULIC REPORT: 2

REPORTING ALL PUMPS

*** REGULATOR REPORT OPTIONS

REGULATOR HYDRAULIC REPORT: 1

REPORTING ALL REGULATORS

*** BLOCK VALVE REPORT OPTIONS

BLOCK VALVE HYDRAULIC REPORT: 1

REPORTING ALL BLOCK VALVES

*** CHECK VALVE REPORT OPTIONS

CHECK VALVE HYDRAULIC REPORT: 1

REPORTING ALL CHECK VALVES

*** RESISTANCE REPORT OPTIONS

RESISTANCE HYDRAULIC REPORT: 1

REPORTING ALL RESISTANCES

*** EXTERNAL REGULATOR REPORT OPTIONS

EXTERNAL REGULATOR HYDRAULIC REPORT: 2

REPORTING ALL EXTERNAL REGULATORS

*** TANKAGE REPORT OPTIONS

TANKAGE HYDRAULIC REPORT: 1

REPORTING ALL TANKS

*** BATCH REPORT OPTIONS

BATCH REPORT: 0

*** NODE MASS BALANCE REPORT OPTIONS

NODE MASS BALANCE REPORT: 0

TREND REPORT

****
*****

The following External Regulators have been selected:
VADINAR SRV BINA

With the following values:
Pressure Temperature
Flow Mode
Maximum Flow Setpoint Minimum Pressure Setpoint
Accumulated Volume

Total Number of Trended data values for this entry is 18

The following Nodes have been selected:
N01 N02 N03 N05 N06 N07 N09 N10 N11
N13 N13A N13B N13C N13D N13E N13F

With the following values:
Pressure Temperature
Density Flux

Total Number of Trended data values for this entry is 64

MAX, TREND EVERY TIME STEP

TRANSIENT SIMULATION SCENARIO REPORT
****

*** AUTOMATIC TIME STEP OPTIONS

MINIMUM TIME STEP: (MINS) 0.017

MAXIMUM TIME STEP: (MINS) 166.667
ACCURACY LEVEL : 5.00

*** TRANSIENT SIMULATION TIMETABLE

RAMP NO.	TIME (MINS) FROM	TO
1	0.000	2.000
2	2.000	4.000
3	4.000	4.500
4	4.500	6.500
5	6.500	15.000

*** EQUIPMENT SETPOINT/CONSTRAINT RAMP SCHEDULE

EQUIPMENT: BLKVST

CURRENT RAMPED SETPOINT/CONSTRAINT TYPES

SETPT/ CNSTRT NO	DESCRIPTION
1	PERCENT OPEN SETPOINT

SCHEDULE FOR PERCENT OPEN SETPOINT

RAMP NO.	TIME (MINS) FROM	TO	SETPOINT/CONSTRAINT VALUE
		0.000	100.000
1	0.000	0.000	100.000
2	0.000	2.000	100.000
3	2.000	4.500	100.000
4	4.500	6.500	0.000
5	6.500	15.000	0.000

EQUIPMENT: BLKVCOT

CURRENT RAMPED SETPOINT/CONSTRAINT TYPES

SETPT/ CNSTRT NO	DESCRIPTION
1	PERCENT OPEN SETPOINT

SCHEDULE FOR PERCENT OPEN SETPOINT

RAMP NO.	TIME (MINS) FROM	TO	SETPOINT/CONSTRAINT VALUE
		0.000	100.000
1	0.000	0.000	100.000
2	0.000	2.000	100.000
3	2.000	4.000	0.000
4	4.000	15.000	0.000

*** EXTERNAL REGULATOR SETPOINT/CONSTRAINT RAMP SCHEDULE

*** INLET FLUID CONDITIONS RAMP SCHEDULE

LIQUID TYPES REPORT

****

NUMBER OF LIQUID TYPES: 1

CURRENT LIQUID PROPERTIES FOR TYPE: CRUDE

*** BULK MODULUS DATA

BULK MODULUS

POINT NO	TEMP (DEG C)	PRESSURE (KG/CM2	GRAVITY (DG API)	MEASURED (KG/CM2	CURVE FIT (KG/CM2	REL ERR (%)
1	5.0	1.0	30.00	16091.	16089.	0.01
2	5.0	50.5	30.00	16091.	16089.	0.01
3	5.0	100.0	30.00	16091.	16089.	0.01
4	15.0	1.0	30.00	15198.	15198.	0.00
5	15.0	50.5	30.00	15198.	15198.	0.00
6	15.0	100.0	30.00	15198.	15198.	0.00
7	25.0	1.0	30.00	14355.	14358.	0.02
8	25.0	50.5	30.00	14355.	14358.	0.02
9	25.0	100.0	30.00	14355.	14358.	0.02
10	5.0	1.0	35.00	14958.	14956.	0.02
11	5.0	50.5	35.00	14958.	14956.	0.02
12	5.0	100.0	35.00	14958.	14956.	0.02
13	15.0	1.0	35.00	14080.	14080.	0.00
14	15.0	50.5	35.00	14080.	14080.	0.00
15	15.0	100.0	35.00	14080.	14080.	0.00
16	25.0	1.0	35.00	13254.	13255.	0.01
17	25.0	50.5	35.00	13254.	13255.	0.01
18	25.0	100.0	35.00	13254.	13255.	0.01

*** COEFFICIENT OF THERMAL EXPANSION DATA

				THERM EXPAN COEFF		
POINT NO	TEMP (DEG C)	PRESSURE (KG/CM2	GRAVITY (DG API)	MEASURED 1/(DEG C)	CURVE FIT 1/(DEG C)	REL ERR (%)
1	5.0	1.0	30.00	0.7887E-03	0.7882E-03	0.06
2	5.0	50.5	30.00	0.7887E-03	0.7882E-03	0.06
3	5.0	100.0	30.00	0.7887E-03	0.7882E-03	0.06
4	15.0	1.0	30.00	0.7989E-03	0.7989E-03	0.00
5	15.0	50.5	30.00	0.7989E-03	0.7989E-03	0.00
6	15.0	100.0	30.00	0.7989E-03	0.7989E-03	0.00
7	25.0	1.0	30.00	0.8091E-03	0.8096E-03	0.05
8	25.0	50.5	30.00	0.8091E-03	0.8096E-03	0.05
9	25.0	100.0	30.00	0.8091E-03	0.8096E-03	0.05
10	5.0	1.0	35.00	0.8203E-03	0.8207E-03	0.05
11	5.0	50.5	35.00	0.8203E-03	0.8207E-03	0.05
12	5.0	100.0	35.00	0.8203E-03	0.8207E-03	0.05
13	15.0	1.0	35.00	0.8314E-03	0.8314E-03	0.00
14	15.0	50.5	35.00	0.8314E-03	0.8314E-03	0.00
15	15.0	100.0	35.00	0.8314E-03	0.8314E-03	0.00

16	25.0	1.0	35.00	0.8425E-03	0.8421E-03	0.05
17	25.0	50.5	35.00	0.8425E-03	0.8421E-03	0.05
18	25.0	100.0	35.00	0.8425E-03	0.8421E-03	0.05

*** HEAT CAPACITY DATA

				HEAT CAPACITY		
POINT NO	TEMP (DEG C)	PRESSURE (KG/CM2	GRAVITY (DG API)	MEASURED (KJ/KG)	CURVE FIT (KJ/KG)	REL ERR (%)
1	5.0	1.0	30.00	1.75206	1.75207	0.00
2	5.0	50.5	30.00	1.75206	1.75207	0.00
3	5.0	100.0	30.00	1.75206	1.75207	0.00
4	15.0	1.0	30.00	1.79350	1.79350	0.00
5	15.0	50.5	30.00	1.79350	1.79350	0.00
6	15.0	100.0	30.00	1.79350	1.79350	0.00
7	25.0	1.0	30.00	1.83494	1.83493	0.00
8	25.0	50.5	30.00	1.83494	1.83493	0.00
9	25.0	100.0	30.00	1.83494	1.83493	0.00
10	5.0	1.0	35.00	1.79810	1.79811	0.00
11	5.0	50.5	35.00	1.79810	1.79811	0.00
12	5.0	100.0	35.00	1.79810	1.79811	0.00
13	15.0	1.0	35.00	1.83955	1.83955	0.00
14	15.0	50.5	35.00	1.83955	1.83955	0.00
15	15.0	100.0	35.00	1.83955	1.83955	0.00
16	25.0	1.0	35.00	1.88099	1.88098	0.00
17	25.0	50.5	35.00	1.88099	1.88098	0.00
18	25.0	100.0	35.00	1.88099	1.88098	0.00

*** KINEMATIC VISCOSITY DATA

		VISCOSITY		
POINT NO	TEMP (DEG C)	MEASURED (CS)	CURVE FIT (CS)	REL ERR (%)
1	30.0	6.000	6.000	0.00
2	129.0	1.500	1.500	0.00

BATCH LAUNCHING TOLERANCE CRITERION FOR
API GRAVITY: 1.00

BATCH LAUNCHING TOLERANCE CRITERION FOR

FLUID COMPOSITION: 10.00 %

INITIAL INLET FLUID CONDITIONS REPORT
****

*** REPORT INITIAL BATCH LINE FILL ***

DEFAULT LIQUID TYPE ID ---------- CRUDE
DEFAULT API ---------- 30.7300

TLNET DRA PARAMETERS REPORT
****

DRA SIMULATION STATUS: INACTIVE

THERE ARE NO TOTALIZED VOLUMES SET FOR THIS NETWORK.

THERE ARE NO ALARMS SET FOR THIS NETWORK.

NETWORK CONFIGURATION REPORT
****

*** LEG DATA

NUMBER OF LEGS: 8

NOMINAL DISTANCE STEP (KM): 4.00

LEG ID	HEAD NODE ID	TAIL NODE ID
L1	N02	N03
L2	N03	N05
L3	N06	N07
L4	N07	N09
L5	N10	N11
L6	N11	N13
L7	N13A	N13B
L8	N13D	N13E

LEG ID	LENGTH (KM)	INSIDE DIAM (INCH)	ABS ROUGH (MICRON)	WALL THICKNESS (INCH)	DISTANCE STEP (KM)
L1	182.73	23.440	45.0000	0.5000	3.97
L2	168.12	23.440	45.0000	0.5000	3.91
L3	125.85	23.440	45.0000	0.5000	3.93
L4	79.35	23.440	45.0000	0.5000	3.97
L5	198.03	23.440	45.0000	0.5000	3.96
L6	180.92	23.440	45.0000	0.5000	3.93
L7	0.05	23.000	45.0000	0.5000	0.05
L8	0.95	23.000	45.0000	0.5000	0.95

*** EQUIPMENT DATA

NUMBER OF EQUIPMENT DEVICES: 7

EQP ID	UPSIDE NODE ID	DOWNSIDE NODE ID	TYPE OF EQUIPMENT	SETPOINT/ CONSTRAINTS
BLKVCOT	N13E	N13F	BLOCK VALVE	PERCENT OPEN
BLKVST	N13	N13A	BLOCK VALVE	PERCENT OPEN
CVBINA	N13B	N13C	RESISTANCE	RESISTANCE
METERBIN	N13C	N13D	RESISTANCE	RESISTANCE
PUMPIP2	N05	N06	PUMP	FREE FLOW

```
                                MIN UP  PRES
                                PERCENT OPEN
PUMPIP4   N09      N10           PUMP        FREE FLOW
                                MIN UP  PRES
                                PERCENT OPEN
PUMPVAD   N01      N02           PUMP        FREE FLOW
                                MIN UP  PRES
                                PERCENT OPEN

-------------------------------------------------
     VALVE PHYSICAL CHARATERISTIC DATA
-------------------------------------------------
                    FULLY       VALVE
 EQP        TYPE OF        OPEN Cv     SIZE
  ID        VALVE       (GPM/PSI)  ( INCH )
--------  -----------   ---------  ---------
BLKVST     BLOCK VALVE      53500.     24.000
BLKVCOT    BLOCK VALVE      53500.     24.000


*** EXTERNAL REGULATOR DATA

NUMBER OF EXTERNAL REGULATORS:  3

-----------------------------------------------------
 XRG      NODE         TYPE OF          SETPOINT/
  ID      ID    EXTERNAL REGULATOR   CONSTRAINTS
--------  --------  -----------------  --------------
BINA      N13F      DELIVERY           CHECK VALVE
                          MIN PRES
SRV       N13C      DELIVERY           CHECK VALVE
                          MIN PRES
VADINAR   N01       SUPPLY             MAX FLOW


*** SINGLE PUMP DATA

NUMBER OF SINGLE PUMPS:  3

----------------------------
 PUMP    PUMP PERF  TURBINE
  ID     TYPE ID    TYPE ID
--------  ---------  --------
PUMPIP2   0          0
```

PUMPIP4 0 0
PUMPVAD 0 0

PUMP ID	PUMP CATEGORY	VLV LOSS (FT)	ADB. EFC (PERCNT)	MCH. EFC (PERCNT)	AUX LOAD (MW)
PUMPVAD	GENERIC	N/A	100.00	100.00	0.00
PUMPIP2	GENERIC	N/A	100.00	100.00	0.00
PUMPIP4	GENERIC	N/A	100.00	100.00	0.00

*** NODE DATA

NUMBER OF NODES: 16

NODE ID	ELEVATION (M)	CONNECTED LEGS / EQUIPMENT / EXTERNAL REGULATORS
N01	10.00	EQP IDS: PUMPVAD XRG IDS: VADINAR
N02	10.00	LEG IDS: L1 EQP IDS: PUMPVAD
N03	154.15	LEG IDS: L1 L2
N05	19.49	LEG IDS: L2 EQP IDS: PUMPIP2
N06	19.49	LEG IDS: L3 EQP IDS: PUMPIP2
N07	396.38	LEG IDS: L3 L4
N09	416.05	LEG IDS: L4 EQP IDS: PUMPIP4
N10	416.05	LEG IDS: L5 EQP IDS: PUMPIP4
N11	408.16	LEG IDS: L5 L6
N13	400.00	LEG IDS: L6 EQP IDS: BLKVST
N13A	400.00	LEG IDS: L7 EQP IDS: BLKVST
N13B	400.00	LEG IDS: L7 EQP IDS: CVBINA
N13C	400.00	EQP IDS: CVBINA METERBIN XRG IDS: SRV
N13D	400.00	LEG IDS: L8

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                EQP IDS: METERBIN
N13E      400.00   LEG IDS: L8
                EQP IDS: BLKVCOT
N13F      400.00   EQP IDS: BLKVCOT
                XRG IDS: BINA


*** USER-DEFINED LINE DATA

NUMBER OF USER-LINES:  1

USER-LINE: MAIN
-----------------------------------------------
COMP   COMP   MILEPOST DISTANCE  VOLUME
TYPE   ID   ( KM ) ( KM ) ( M3 )
------ -------- -------- -------- ------------
XRG   VADINAR     0.0     0.0       0.000
NOD   N01         0.0     0.0       0.000
EQP   PUMPVAD     0.0     0.0       0.000
NOD   N02         0.0     0.0       0.000
LEG   L1          0.0     0.0       0.000
NOD   N03       182.7   182.7      50.878
LEG   L2        182.7   182.7      50.878
NOD   N05       350.9   350.9      97.688
EQP   PUMPIP2   350.9   350.9      97.688
NOD   N06       350.9   350.9      97.688
LEG   L3        350.9   350.9      97.688
NOD   N07       476.7   476.7     132.730
LEG   L4        476.7   476.7     132.730
NOD   N09       556.0   556.0     154.822
EQP   PUMPIP4   556.0   556.0     154.822
NOD   N10       556.0   556.0     154.822
LEG   L5        556.0   556.0     154.822
NOD   N11       754.1   754.1     209.960
LEG   L6        754.1   754.1     209.960
NOD   N13       935.0   935.0     260.335
EQP   BLKVST    935.0   935.0     260.335
NOD   N13A      935.0   935.0     260.335
LEG   L7        935.0   935.0     260.335
NOD   N13B      935.1   935.1     260.348
EQP   CVBINA    935.1   935.1     260.348
NOD   N13C      935.1   935.1     260.348
EQP   METERBIN  935.1   935.1     260.348
NOD   N13D      935.1   935.1     260.348
```

```
LEG   L8       935.1    935.1     260.348
NOD   N13E     936.0    936.0     260.603
EQP   BLKVCOT  936.0    936.0     260.603
NOD   N13F     936.0    936.0     260.603
XRG   BINA     936.0    936.0     260.603
```

*** ELEVATION PROFILE DATA

NUMBER OF USER LINE ELEVATION PROFILES: 1

USER LINE: MAIN

MILEPOST (KM)	ELEVATION (M)	CRITICAL POINT (0=NO,1=YES)
0.00	10.0	0
100.00	60.0	0
125.00	130.0	0
150.00	100.0	0
160.00	160.0	0
180.00	160.0	0
250.00	10.0	0
320.00	10.0	0
385.00	30.0	0
400.00	90.0	0
405.00	70.0	0
460.00	280.0	0
475.00	410.0	0
490.00	290.0	0
500.00	330.0	0
510.00	370.0	0
515.00	290.0	0
525.00	370.0	0
530.00	310.0	0
550.00	410.0	0
570.00	430.0	0
580.00	390.0	0
615.00	510.0	0
660.00	470.0	0
675.00	530.0	0
690.00	470.0	0
710.00	490.0	0
720.00	410.0	0

730.00 430.0 0
745.00 390.0 0
770.00 440.0 0
780.00 440.0 0
790.00 380.0 0
810.00 380.0 0
830.00 460.0 0
840.00 390.0 0
855.00 510.0 0
890.00 530.0 0
920.00 390.0 0
925.00 400.0 0
930.00 390.0 0
935.00 400.0 0
936.00 400.0 0

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SYSTEM-WIDE FLUID CONDITIONS REPORT
****

SYSTEM-WIDE FLUID TEMPERATURE (DEG C): 20.00

LIQUID TYPE ID: CRUDE
SYSTEM-WIDE FLUID API GRAV (DG API): 30.73

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INITIAL MODES/SETPOINTS/CONSTRAINTS REPORT
****

*** EQUIPMENT DATA

EQP ID	TYPE OF EQUIPMENT	INITIAL MODE	SETPOINT/ CONSTRAINTS	SETPT/CNSTRT VALUE
BLKVCOT	BLOCK VALVE	BLOCK VALVE	*PERCENT OPEN	100.000
BLKVST	BLOCK VALVE	BLOCK VALVE	*PERCENT OPEN	100.000
CVBINA	RESISTANCE	RESISTANCE	*RESISTANCE	0.00

KQ2=ABS(PU2-PD2)

METERBIN RESISTANCE RESISTANCE *RESISTANCE 0.00
KQ2=ABS(PU2-PD2)
PUMPIP2 PUMP MIN PU MIN UP PRES 5.00 A)(KG
PERCENT OPEN 1.000
PUMPIP4 PUMP MIN PU MIN UP PRES 5.00 A)(KG
PERCENT OPEN 1.000
PUMPVAD PUMP MIN PU MIN UP PRES 2.00 A)(KG
PERCENT OPEN 1.000

NOTE: * INDICATES CONSTRAINT IS FORCED BY PROGRAM

*** EXTERNAL REGULATOR DATA

XRG ID	TYPE OF EXTERNAL REGULATOR	INITIAL MODE	SETPOINT/ CONSTRAINTS	SETPT/CNSTRT VALUE
BINA	DELIVERY	MIN PRES	MIN PRES	2.00 A)(KG
SRV	DELIVERY	MIN PRES	MIN PRES	12.00 A)(KG
VADINAR	SUPPLY	MAX FLOW	MAX FLOW	862.0 (M3/HR)

TLNET CASE SIZE REPORT AND MAXIMUM SIZES

NUMBER OF EQUIPMENT	7	100
NUMBER OF LEGS	8	75
NUMBER OF NODES	16	500
NUMBER OF EXTERNAL REGULATORS	3	100
NUMBER OF KNOTS	247	800
NUMBER OF XREG CONSTRAINTS	5	600
NUMBER OF EQUIP CONSTRAINTS	13	500
NUMBER OF EQUIP VARIABLE DATA	33	700
NUMBER OF USER LINES	1	30
NUMBER OF TANKS	0	50

********** STEADY STATE CONVERGENCE SUMMARY **********

ITERATION NUMBER	TOLERANCE VALUES CONVERGENCE	HYDRAULIC	TEMPERATURE	ERROR COMPONENT NAME	(TYPE)
1	.10000E-03	.10610E+01	.00000E+00	SRV	(XREG)
2	.10000E-03	.10998E+01	.00000E+00	SRV	(XREG)
3	.10000E-03	.78967E+00	.00000E+00	SRV	(XREG)
4	.10000E-03	.31250E+00	.00000E+00	N01	(NODE)
5	.10000E-03	.45455E+00	.00000E+00	N01	(NODE)
6	.10000E-03	.83333E+00	.00000E+00	N01	(NODE)
7	.10000E-03	.28619E+01	.00000E+00	N01	(NODE)
8	.10000E-03	.14449E+00	.00000E+00	N07	(NODE)
9	.10000E-03	.64198E-03	.00000E+00	SRV	(XREG)
10	.10000E-03	.83517E-05	.00000E+00	N13D	(NODE)
---------- MODE CHANGES ----------					
10	XREG SRV	FROM: MIN PRES	TO: CLOSED		
11	.10000E-03	.19717E-06	.00000E+00	N10	(NODE)
12	.10000E-03	.17004E+03	.00000E+00	SRV	(XREG)
13	.10000E-03	.36312E+00	.00000E+00	N13C	(NODE)
14	.10000E-03	.28653E-03	.00000E+00	N10	(NODE)
15	.10000E-03	.19754E-04	.00000E+00	N10	(NODE)
16	.10000E-03	.14444E-06	.00000E+00	N10	(NODE)

REFERENCE PRESSURE = 0.00 A)(KG

REFERENCE TEMPERATURE = 15.56 (DEG C)

LEG HYDRAULIC DETAILED REPORT

****

TIME = 0.000 (MINS)

USER LINE: MAIN

DISTANCE (KM)	PRESSURE A) (KG/CM	MAX-PRES A) (KG/CM	MIN-PRES A) (KG/CM	DENSITY (KG/M3)	VELOCITY (M/S)	FLOW (M3/HR)	TEMP (DEG C)	HEAD (M)	ELEV (M)	API GRAV	VISCOSITY FACTOR	FRICTION
LEG: L1 23.440 IN. D. (INCH) FROM NODE: N02 TO NODE: N03												
0.00	44.38	59.48	42.59	871.7731	0.86	862.00	20.00	531.2	10.0	30.73	.75620E+01	0.19864E-01
3.97	43.77	59.58	42.21	871.7368	0.86	862.00	20.00	526.2	12.0	30.73	.75620E+01	0.19863E-01
7.94	43.16	59.68	41.83	871.7004	0.86	862.00	20.00	521.2	14.0	30.73	.75620E+01	0.19863E-01
11.92	42.55	59.78	41.45	871.6641	0.86	862.00	20.00	516.2	16.0	30.73	.75620E+01	0.19863E-01
15.89	41.94	59.88	41.07	871.6278	0.86	862.00	20.00	511.3	17.9	30.73	.75620E+01	0.19863E-01
19.86	41.33	59.98	40.68	871.5915	0.86	862.00	20.00	506.3	19.9	30.73	.75620E+01	0.19862E-01
23.83	40.73	60.08	40.09	871.5552	0.86	862.00	20.00	501.3	21.9	30.73	.75620E+01	0.19862E-01
27.81	40.12	60.18	39.50	871.5189	0.86	862.00	20.00	496.3	23.9	30.73	.75620E+01	0.19862E-01
31.78	39.51	60.28	38.90	871.4825	0.86	862.00	20.00	491.3	25.9	30.73	.75620E+01	0.19862E-01
35.75	38.90	60.38	38.31	871.4463	0.86	862.00	20.00	486.4	27.9	30.73	.75620E+01	0.19862E-01
39.72	38.29	60.48	37.72	871.4100	0.86	862.00	20.00	481.4	29.9	30.73	.75620E+01	0.19861E-01
43.70	37.68	60.58	37.12	871.3737	0.86	862.00	20.00	476.4	31.8	30.73	.75620E+01	0.19861E-01
47.67	37.07	60.68	36.53	871.3373	0.86	862.00	20.00	471.4	33.8	30.73	.75620E+01	0.19861E-01
51.64	36.47	60.78	35.94	871.3010	0.86	862.00	20.00	466.4	35.8	30.73	.75620E+01	0.19861E-01
55.61	35.86	60.88	35.35	871.2647	0.86	862.00	20.00	461.4	37.8	30.73	.75620E+01	0.19860E-01
59.59	35.25	60.98	34.75	871.2284	0.86	862.00	20.00	456.4	39.8	30.73	.75620E+01	0.19860E-01
63.56	34.64	61.08	34.16	871.1921	0.86	862.00	20.00	451.5	41.8	30.73	.75620E+01	0.19860E-01
67.53	34.03	61.18	33.57	871.1558	0.86	862.00	20.00	446.5	43.8	30.73	.75620E+01	0.19860E-01
71.50	33.42	61.28	32.97	871.1194	0.86	862.00	20.00	441.5	45.8	30.73	.75620E+01	0.19859E-01
75.48	32.81	61.38	32.38	871.0831	0.86	862.00	20.00	436.5	47.7	30.73	.75620E+01	0.19859E-01
79.45	32.20	61.48	31.79	871.0468	0.86	862.00	20.00	431.5	49.7	30.73	.75620E+01	0.19859E-01

83.42	31.60	61.58	31.19	871.0105	0.86	862.00	20.00	426.5	51.7	30.73	.75620E+01	0.19859E-01
87.39	30.99	61.68	30.60	870.9742	0.86	862.00	20.00	421.5	53.7	30.73	.75620E+01	0.19859E-01
91.37	30.38	61.78	30.01	870.9379	0.86	862.00	20.00	416.5	55.7	30.73	.75620E+01	0.19858E-01
95.34	29.77	61.88	29.41	870.9016	0.86	862.00	20.00	411.5	57.7	30.73	.75620E+01	0.19858E-01
99.31	29.16	61.98	28.82	870.8653	0.86	862.00	20.00	406.5	59.7	30.73	.75620E+01	0.19858E-01
103.28	27.89	61.42	27.57	870.7899	0.86	862.00	20.00	401.6	69.2	30.73	.75620E+01	0.19857E-01
107.26	26.49	60.73	26.18	870.7061	0.86	862.00	20.00	396.6	80.3	30.73	.75620E+01	0.19857E-01
111.23	25.09	60.03	24.79	870.6224	0.86	862.00	20.00	391.6	91.4	30.73	.75620E+01	0.19856E-01
115.20	23.68	59.33	23.41	870.5387	0.86	862.00	20.00	386.6	102.6	30.73	.75620E+01	0.19856E-01
119.17	22.28	58.64	22.02	870.4550	0.86	862.00	20.00	381.6	113.7	30.73	.75620E+01	0.19855E-01
123.14	20.87	57.94	20.63	870.3713	0.86	862.00	20.00	376.6	124.8	30.73	.75620E+01	0.19855E-01
127.12	20.21	57.98	19.98	870.3316	0.86	862.00	20.00	371.6	127.5	30.73	.75620E+01	0.19855E-01
131.09	20.18	58.67	19.97	870.3303	0.86	862.00	20.00	366.6	122.7	30.73	.75620E+01	0.19855E-01
135.06	20.16	59.36	19.97	870.3290	0.86	862.00	20.00	361.6	117.9	30.73	.75620E+01	0.19855E-01
139.03	20.14	60.05	19.96	870.3278	0.86	862.00	20.00	356.6	113.2	30.73	.75620E+01	0.19855E-01
143.01	20.12	60.74	19.95	870.3264	0.86	862.00	20.00	351.6	108.4	30.73	.75620E+01	0.19855E-01
146.98	20.10	61.43	19.95	870.3251	0.86	862.00	20.00	346.5	103.6	30.73	.75620E+01	0.19855E-01
150.95	19.48	61.52	19.34	870.2883	0.86	862.00	20.00	341.5	105.7	30.73	.75620E+01	0.19854E-01
154.92	16.97	59.71	16.85	870.1388	0.86	862.00	20.00	336.6	129.5	30.73	.75620E+01	0.19853E-01
158.90	14.46	57.91	14.36	869.9893	0.86	862.00	20.00	331.6	153.4	30.73	.75620E+01	0.19852E-01
162.87	13.45	57.60	13.36	869.9290	0.86	862.00	20.00	326.6	160.0	30.73	.75620E+01	0.19852E-01
166.84	13.01	57.87	12.94	869.9030	0.86	862.00	20.00	321.5	160.0	30.73	.75620E+01	0.19852E-01
170.81	12.58	58.15	12.52	869.8770	0.86	862.00	20.00	316.5	160.0	30.73	.75620E+01	0.19852E-01
174.79	12.14	58.42	12.10	869.8510	0.86	862.00	20.00	311.5	160.0	30.73	.75620E+01	0.19852E-01
178.76	11.70	58.70	11.68	869.8250	0.86	862.00	20.00	306.5	160.0	30.73	.75620E+01	0.19851E-01
182.73	11.77	59.48	11.77	869.8293	0.86	862.00	20.00	301.5	154.1	30.73	.75620E+01	0.19851E-01

LEG: L2 23.440 IN. D. (INCH) FROM NODE: N03 TO NODE: N05

182.73	11.77	59.48	11.77	869.8293	0.86	862.00	20.00	301.5	154.1	30.73	.75620E+01	0.19851E-01
186.64	12.07	59.94	12.07	869.8470	0.86	862.00	20.00	296.5	145.8	30.73	.75620E+01	0.19852E-01

190.55	12.37	60.40	12.37	869.8649	0.86	862.00	20.00	291.6	137.4	30.73	.75620E+01	0.19852E-01
194.46	12.67	60.85	12.67	869.8826	0.86	862.00	20.00	286.6	129.0	30.73	.75620E+01	0.19852E-01
198.37	12.97	61.31	12.97	869.9003	0.86	862.00	20.00	281.7	120.6	30.73	.75620E+01	0.19852E-01
202.28	13.27	61.77	13.27	869.9182	0.86	862.00	20.00	276.7	112.3	30.73	.75620E+01	0.19852E-01
206.19	13.57	62.23	13.57	869.9359	0.86	862.00	20.00	271.8	103.9	30.73	.75620E+01	0.19852E-01
210.10	13.86	62.68	13.86	869.9537	0.86	862.00	20.00	266.8	95.5	30.73	.75620E+01	0.19852E-01
214.01	14.16	63.14	14.16	869.9716	0.86	862.00	20.00	261.9	87.1	30.73	.75620E+01	0.19852E-01
217.92	14.46	63.60	14.46	869.9893	0.86	862.00	20.00	256.9	78.7	30.73	.75620E+01	0.19852E-01
221.83	14.76	64.06	14.76	870.0071	0.86	862.00	20.00	252.0	70.4	30.73	.75620E+01	0.19853E-01
225.74	15.06	64.52	15.06	870.0249	0.86	862.00	20.00	247.0	62.0	30.73	.75620E+01	0.19853E-01
229.65	15.36	64.97	15.36	870.0427	0.86	862.00	20.00	242.1	53.6	30.73	.75620E+01	0.19853E-01
233.56	15.66	65.43	15.66	870.0605	0.86	862.00	20.00	237.2	45.2	30.73	.75620E+01	0.19853E-01
237.47	15.96	65.89	15.96	870.0784	0.86	862.00	20.00	232.2	36.9	30.73	.75620E+01	0.19853E-01
241.38	16.25	66.35	16.25	870.0961	0.86	862.00	20.00	227.3	28.5	30.73	.75620E+01	0.19853E-01
245.29	16.55	66.81	16.55	870.1140	0.86	862.00	20.00	222.3	20.1	30.73	.75620E+01	0.19853E-01
249.20	16.85	67.26	16.85	870.1317	0.86	862.00	20.00	217.4	11.7	30.73	.75620E+01	0.19853E-01
253.11	16.57	67.14	16.57	870.1151	0.86	862.00	20.00	212.4	10.0	30.73	.75620E+01	0.19853E-01
257.02	16.14	66.87	16.14	870.0895	0.86	862.00	20.00	207.5	10.0	30.73	.75620E+01	0.19853E-01
260.93	15.71	66.59	15.71	870.0638	0.86	862.00	20.00	202.6	10.0	30.73	.75620E+01	0.19853E-01
264.84	15.28	66.32	15.28	870.0383	0.86	862.00	20.00	197.6	10.0	30.73	.75620E+01	0.19853E-01
268.75	14.85	66.05	14.85	870.0127	0.86	862.00	20.00	192.7	10.0	30.73	.75620E+01	0.19853E-01
272.66	14.42	65.77	14.42	869.9871	0.86	862.00	20.00	187.8	10.0	30.73	.75620E+01	0.19852E-01
276.56	13.99	65.50	13.99	869.9615	0.86	862.00	20.00	182.8	10.0	30.73	.75620E+01	0.19852E-01
280.47	13.56	65.23	13.56	869.9359	0.86	862.00	20.00	177.9	10.0	30.73	.75620E+01	0.19852E-01
284.38	13.13	64.95	13.13	869.9103	0.86	862.00	20.00	172.9	10.0	30.73	.75620E+01	0.19852E-01
288.29	12.70	64.68	12.70	869.8847	0.86	862.00	20.00	168.0	10.0	30.73	.75620E+01	0.19852E-01
292.20	12.27	64.41	12.27	869.8591	0.86	862.00	20.00	163.1	10.0	30.73	.75620E+01	0.19852E-01
296.11	11.84	64.13	11.84	869.8335	0.86	862.00	20.00	158.1	10.0	30.73	.75620E+01	0.19851E-01
300.02	11.41	63.86	11.41	869.8079	0.86	862.00	20.00	153.2	10.0	30.73	.75620E+01	0.19851E-01
303.93	10.99	63.59	10.99	869.7823	0.86	862.00	20.00	148.2	10.0	30.73	.75620E+01	0.19851E-01
307.84	10.56	63.31	10.56	869.7567	0.86	862.00	20.00	143.3	10.0	30.73	.75620E+01	0.19851E-01

311.75	10.13	63.04	10.13	869.7311	0.86	862.00	20.00	138.4	10.0	30.73	.75620E+01	0.19851E-01
315.66	9.70	62.77	9.70	869.7054	0.86	862.00	20.00	133.4	10.0	30.73	.75620E+01	0.19851E-01
319.57	9.27	62.49	9.27	869.6799	0.86	862.00	20.00	128.5	10.0	30.73	.75620E+01	0.19851E-01
323.48	8.74	62.13	8.74	869.6487	0.86	862.00	20.00	123.5	11.1	30.73	.75620E+01	0.19850E-01
327.39	8.21	61.75	8.21	869.6169	0.86	862.00	20.00	118.6	12.3	30.73	.75620E+01	0.19850E-01
331.30	7.67	61.37	7.67	869.5851	0.86	862.00	20.00	113.6	13.5	30.73	.75620E+01	0.19850E-01
335.21	7.14	60.99	7.14	869.5533	0.86	862.00	20.00	108.7	14.7	30.73	.75620E+01	0.19850E-01
339.12	6.60	60.61	6.60	869.5214	0.86	862.00	20.00	103.8	15.9	30.73	.75620E+01	0.19850E-01
343.03	6.07	60.24	6.07	869.4896	0.86	862.00	20.00	98.8	17.1	30.73	.75620E+01	0.19849E-01
346.94	5.53	59.86	5.53	869.4578	0.86	862.00	20.00	93.9	18.3	30.73	.75620E+01	0.19849E-01
350.85	5.00	59.48	5.00	869.4259	0.86	862.00	20.00	88.9	19.5	30.73	.75620E+01	0.19849E-01

LEG: L3 23.440 IN. D. (INCH) FROM NODE: N06 TO NODE: N07

350.85	62.04	80.27	59.48	872.8281	0.86	862.00	20.00	742.5	19.5	30.73	.75620E+01	0.19870E-01
354.78	61.51	79.63	59.13	872.7960	0.86	862.00	20.00	737.6	20.7	30.73	.75620E+01	0.19870E-01
358.72	60.97	78.99	58.59	872.7640	0.86	862.00	20.00	732.7	21.9	30.73	.75620E+01	0.19870E-01
362.65	60.43	78.35	58.06	872.7321	0.86	862.00	20.00	727.8	23.1	30.73	.75620E+01	0.19869E-01
366.58	59.90	77.80	57.52	872.7000	0.86	862.00	20.00	722.9	24.3	30.73	.75620E+01	0.19869E-01
370.51	59.36	77.50	56.98	872.6680	0.86	862.00	20.00	718.0	25.5	30.73	.75620E+01	0.19869E-01
374.45	58.83	77.21	56.45	872.6359	0.86	862.00	20.00	713.1	26.8	30.73	.75620E+01	0.19869E-01
378.38	58.29	76.91	55.91	872.6039	0.86	862.00	20.00	708.2	28.0	30.73	.75620E+01	0.19869E-01
382.31	57.75	76.61	55.38	872.5719	0.86	862.00	20.00	703.2	29.2	30.73	.75620E+01	0.19868E-01
386.25	56.82	75.91	54.44	872.5159	0.86	862.00	20.00	698.4	35.0	30.73	.75620E+01	0.19868E-01
390.18	55.01	74.34	52.64	872.4083	0.86	862.00	20.00	693.5	50.7	30.73	.75620E+01	0.19867E-01
394.11	53.21	72.78	50.83	872.3006	0.86	862.00	20.00	688.6	66.4	30.73	.75620E+01	0.19867E-01
398.04	51.41	71.21	49.03	872.1929	0.86	862.00	20.00	683.8	82.2	30.73	.75620E+01	0.19866E-01
401.98	50.99	71.02	48.61	872.1677	0.86	862.00	20.00	678.8	82.1	30.73	.75620E+01	0.19866E-01
405.91	51.31	71.58	48.93	872.1868	0.86	862.00	20.00	673.9	73.5	30.73	.75620E+01	0.19866E-01
409.84	49.57	70.08	47.19	872.0829	0.86	862.00	20.00	669.0	88.5	30.73	.75620E+01	0.19865E-01
413.78	47.83	68.59	45.45	871.9791	0.86	862.00	20.00	664.1	103.5	30.73	.75620E+01	0.19865E-01

417.71	46.09	68.31	43.71	871.8752	0.86	862.00	20.00	659.3	118.5	30.73	.75620E+01	0.19864E-01
421.64	44.35	68.03	41.97	871.7714	0.86	862.00	20.00	654.4	133.5	30.73	.75620E+01	0.19864E-01
425.57	42.61	67.75	40.23	871.6675	0.86	862.00	20.00	649.5	148.6	30.73	.75620E+01	0.19863E-01
429.51	40.87	67.46	38.49	871.5638	0.86	862.00	20.00	644.6	163.6	30.73	.75620E+01	0.19862E-01
433.44	39.13	67.18	36.75	871.4600	0.86	862.00	20.00	639.7	178.6	30.73	.75620E+01	0.19862E-01
437.37	37.39	66.90	35.01	871.3563	0.86	862.00	20.00	634.8	193.6	30.73	.75620E+01	0.19861E-01
441.31	35.65	66.62	33.27	871.2525	0.86	862.00	20.00	629.9	208.6	30.73	.75620E+01	0.19860E-01
445.24	33.91	66.33	31.53	871.1487	0.86	862.00	20.00	625.0	223.6	30.73	.75620E+01	0.19860E-01
449.17	32.17	66.05	29.80	871.0450	0.86	862.00	20.00	620.1	238.7	30.73	.75620E+01	0.19859E-01
453.10	30.44	65.77	28.06	870.9413	0.86	862.00	20.00	615.2	253.7	30.73	.75620E+01	0.19858E-01
457.04	28.70	65.48	26.32	870.8377	0.86	862.00	20.00	610.3	268.7	30.73	.75620E+01	0.19858E-01
460.97	26.55	64.79	24.17	870.7096	0.86	862.00	20.00	605.3	288.4	30.73	.75620E+01	0.19857E-01
464.90	23.15	62.84	20.77	870.5071	0.86	862.00	20.00	600.5	322.5	30.73	.75620E+01	0.19856E-01
468.84	19.75	60.90	17.38	870.3046	0.86	862.00	20.00	595.5	356.6	30.73	.75620E+01	0.19854E-01
472.77	16.36	58.95	13.98	870.1022	0.86	862.00	20.00	590.6	390.7	30.73	.75620E+01	0.19853E-01
476.70	15.43	59.48	13.05	870.0469	0.86	862.00	20.00	585.7	396.4	30.73	.75620E+01	0.19853E-01

LEG: L4 23.440 IN. D. (INCH) FROM NODE: N07 TO NODE: N09

476.70	15.43	59.48	13.05	870.0469	0.86	862.00	20.00	585.7	396.4	30.73	.75620E+01	0.19853E-01
480.67	17.75	62.34	15.49	870.1853	0.86	862.00	20.00	580.6	364.6	30.73	.75620E+01	0.19854E-01
484.64	20.08	65.19	17.94	870.3239	0.86	862.00	20.00	575.6	332.9	30.73	.75620E+01	0.19855E-01
488.60	22.40	68.05	20.38	870.4624	0.86	862.00	20.00	570.5	301.2	30.73	.75620E+01	0.19855E-01
492.57	22.04	68.21	20.14	870.4410	0.86	862.00	20.00	565.5	300.3	30.73	.75620E+01	0.19855E-01
496.54	20.23	66.91	18.44	870.3328	0.86	862.00	20.00	560.5	316.2	30.73	.75620E+01	0.19855E-01
500.51	18.41	65.61	16.74	870.2246	0.86	862.00	20.00	555.6	332.0	30.73	.75620E+01	0.19854E-01
504.47	16.59	64.31	15.05	870.1164	0.86	862.00	20.00	550.6	347.9	30.73	.75620E+01	0.19853E-01
508.44	14.78	63.01	13.35	870.0082	0.86	862.00	20.00	545.6	363.8	30.73	.75620E+01	0.19853E-01
512.41	17.15	65.92	15.84	870.1495	0.86	862.00	20.00	540.5	331.5	30.73	.75620E+01	0.19853E-01
516.38	19.36	68.66	18.17	870.2814	0.86	862.00	20.00	535.5	301.0	30.73	.75620E+01	0.19854E-01
520.34	16.17	65.98	15.10	870.0909	0.86	862.00	20.00	530.5	332.7	30.73	.75620E+01	0.19853E-01

524.31	12.97	63.29	12.02	869.9006	0.86	862.00	20.00	525.6	364.5	30.73	.75620E+01	0.19852E-01
528.28	15.48	66.33	14.64	870.0497	0.86	862.00	20.00	520.5	330.7	30.73	.75620E+01	0.19853E-01
532.24	15.86	67.24	15.15	870.0727	0.86	862.00	20.00	515.5	321.2	30.73	.75620E+01	0.19853E-01
536.21	13.70	65.60	13.10	869.9440	0.86	862.00	20.00	510.5	341.1	30.73	.75620E+01	0.19852E-01
540.18	11.54	63.95	11.06	869.8152	0.86	862.00	20.00	505.5	360.9	30.73	.75620E+01	0.19851E-01
544.15	9.38	62.30	9.02	869.6866	0.86	862.00	20.00	500.5	380.7	30.73	.75620E+01	0.19851E-01
548.11	7.22	60.66	6.98	869.5579	0.86	862.00	20.00	495.5	400.6	30.73	.75620E+01	0.19850E-01
552.08	5.78	59.74	5.66	869.4724	0.86	862.00	20.00	490.5	412.1	30.73	.75620E+01	0.19849E-01
556.05	5.00	59.48	5.00	869.4259	0.86	862.00	20.00	485.5	416.0	30.73	.75620E+01	0.19849E-01

LEG: L5 23.440 IN. D. (INCH) FROM NODE: N10 TO NODE: N11

556.05	48.23	59.48	32.35	872.0033	0.86	862.00	20.00	981.3	416.0	30.73	.75620E+01	0.19865E-01
560.01	47.45	59.12	31.95	871.9568	0.86	862.00	20.00	976.4	420.0	30.73	.75620E+01	0.19865E-01
563.97	46.67	58.76	31.55	871.9103	0.86	862.00	20.00	971.4	424.0	30.73	.75620E+01	0.19864E-01
567.93	45.89	58.40	31.15	871.8638	0.86	862.00	20.00	966.5	427.9	30.73	.75620E+01	0.19864E-01
571.89	45.94	58.87	31.57	871.8664	0.86	862.00	20.00	961.5	422.4	30.73	.75620E+01	0.19864E-01
575.85	46.89	60.24	32.89	871.9229	0.86	862.00	20.00	956.5	406.6	30.73	.75620E+01	0.19864E-01
579.81	47.83	61.60	34.21	871.9794	0.86	862.00	20.00	951.5	390.8	30.73	.75620E+01	0.19865E-01
583.77	46.34	60.53	33.10	871.8901	0.86	862.00	20.00	946.5	402.9	30.73	.75620E+01	0.19864E-01
587.73	44.72	59.33	31.86	871.7936	0.86	862.00	20.00	941.6	416.5	30.73	.75620E+01	0.19864E-01
591.69	43.10	58.13	30.62	871.6971	0.86	862.00	20.00	936.7	430.1	30.73	.75620E+01	0.19863E-01
595.65	41.49	56.93	29.38	871.6005	0.86	862.00	20.00	931.8	443.7	30.73	.75620E+01	0.19862E-01
599.62	39.87	55.73	28.14	871.5041	0.86	862.00	20.00	926.8	457.3	30.73	.75620E+01	0.19862E-01
603.58	38.25	54.53	26.90	871.4075	0.86	862.00	20.00	921.9	470.8	30.73	.75620E+01	0.19861E-01
607.54	36.63	53.33	25.66	871.3111	0.86	862.00	20.00	916.9	484.4	30.73	.75620E+01	0.19861E-01
611.50	35.02	52.14	24.42	871.2147	0.86	862.00	20.00	912.0	498.0	30.73	.75620E+01	0.19860E-01
615.46	33.57	51.11	23.36	871.1285	0.86	862.00	20.00	907.1	509.6	30.73	.75620E+01	0.19860E-01
619.42	33.44	51.40	23.61	871.1208	0.86	862.00	20.00	902.1	506.1	30.73	.75620E+01	0.19859E-01
623.38	33.32	51.70	23.86	871.1132	0.86	862.00	20.00	897.1	502.6	30.73	.75620E+01	0.19859E-01
627.34	33.19	51.99	24.11	871.1056	0.86	862.00	20.00	892.1	499.0	30.73	.75620E+01	0.19859E-01

631.30	33.06	52.28	24.36	871.0979	0.86	862.00	20.00	887.1	495.5	30.73	.75620E+01	0.19859E-01
635.26	32.93	52.58	24.61	871.0903	0.86	862.00	20.00	882.1	492.0	30.73	.75620E+01	0.19859E-01
639.22	32.80	52.87	24.86	871.0826	0.86	862.00	20.00	877.1	488.5	30.73	.75620E+01	0.19859E-01
643.18	32.68	53.16	25.11	871.0750	0.86	862.00	20.00	872.1	484.9	30.73	.75620E+01	0.19859E-01
647.14	32.55	53.46	25.35	871.0674	0.86	862.00	20.00	867.2	481.4	30.73	.75620E+01	0.19859E-01
651.10	32.42	53.75	25.60	871.0598	0.86	862.00	20.00	862.2	477.9	30.73	.75620E+01	0.19859E-01
655.06	32.29	54.04	25.85	871.0521	0.86	862.00	20.00	857.2	474.4	30.73	.75620E+01	0.19859E-01
659.02	32.16	54.34	26.08	871.0444	0.86	862.00	20.00	852.2	470.9	30.73	.75620E+01	0.19859E-01
662.98	30.77	53.36	24.80	870.9611	0.86	862.00	20.00	847.2	481.9	30.73	.75620E+01	0.19858E-01
666.95	28.95	51.96	23.10	870.8529	0.86	862.00	20.00	842.3	497.8	30.73	.75620E+01	0.19858E-01
670.91	27.14	50.56	21.40	870.7448	0.86	862.00	20.00	837.3	513.6	30.73	.75620E+01	0.19857E-01
674.87	25.32	49.17	19.70	870.6367	0.86	862.00	20.00	832.4	529.5	30.73	.75620E+01	0.19856E-01
678.83	26.18	50.44	20.66	870.6874	0.86	862.00	20.00	827.4	514.7	30.73	.75620E+01	0.19857E-01
682.79	27.12	51.81	21.72	870.7437	0.86	862.00	20.00	822.3	498.9	30.73	.75620E+01	0.19857E-01
686.75	28.06	53.18	22.78	870.7999	0.86	862.00	20.00	817.3	483.0	30.73	.75620E+01	0.19857E-01
690.71	28.70	54.24	23.52	870.8378	0.86	862.00	20.00	812.3	470.7	30.73	.75620E+01	0.19858E-01
694.67	27.92	53.88	22.86	870.7914	0.86	862.00	20.00	807.3	474.7	30.73	.75620E+01	0.19857E-01
698.63	27.14	53.52	22.19	870.7449	0.86	862.00	20.00	802.4	478.6	30.73	.75620E+01	0.19857E-01
702.59	26.36	53.16	21.53	870.6984	0.86	862.00	20.00	797.4	482.6	30.73	.75620E+01	0.19857E-01
706.55	25.58	52.80	20.86	870.6520	0.86	862.00	20.00	792.4	486.6	30.73	.75620E+01	0.19857E-01
710.51	25.20	52.84	20.60	870.6293	0.86	862.00	20.00	787.4	485.9	30.73	.75620E+01	0.19856E-01
714.47	27.52	55.60	23.03	870.7678	0.86	862.00	20.00	782.4	454.2	30.73	.75620E+01	0.19857E-01
718.43	29.85	58.35	25.47	870.9063	0.86	862.00	20.00	777.3	422.5	30.73	.75620E+01	0.19858E-01
722.39	30.09	59.01	25.82	870.9207	0.86	862.00	20.00	772.3	414.8	30.73	.75620E+01	0.19858E-01
726.35	28.96	58.31	24.81	870.8536	0.86	862.00	20.00	767.3	422.7	30.73	.75620E+01	0.19858E-01
730.31	27.97	57.73	23.93	870.7942	0.86	862.00	20.00	762.4	429.2	30.73	.75620E+01	0.19857E-01
734.27	28.45	58.64	24.52	870.8231	0.86	862.00	20.00	757.4	418.6	30.73	.75620E+01	0.19858E-01
738.24	28.94	59.54	25.12	870.8519	0.86	862.00	20.00	752.4	408.0	30.73	.75620E+01	0.19858E-01
742.20	29.42	60.45	25.72	870.8808	0.86	862.00	20.00	747.3	397.5	30.73	.75620E+01	0.19858E-01
746.16	29.44	60.89	25.85	870.8818	0.86	862.00	20.00	742.4	392.3	30.73	.75620E+01	0.19858E-01
750.12	28.31	60.18	24.84	870.8147	0.86	862.00	20.00	737.4	400.2	30.73	.75620E+01	0.19858E-01

754.08	27.19	59.48	23.83	870.7477	0.86	862.00	20.00	732.4	408.2	30.73	.75620E+01	0.19857E-01

LEG: L6 23.440 IN. D. (INCH) FROM NODE: N11 TO NODE: N13

754.08	27.19	59.48	23.83	870.7477	0.86	862.00	20.00	732.4	408.2	30.73	.75620E+01	0.19857E-01
758.01	26.07	58.78	23.05	870.6812	0.86	862.00	20.00	727.5	416.0	30.73	.75620E+01	0.19857E-01
761.94	24.95	58.08	22.28	870.6146	0.86	862.00	20.00	722.5	423.9	30.73	.75620E+01	0.19856E-01
765.88	23.84	57.37	21.51	870.5480	0.86	862.00	20.00	717.6	431.8	30.73	.75620E+01	0.19856E-01
769.81	22.72	56.67	20.73	870.4814	0.86	862.00	20.00	712.7	439.6	30.73	.75620E+01	0.19856E-01
773.74	22.26	56.62	20.38	870.4537	0.86	862.00	20.00	707.7	440.0	30.73	.75620E+01	0.19855E-01
777.68	21.82	56.61	19.94	870.4280	0.86	862.00	20.00	702.7	440.0	30.73	.75620E+01	0.19855E-01
781.61	22.23	57.43	20.35	870.4523	0.86	862.00	20.00	697.8	430.3	30.73	.75620E+01	0.19855E-01
785.54	23.85	59.48	21.97	870.5490	0.86	862.00	20.00	692.8	406.7	30.73	.75620E+01	0.19856E-01
789.48	25.48	61.52	23.59	870.6456	0.86	862.00	20.00	687.8	383.1	30.73	.75620E+01	0.19857E-01
793.41	25.32	61.78	23.44	870.6362	0.86	862.00	20.00	682.8	380.0	30.73	.75620E+01	0.19856E-01
797.34	24.89	61.77	23.01	870.6105	0.86	862.00	20.00	677.9	380.0	30.73	.75620E+01	0.19856E-01
801.28	24.45	61.75	22.57	870.5847	0.86	862.00	20.00	672.9	380.0	30.73	.75620E+01	0.19856E-01
805.21	24.02	61.74	22.14	870.5590	0.86	862.00	20.00	667.9	380.0	30.73	.75620E+01	0.19856E-01
809.14	23.59	61.72	21.71	870.5333	0.86	862.00	20.00	663.0	380.0	30.73	.75620E+01	0.19856E-01
813.07	22.09	60.63	20.21	870.4437	0.86	862.00	20.00	658.1	392.3	30.73	.75620E+01	0.19855E-01
817.01	20.29	59.24	18.41	870.3364	0.86	862.00	20.00	653.1	408.0	30.73	.75620E+01	0.19855E-01
820.94	18.49	57.86	16.61	870.2291	0.86	862.00	20.00	648.2	423.8	30.73	.75620E+01	0.19854E-01
824.87	16.69	56.47	14.81	870.1218	0.86	862.00	20.00	643.2	439.5	30.73	.75620E+01	0.19853E-01
828.81	14.89	55.08	13.01	870.0146	0.86	862.00	20.00	638.3	455.2	30.73	.75620E+01	0.19853E-01
832.74	15.71	56.32	13.83	870.0635	0.86	862.00	20.00	633.3	440.8	30.73	.75620E+01	0.19853E-01
836.67	17.67	58.71	15.79	870.1804	0.86	862.00	20.00	628.3	413.3	30.73	.75620E+01	0.19854E-01
840.61	18.84	60.30	16.96	870.2502	0.86	862.00	20.00	623.3	394.8	30.73	.75620E+01	0.19854E-01
844.54	15.67	57.54	13.80	870.0615	0.86	862.00	20.00	618.4	426.3	30.73	.75620E+01	0.19853E-01
848.47	12.50	54.78	10.63	869.8727	0.86	862.00	20.00	613.5	457.8	30.73	.75620E+01	0.19852E-01
852.41	9.34	52.02	7.46	869.6841	0.86	862.00	20.00	608.5	489.2	30.73	.75620E+01	0.19851E-01
856.34	7.03	50.12	5.16	869.5469	0.86	862.00	20.00	603.6	510.8	30.73	.75620E+01	0.19850E-01

860.27	6.40	49.91	4.53	869.5095	0.86	862.00	20.00	598.6	513.0	30.73	.75620E+01	0.19849E-01
864.20	5.78	49.70	3.90	869.4721	0.86	862.00	20.00	593.6	515.3	30.73	.75620E+01	0.19849E-01
868.14	5.15	49.49	3.28	869.4348	0.86	862.00	20.00	588.6	517.5	30.73	.75620E+01	0.19849E-01
872.07	4.52	49.28	2.65	869.3974	0.86	862.00	20.00	583.7	519.8	30.73	.75620E+01	0.19849E-01
876.00	3.89	49.06	2.02	869.3600	0.86	862.00	20.00	578.7	522.0	30.73	.75620E+01	0.19849E-01
879.94	3.26	48.85	1.39	869.3226	0.86	862.00	20.00	573.7	524.2	30.73	.75620E+01	0.19848E-01
883.87	2.64	48.64	0.77	869.2852	0.86	862.00	20.00	568.7	526.5	30.73	.75620E+01	0.19848E-01
887.80	2.01	48.43	0.14	869.2479	0.86	862.00	20.00	563.7	528.7	30.73	.75620E+01	0.19848E-01
891.74	2.17	49.01	0.30	869.2574	0.86	862.00	20.00	558.8	521.9	30.73	.75620E+01	0.19848E-01
895.67	3.33	50.60	1.46	869.3266	0.86	862.00	20.00	553.8	503.5	30.73	.75620E+01	0.19848E-01
899.60	4.49	52.18	2.62	869.3958	0.86	862.00	20.00	548.8	485.2	30.73	.75620E+01	0.19849E-01
903.54	5.66	53.77	3.79	869.4650	0.86	862.00	20.00	543.8	466.8	30.73	.75620E+01	0.19849E-01
907.47	6.82	55.36	4.95	869.5342	0.86	862.00	20.00	538.8	448.5	30.73	.75620E+01	0.19850E-01
911.40	7.98	56.94	6.11	869.6034	0.86	862.00	20.00	533.8	430.1	30.73	.75620E+01	0.19850E-01
915.34	9.14	58.53	7.27	869.6726	0.86	862.00	20.00	528.9	411.8	30.73	.75620E+01	0.19850E-01
919.27	10.31	60.12	8.44	869.7418	0.86	862.00	20.00	523.9	393.4	30.73	.75620E+01	0.19851E-01
923.20	9.62	59.84	7.75	869.7007	0.86	862.00	20.00	518.9	396.4	30.73	.75620E+01	0.19851E-01
927.13	9.24	59.88	7.37	869.6783	0.86	862.00	20.00	513.9	395.7	30.73	.75620E+01	0.19851E-01
931.07	9.12	60.18	7.25	869.6713	0.86	862.00	20.00	508.9	392.1	30.73	.75620E+01	0.19850E-01
935.00	8.00	59.48	6.14	869.6049	0.86	862.00	20.00	504.0	400.0	30.73	.75620E+01	0.19850E-01

LEG: L7 23.000 IN. D. (INCH) FROM NODE: N13A TO NODE: N13B

935.00	8.00	59.48	6.14	869.6048	0.90	862.00	20.00	504.0	400.0	30.73	.75620E+01	0.19780E-01
935.05	8.00	59.48	6.13	869.6044	0.90	862.00	20.00	503.9	400.0	30.73	.75620E+01	0.19780E-01

LEG: L8 23.000 IN. D. (INCH) FROM NODE: N13D TO NODE: N13E

935.05	2.11	59.48	1.96	869.2542	0.90	862.00	20.00	436.2	400.0	30.73	.75620E+01	0.19778E-01
936.00	2.00	59.48	2.00	869.2474	0.90	862.00	20.00	434.9	400.0	30.73	.75620E+01	0.19778E-01

REGULATOR HYDRAULIC SUMMARY REPORT

****

TIME = 0.000 (MINS)

ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
° NO ITEMS TO REPORT °
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

BLOCK VALVE HYDRAULIC SUMMARY REPORT

****

TIME = 0.000 (MINS)

EQP ID	MODE OF CONTROL	PRESSURE A)(KG UP	PRESSURE A)(KG DOWN	FLOW (M3/HR) UP	FLOW (M3/HR) DOWN	TEMPERATURE (DEG C) UP	TEMPERATURE (DEG C) DOWN
BLKVCOT	BLOCK VALVE	2.00	2.00	862.00	20.00	20.00	
BLKVST	BLOCK VALVE	8.00	8.00	862.00	20.00	20.00	

CHECK VALVE HYDRAULIC SUMMARY REPORT

****

TIME = 0.000 (MINS)

ÉÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ»
° NO ITEMS TO REPORT °
ÈÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍÍ¼

RESISTANCE HYDRAULIC SUMMARY REPORT

****

TIME = 0.000 (MINS)

EQP ID	MODE OF CONTROL	PRESSURE A)(KG UP	PRESSURE A)(KG DOWN	FLOW (M3/HR) UP	FLOW (M3/HR) DOWN	TEMPERATURE (DEG C) UP	TEMPERATURE (DEG C) DOWN
CVBINA	RESISTANCE	8.00	4.11	862.00	20.00	20.00	
METERBIN	RESISTANCE	4.11	2.11	862.00	20.00	20.00	

PUMP HYDRAULIC DETAILED REPORT

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**************************************************

TIME =      0.000 ( MINS )
EQUIPMENT ID: PUMPIP2  FROM NODE: N05     TO NODE: N06

  PUMP
  MIN PU     MODE     (PU = PUMIN)
  UPSIDE PRESSURE                5.00 A )( KG
  DOWNSIDE PRESSURE             62.04 A )( KG
  HEAD DIFFERENTIAL            653.60 ( M )
  STANDARD FLOW THRU EQUIPMENT       862.0 (M3/HR )
  ACTUAL FLOW THRU EQUIPMENT         863.1 (M3/HR )
  UPSIDE TEMPERATURE            20.00 (DEG C )
  DOWNSIDE TEMPERATURE          20.00 (DEG C )
  CURRENT SPEED                 0.00 ( RPM )
  ADIABATIC EFFIC              100.00
  POWER REQUIRED                1.34 ( MW )
  POWER AVAILABLE               1.34 ( MW )
  PERCENT OPEN SETPOINT           1.000
  FREE FLOW   CONSTRAINT
  UP PRES SETPT/MIN CONSTRAINT       5.0 A )( KG

EQUIPMENT ID: PUMPIP4  FROM NODE: N09     TO NODE: N10

  PUMP
  MIN PU     MODE     (PU = PUMIN)
  UPSIDE PRESSURE                5.00 A )( KG
  DOWNSIDE PRESSURE             48.23 A )( KG
  HEAD DIFFERENTIAL            495.84 ( M )
  STANDARD FLOW THRU EQUIPMENT       862.0 (M3/HR )
  ACTUAL FLOW THRU EQUIPMENT         863.5 (M3/HR )
  UPSIDE TEMPERATURE            20.00 (DEG C )
  DOWNSIDE TEMPERATURE          20.00 (DEG C )
  CURRENT SPEED                 0.00 ( RPM )
  ADIABATIC EFFIC              100.00
  POWER REQUIRED                1.02 ( MW )
  POWER AVAILABLE               1.02 ( MW )
  PERCENT OPEN SETPOINT           1.000
  FREE FLOW   CONSTRAINT
  UP PRES SETPT/MIN CONSTRAINT       5.0 A )( KG

EQUIPMENT ID: PUMPVAD  FROM NODE: N01     TO NODE: N02

  PUMP
```

MIN PU MODE (PU = PUMIN)
UPSIDE PRESSURE 2.00 A)(KG
DOWNSIDE PRESSURE 44.38 A)(KG
HEAD DIFFERENTIAL 486.26 (M)
STANDARD FLOW THRU EQUIPMENT 862.0 (M3/HR)
ACTUAL FLOW THRU EQUIPMENT 863.7 (M3/HR)
UPSIDE TEMPERATURE 20.00 (DEG C)
DOWNSIDE TEMPERATURE 20.00 (DEG C)
CURRENT SPEED 0.00 (RPM)
ADIABATIC EFFIC 100.00
POWER REQUIRED 1.00 (MW)
POWER AVAILABLE 1.00 (MW)
PERCENT OPEN SETPOINT 1.000
FREE FLOW CONSTRAINT
UP PRES SETPT/MIN CONSTRAINT 2.0 A)(KG

EXTERNAL REGULATOR HYDRAULIC DETAILED REPORT
****

TIME = 0.000 (MINS)

MASS FLOWRATE BALANCE (ACTUAL CONDITIONS) = 0.000 SLUG/SEC

SYSTEM PACKING RATE (STANDARD CONDITIONS) = 0.000 (M3/HR)

EXTERNAL REGULATOR ID: BINA AT NODE: N13F

DELIVERY
MIN PRES MODE (P = PMIN)
PRESSURE 2.00 A)(KG
STANDARD FLOW 862. (M3/HR)
ACTUAL FLOW 865. (M3/HR)
TEMPERATURE 20.00 (DEG C)
CUMULATIVE FLOW THROUGH XRG 0. (M3)
PRES SETPT/MIN CONSTRAINT 2.00 A)(KG
CHECK VALVE CONSTRAINT

EXTERNAL REGULATOR ID: SRV AT NODE: N13C

DELIVERY
CLOSED MODE (NO FLOW, Q = 0)
PRESSURE 4.11 A)(KG

STANDARD FLOW 0. (M3/HR)
ACTUAL FLOW 0. (M3/HR)
TEMPERATURE 20.00 (DEG C)
CUMULATIVE FLOW THROUGH XRG 0. (M3)
PRES SETPT/MIN CONSTRAINT 12.00 A)(KG
CHECK VALVE CONSTRAINT

EXTERNAL REGULATOR ID: VADINAR AT NODE: N01

SUPPLY
MAX FLOW MODE (Q = QMAX)
PRESSURE 2.00 A)(KG
STANDARD FLOW -862. (M3/HR)
ACTUAL FLOW -865. (M3/HR)
TEMPERATURE 20.00 (DEG C)
CUMULATIVE FLOW THROUGH XRG 0. (M3)
FLOW SETPT/MAX CONSTRAINT -862.00 (M3/HR)

TLNET TRANSIENT OUTPUT OPTIONS REPORT
****

REPORT TYPES:
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0 = NO REPORT
1 = SUMMARY REPORT
2 = DETAIL REPORT

*** LEG REPORT OPTIONS

LEG HYDRAULIC REPORT: 2

REPORTING ALL LEGS

*** PUMP REPORT OPTIONS

PUMP HYDRAULIC REPORT: 2

REPORTING ALL PUMPS

*** REGULATOR REPORT OPTIONS

REGULATOR HYDRAULIC REPORT: 1

REPORTING ALL REGULATORS

*** BLOCK VALVE REPORT OPTIONS

BLOCK VALVE HYDRAULIC REPORT: 1

REPORTING ALL BLOCK VALVES

*** CHECK VALVE REPORT OPTIONS

CHECK VALVE HYDRAULIC REPORT: 1

REPORTING ALL CHECK VALVES

*** RESISTANCE REPORT OPTIONS

RESISTANCE HYDRAULIC REPORT: 1

REPORTING ALL RESISTANCES

*** EXTERNAL REGULATOR REPORT OPTIONS

EXTERNAL REGULATOR HYDRAULIC REPORT: 2

REPORTING ALL EXTERNAL REGULATORS

*** TANKAGE REPORT OPTIONS

TANKAGE HYDRAULIC REPORT: 1

REPORTING ALL TANKS

*** BATCH REPORT OPTIONS

BATCH REPORT: 0

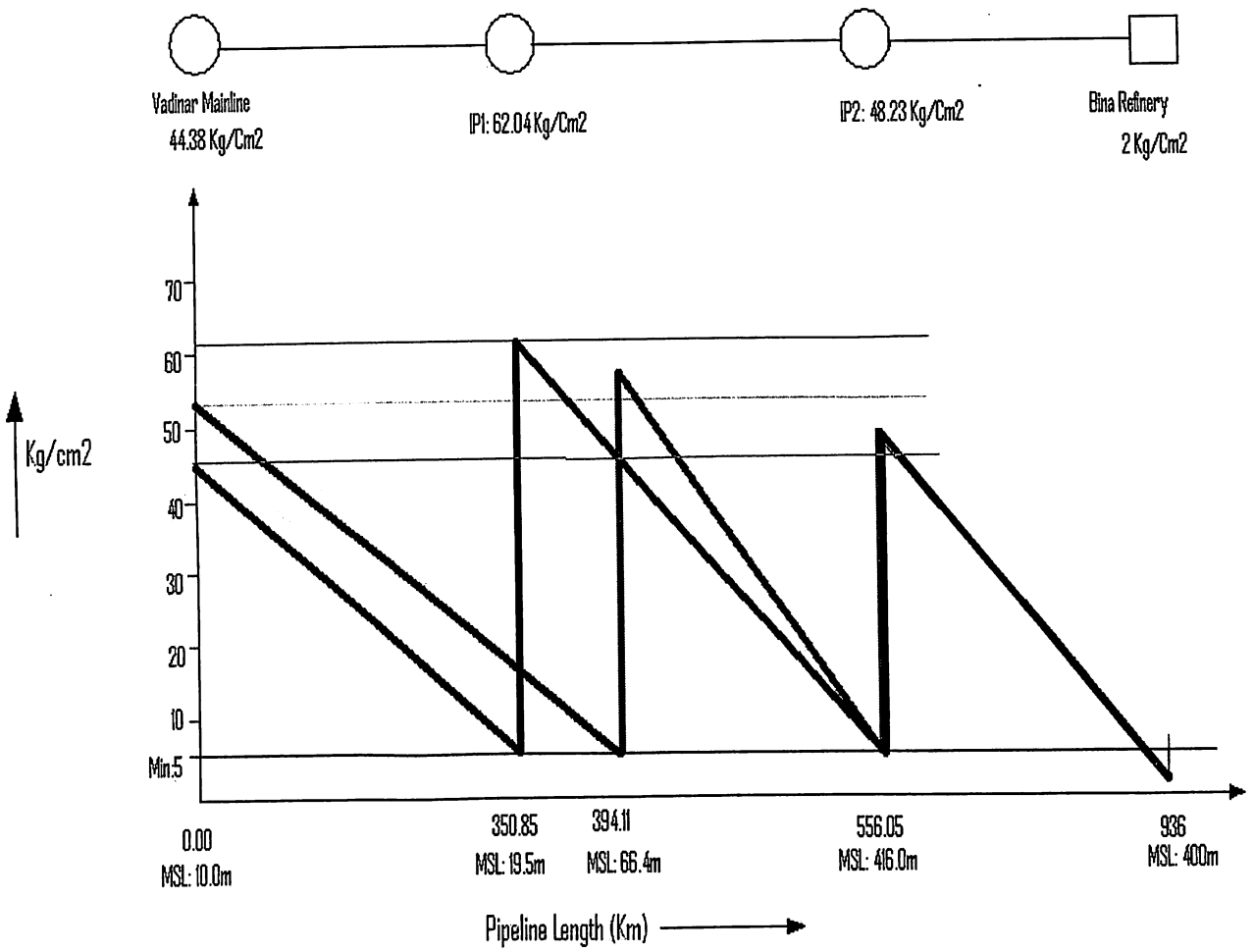
*** NODE MASS BALANCE REPORT OPTIONS

NODE MASS BALANCE REPORT: 0

CHAPTER 6
CONCLUSION

6.1 GRAPHICAL ANALYSIS:

TABLE: 5 OPTIMISATION FOR PUMP LOCATIONS.



6.2 For Optimisation:

From the output, the value obtained for the intermediate pumping station: 1 is not optimized location for the BORL pipeline. In the future expansion of the throughput is not possible for the current location of IP: 1 because now the IP: 1, pumping pressure is 62.04Kg/cm^2. Here the max operating pressure of the line is 63.7 Kg/cm^2

(and the design pressure is 70.1Kg/Cm^2). For optimization and for future expansion the mainline pumping pressure can be increased from 44.38 Kg/cm^2 to 50 Kg/cm^2, so that IP: 1 chainage will be much forward than current location (say may be from Ch: 350.85Km to Ch: 394.11Km). By relocating the IP: 1, the operating pressure can be much lesser than current fixed pressure (i.e. to 57 Kg/Cm^2).

Now the current pressure can be reduced to 57 Kg/Cm^2 from 62 kg/Cm^2, so that in future the throughput can handled much more than now (current throughput is 862 m^3/Hr). There's no need in changing IP: 2 location. And also surge relief valve timings is calculated by TLNet for the shut off/on part.

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[2] A.P.Moser, Buried Pipe Design, McGraw Hill. 1990.

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[4] C.B. Lester, Hydraulics for Pipeliners, Vol-1, Gulf Publishing Company, 1990.

[5] Transient Liquid Net Analysis, 5.1 Version Manual, 1984.

[6] Bharath Oman Refinery Limited Pipeline data's (Job No: 1205 specified by EIL).

[7] Engineers India Limited web sites.

[8] E.shashi Menon, Liquid Pipeline Hydraulics, PD Hengineer.com, online course Material.

ANNEXURE

LIST OF CODES AND STANDARDS

In addition to the codes/standards mentioned, the latest edition of the below listed equivalent codes and standards shall also be used for design of proposed pipeline. The listing includes, but is not limited to, the following:

1. Line Pipes

API 5L	Specification for Line pipe
API 5L1	Recommended Practice for Railroad Transportation of Line pipe

2. Valves

API 6D	Specification for pipeline valves (Steel Gate, Plug, Ball and Check Valves)
ASTM A694	Forgings, Carbon & Alloy steel for Pipe Flanges, Fittings, Valves & parts for High Pressure Transmission Service.
MSS-SP-6	Finishes for Contact Faces of connecting End Flanges of Ferrous Valves and Fittings.
BS 5351	Steel Ball Valves for the Petroleum, Petrochemical and Allied Industries

3. Flanges and Fittings

MSS-SP-44	Steel Pipeline Flanges
ANSI B16.5	Pipe Flanges and Flanged Fittings
ANSI 16.20	Ring-joint Gaskets & Grooves for Steel Pipe Flanges

4. WELDINGS

API 1104	Standard for Welding Pipelines and Related Facilities
AWS A3.0	Welding Terms and Definitions
AWS A5.1	Welding Electrodes

IP Model Code of Safe Practice in the Petroleum Industry parts 3, 6 and 9.