DETAIL DESIGN OF GAS PIPELINE

A Project Work
Submitted in the Partial Fulfillment of the Requirements
For the Degree of

MASTER OF TECHNOLOGY

IN

PIPELINE ENGINEERING

Under the Guidance of

Internal

Mr. R.P. Shriwas
Professor
College of Engineering
University of Petroleum and Energy Studies

External

Mr. Rajiv Maini
Assistant Vice President
Tractebel Engineers &Limited
New Delhi

BY

SIVARAJA SUNDARAM .A
ROLL No: R160205009

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
DEHRADUN

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Tractebel Engineers and Constructors Pvt. Ltd

10-A, Shivaji Marg
New Delhi - 110015 (India)
Phone: + 91 11 4701 2200
Fax: + 91 11 4701 2244

May 14, 2007
TECPL/APNT/0458

TO WHOM SO EVER IT MAY CONCERN

This is to certify that Mr. Sivaraja Sundaram S/O. Sh. N.Avadaiappan has done his M.Tech Project "Detail Design of Pipeline" with Tractebel Engineers and Constructors Pvt. Ltd. for the period of two months (March 01, 2007 to April 30, 2007).

During this period he has proved himself a diligent and hard working person.

We wish him all the best for his future assignments.

BKMital.

Bhawna K. Mital
Assistant Manager – HR

Rajiva K. Srivastava
General Manager – HR

CERTIFICATE

This to certify that the work contained in this thesis entitled **"Detail Design Of Gas Pipeline"** has been carried out by **Sivaraja Sundaram A** under the supervision of Mr. Rajiv Maimi, AVP, Pipelines Engineering Division, Tractebel Engineers Limited, New Delhi and me. That this work has not been submitted elsewhere for a degree.

18/05/2007

Mr. R.P. Shriwas,
Professor,
College of Engineering,
University of Petroleum and Energy Studies,
Dehradun – 248007.

CERTIFICATE

This to certify that the project work entitled on **"Detail Design Of Gas Pipeline"** submitted by **Sivaraja Sundaram A** in partial fulfillment of the requirement for the degree of Masters of Technology in Pipeline Engineering, at College of Engineering, University of Petroleum and Energy Studies, Dehradun is a record of the work carried out by him.

18/05/07

Dr.B.P.Pandey,
Dean,
College of Engineering.

ACKNOWLEDGEMENT

At the very first thought I would like to thank the Engineering Head of Tractebel Engineers & Constructors Private Limited, **Mr.Rajiv Maini** for granting me this opportunity to undergo the Project in this company.

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18/5/07.

A. Sivaraja Sundaram

M.Tech (Pipeline Engineering)

UPES

Dehradun

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Abstract

Natural gas is a naturally occurring mixture of hydrocarbon and non-hydrocarbon gases found in porous formations beneath the earth's surface, often in association with crude petroleum. The principal constituent of most natural gases is methane.

The growth of natural gas transport by pipeline has led to the establishment of a large network of pipelines throughout the world. The total length of world's pipeline is amounted to millions of kilometers.

I had the opportunity to carry out my project work in the company named "Tractebel Engineers & Constructors Pvt Ltd" who are providing Gas Pipeline Design services and have their global presence.

This Project work involves Design of Pipe size, Design of Buoyancy Control. This project report covers theoretical inputs from codes which have been used as guiding principles for designing the pipeline systems in Chapter 1.

This Project work details have been covered in Chapter 2 and the discussions, Conclusions and recommendations have been covered under Chapter3.

The best design options in respect of Design of Pipe size, Design of Buoyancy Control, and Design of Wall Thickness have been brought out in the conclusions.

Tractebel-An Introduction

Tractebel Group

Suez-Tractebel SA, head quartered in Belgium, is a global leader in energy and service business. Its major operations are in the field of gas, electricity and engineering services in these sectors as well as infrastructure sector.

Tractebel Engineering

Tractebel Engineering, its engineering division, is specialized in consultancy and engineering services. Tractebel Engineering offers its services backed by several decades of rich experience in energy sector.

In the hydrocarbon sector Tractebel is a global leader and has extensive experience in the following areas:

- Gas and hydrocarbon storage terminals, both underground as well as above ground for LNG, LPG, CNG, Propane gases etc.

- Handling facilities like pipelines and gas processing/treatment plants for Natural gas, LPG, LNG, CNG, Petroleum products etc.

TECPL, an ISO 9001:2000 certified company in India, is a wholly owned subsidiary of Tractebel Engineering, Belgium a division of Suez – Energy Services of "SUEZ GROUP" company France. TECPL offers comprehensive engineering and project management consultancy services in the energy and transport sector.

In India, they provide services to major players in energy sector like ONGC, GAIL, IOCL, BPCL, GSPL, IGL, AGL, GSPC Gas, OIL.

RELEVANT EXCERPTS FROM LITERATURE & CODES

Chapter – I

1.1 General

The design of pipelines is usually performed in three stages, namely;

Conceptual engineering,
Preliminary engineering or pre-engineering,
Detail engineering.

a. Conceptual Engineering

The primary objectives are normally:

- To establish technical feasibility and constraints on the system design and construction;
- To eliminate non viable options;
- To identify the required information for the forthcoming design and construction;
- To allow basic cost and scheduling exercises to be performed;
- To identify interfaces with other systems planned or currently in existence.

b. Preliminary engineering or Basic engineering

The primary objectives are normally:

- Perform pipeline design so that system concept is fixed. This will include:
- To verify the sizing of the pipeline;
- Determining the pipeline grade and wall thickness;

- Verifying the pipeline against design and code requirements for installation, commissioning and operation;
- Prepare authority applications;
- Perform a material take off sufficient to order the linepipe.

C. Detail engineering

The detailed engineering phase is, as the description suggests, the development of the design to a point where the technical input for all procurement and construction tendering can be defined in sufficient detail.

The main primary objectives can be summarized as:

1. Design of Pipe Size
2. Design of Buoyancy Control

M/s Gas Authority of India Limited (GAIL), the nodal agency for Nation wide transportation propose to install Gas Pipeline from its Dabhol to Chennai

1.2 Design of Pipe Size

1. Optimization Parameters

1. Routing

For new pipeline systems, the routing of the system is an important consideration, although the possibility of routing a commodity through an existing system should also be explored.

Factors to be considered when selecting an appropriate pipeline route include terrain, topography, environment constraints, population centers, and the existence of corridors. The importance of each factor can vary from location to location, but costs, schedules, and a reasonable effort to minimize environmental impact ultimately determine the route.

For an addition to an existing system, the routing considerations may be as simple as paralleling the existing system. However, situations may arise where a new route offers significant savings or other benefits over following the same route.

2. Design Year

Generally, there is a projection of throughout requirements over a number of years. The designer is faced with the task of deciding which year to use in the forecast as the design year. For a new pipeline system, the capacity incorporated in the intial design may or may not be considered as one of the optimization parameters. In the case of an existing system, the concern is whether to provide additional capacity for only one year or for several years.

3. Maximum Operating Pressure

For a long pipeline with few delivery points, the higher the MOP the more efficient the system. However, the length of the line, the number of delivery points, required delivery pressure, available supply pressure, local code restraints and cost premiums can all influence the MOP. Although the MOP is a function of many variables, it can be considered an optimization parameter.

When looping a system, the MOP of the existing pipeline should not be the only choice for the now loop. If a total loop-out is likely within a few years, one option is a higher pressure line eventually isolated from the existing system. It is also possible to consider more than one MOP along the pipeline system. If long sections have no delivery points, a high MOP may be appropriate. At major delivery points, low MOPs may be more economic, since there is no benefit to adding energy only to waste it through a pressure-reduction device at the delivery location.

4. Load Factor

Pipeline volume information is complied to provide a forecast by year for the design day maxima and minima, as well as for the average daily volumes. The load factor is defined as the average daily volume divided by the peak daily volume. If a pipeline system does not have storage facilities to accommodate peak demand, other pipeline facilities must be sized to transport this gas. However, as the load factor approaches 1.0 (always meeting demand), special allowances for peak demand are no longer necessary.

Storage facilities are often installed to reduce the number of other facilities required. Pipeline systems that have a higher storage capacity typically need fewer additional facilities. Most often the combined capital and operating costs of storage facilities are less than the costs of other pipeline facilities. However, there is rarely a linear relationship between storage costs and other facility costs, so it is necessary to determine an optimum combination of the two.

Depending on the fluid, various storage options are available. Options for gas include:

- Salt Caverns
- Underground Caverns
- Abandoned Reservoirs
- Liquefied natural gas pipelines
- Compressed natural gas pipelines
- Pipeline Bottles

If the load factor is low, the range over which compressor or pump stations must operate efficiently is very wide and multiunit stations are common. The number of operating units is varied to allow the stations to meet changing demand. Systems with high load factors often have single unit stations. However, stand by units are included to increase the reliability of the system. Generally the unit volume cost of transportation decreases as the load factor increases.

5. Pipe Size

For short systems, the optimum pipe size is the minimum size required to meet the maximum input pressure, the minimum output pressure, and the demand. Of course, the size is limited by standard diameters manufactured by pipe mills.

For long systems, the ideal line will include a combination of pipe and compressor stations. The possible combinations are almost limitless. Designers have developed some simple rules of thumb to provide the initial direction.

Optimum pipe diameter is affected by the desired pressure drop along the pipeline. For an efficient pipeline system, experience has shown that the pressure drop along a gas pipeline should range between 15 and 25 kPa/km. Below this range, the pipe is underutilized and the capital expenditure is excessive. Above this range, friction losses are high and the fuel consumption is excessive. This range will vary depending on the specific costs of materials and services for different projects.

When looping an existing system, the pressure drop can be used as a guide to selecting the length and diameter of the loop. Another rule is to limit the minimum loop diameter to at least the diameter of the largest existing line being looped. This is especially important if the throughout is increasing annually. Another factor to consider when looping is whether to add enough loop to meet the design requirements (a neat loop) or to loop between existing valve sites (a practical loop).

6. Compressor Station Spacing

For gas pipelines where intermediate compression is required, there is considerable flexibility in the location of the compressor stations. Shifting the location changes the pressure at the inlct to the station and hence the compression ratio. If the stations are limited by the compression ratio, then the compressor ratio is included as an optimization parameter.

If the flow is relatively low, either centrifugal or reciprocating compressors can be used. For the higher flows typically found in mainline pipe systems, centrifugal compressors are generally used. Reciprocating compressors should be used for power requirements less than 5500 kilowatts. Compression ratios for centrifugal compressors are generally less than 1.5. Staging is required for larger ratios. The most efficient centrifugal compression ratios tend to be in the 1.25 to 1.35 range. Reciprocating compression ratios can well exceed 1.5 but they tend to be limited by the flow. Capital costs and fuel costs are the key factors in determining the optimum spacing between compressor stations.

7. Environmental/Socioeconomic Factors

The optimum spacing of compressor stations is primarily based on system optimization and hydraulic requirements. However, sometimes it is necessary to adjust the station locations in response to environmental or socioeconomic factors. Such changes in location could affect the overall design efficiency, and it is possible that the compressor units and cooling/heating requirements may be different. This usually increases the capital costs.

8. Heating and Cooling

High gas temperatures in pipeline result in high pressure losses. Significant savings can be achieved by cooling the gas downstream of the compressor. Although money must be invested to install and operate coolers, usually the resulting reduction in pipe sizes or compression requirements justifies the cost.

The absence of cooling may have many undesirable effects. For instance, the inlet and outlet temperatures of the pipeline can progressively rise at successive compressor stations along the line and result in increasing pressure losses. This effect is termed “cascading”. Consistently high discharge temperature can also cause metallurgical problems. Pipeline coating may also be damaged, especially at high discharge temperature of 65 °*C* or more.

1.3. Population Density Index & Class Location

When Survey is performed for gas pipelines, the class locations based on population density index as per code ASME B31.8 “Gas Transmission and Distribution Piping Systems” shall be recorded along with chainages at change points of each class location.

Population density index along the pipeline route shall be determined as follows:

A zone, 400 M (One Quarter Mile) wide (200 M either Side) shall be considered along the pipeline route with the pipeline in the center-line of this zone. Then the entire route of the pipeline shall be divided into lengths of 1600 M (One Mile) such that the individual lengths will include the maximum number of dwellings intended for human occupancy. The number of such dwellings which are intended of human occupancy within each 1600 M (One Mile) zone shall be counted and reported along the other survey data.

1. Classification Guidelines

Areas shall be classified based on guidelines as given below:

A. Class 1 Location (Including Its Subparts)

   Class 1 location is any 1600 M (One Mile) section that has 10 or fewer dwellings intended for human occupancy.

B. Class 2 Location

   Class 2 location is any 1600 M (One Mile) section that has More than 10 but less than 46 dwellings intended for human occupancy.

C. Class 3 Location

Class 3 location is any 1600 M (One Mile) section that has 46 or more dwellings intended for human occupancy except when a Class 4 Location Prevails.

D. Class 4 Location

Class 4 location include areas where multi-storey buildings are prevalent, and where traffic is heavy or dense and where there may be numerous other utilities underground

1.4. Capacity Augmentation

If the future capacity of the pipeline is increased to 20MMSCMD. The simulation is done without changing the diameter of the pipe The Pipeline through put capacity is increased by two methods.

1. Looping the Pipeline
2. Compressor Stations
3. Combination of 1&2.

1. Looping the Pipeline

Looping the gas pipeline is equivalent to increase in the pipe diameter, and hence results in increased through put capability. This method of increasing pipeline capacity by looping involves initial capital investment. However operating cost will be negligible compared to compressor stations.

1.1. Some Important Considerations regarding Pipeline Looping

There are two important parameters to consider when choosing the location for a pipeline loop: temperature and pressure. Considering pipeline pressure, the magnitude of the pressure drop is higher at the downstream section of the pipeline because the gas has expanded. Hence, considering pressure alone, looping at the downstream portion of the pipeline is more efficient.

However, temperature must also be considered. At the upstream part of the pipeline, particularly downstream of a compressor station, the gas temperature is typically much higher than in other places along the line. Adding a loop increase where the gas temperature is hotter increases the heat transfer from the pipeline to the immediate environment. This is especially true if the ground temperature is significantly less than the gas temperature. When higher rates of cooling occur, the pressure drop along the pipeline is considerably less. Therefore, it is most often recommended that under steady-state conditions, pipeline looping be in an upstream region, such as immediately downstream of a compressor station, especially if the gas is hot. It should be noted that a comprehensive simulation involving a gas temperature profile giving consideration to elevation changes is always necessary to determine the exact location of looping in steady-state conditions. Typically, in situations where the gas temperature, or the difference is less than 5-10 $°C$, temperature is no longer an important consideration when choosing a location for a loop.

1.2 Advantages

1. Low capital investment when compared to overall cost of compressor in longer term.
2. Operating cost is negligible when compared with compressor operating cost.

1.3 Disadvantages

1. The time period for the project completion is comparatively higher.

2. Compressor Stations

Compressor compress the natural gas and raises its pressure and its temperature to the level that it is required to ensure that the gas is transported to the delivery point at required flow and pressure. So by compressing high volume of gas, can be transported through low throughput capacity pipeline. Though initial capital cost of compressor is low, the operating cost is higher and can be major disadvantage.

2.1 Advantages

1. Comparatively project can be implemented faster with minimum problem to existing system
2. Capital investment is low.

2.2 Disadvantages

1. Gas cannot be compressed beyond design pressure as pipeline is designed for that pressure.
2. The compressor operating cost per year is low, however for the entire design life, the operating cost of compressor is comparatively higher when compared with the cost of looping option in some cases.

1.5. Assumptions

- It is assumed for the study that the maximum gas pressure available at "Dabhol" will be $45b\,\arg$.
- The pressure at the inlet battery limit shall be considered as 93barg. At the outlet of intermediate compressor station (if any), the gas temperature will be maintained below $50°C$.
- After this compression (if any), the maximum pipeline pressure will be increased to a maximum pressure of 93barg.
- For gas delivery at Chennai entry points, the minimum required pressure shall be chosen as 44.14 barg.

- The influence of internal coating on transport capacity will be studied by considering scenario with both internally coated and non coated line pipes.
- Class 1 to be considered.

1.6 Basic Input

1. **Gas Composition**

GAS COMPOSITION REPORT		
COMPONENTS (Mole %)		Lean LNG
METHANE	C1	94.742
ETHANE	C2	2.390
PROPANE	C3	0.399
BUTANE	C4	0.020
PENTANE	C5	0.009
HEXANE	C6	0.000
HEPTANE	C7	0.000
CARBON DIOXIDE	CO2	1.970
NITROGEN	N2	0.470
TOTAL MOLE		100.000

2. **Gas Demand**

1. At Goa	11 MMSCMD
2. At Bangalore	2 MMSCMD
3. At Chennai	3 MMSCMD

3. Pipeline Data

Throughput	16 MMSCMD
Design Pressure	93 bar
MAOP	83 bar
∅ outside (nominal)	ND 30", 28",26"
Steel grade :	API5L X60 and 70
Wall thickness calculation according to ASME B31.8 with :	
Design factor :	0.7 for class 1 0.6 for class 2 0.5 for class 3 0.4 for class 4

1.7. Equations/Formulas

A. Fully Turbulent Equations

1. Panhandle B

The Panhandle B equation is normally suitable for high-flow-rate, large-diameter (i.e. pipes larger than NPS 24) and high-pressure systems. The degree of accuracy depends on how precisely the pipeline efficiency is measured.

$$Q_b = 737.02\left(\frac{T_b}{P_b}\right)^{1.02}\left[\frac{P_1^2 - P_2^2 - E}{G^{0.961}.L.T_{ave}.Z_{ave}}\right]^{0.510}.D^{2.23}$$

Where

Q_b = gas flow rate at base conditions, SCF/D

T_b = temperature at base conditions, 520 deg. R

P_b = pressure at base condition, 14.7 psia

P_1 = gas inlet pressure, psia.

P_2 = gas exit pressure, psia.

G = gas gravity, dimensionless

L = pipeline length, miles

T_{ave} = average temperature, deg. R

Z_{ave} = average compressibility factor, dimensionless

D = pipeline inside diameter, inch.

2. Weymouth

The Weymouth equation is normally suitable for high-flow-rate, large-diameter, and high-pressure systems. This equation tends to overestimate the pressure drop predictions, and contains a lower degree of accuracy relative to the other equations. Weymouth is commonly used in distribution networks for the sake of safety in predicting pressure drop.

$$Q_b = 432.7\left(\frac{T_b}{P_b}\right)\left[\frac{P_1^2 - P_2^2 - E}{G\ .L.T_{ave}.Z_{ave}}\right]^{0.5}.D^{2.667}$$

3. AGA Fully Turbulent

The AGA fully turbulent is the most frequently recommended and widely used equation in high-pressure, high-flow-rate systems for medium – to large-diameter pipelines. It predicts both flow and pressure drop with a high degree of accuracy, especially if the effective roughness values used in the equation have been measured accurately.

$$Q_b = 38.774\left(\frac{T_b}{P_b}\right)\left[\frac{P_1^2 - P_2^2 - E}{G\ .L.T_{ave}.Z_{ave}}\right]^{0.5}\left[4\log\frac{3.7D}{K_e}\right].D^{2.5}$$

Where the transmission factor is defined using the Nikuradse equation

$$\sqrt{\frac{1}{f}} = \left[4\log\frac{3.7D}{K_e}\right]$$

4. Colebrook-White

This equation combines both partially and fully turbulent flow regimes and is most suitable for cases where the pipeline is operating in the transition zone. This equation is again used for large-diameters, high-pressure, and medium-to high-flow-rate systems. It predicts a higher pressure drop or lower flow rates than the AGA fully turbulent equation.

$$Q_b = 38.774\left(\frac{T_b}{P_b}\right)\left[\frac{P_1^2 - P_2^2 - E}{G\ .L.T_{ave}.Z_{ave}}\right]^{0.5}\left[-4\log\left(\frac{K_e}{3.7D}+\frac{1.4126\sqrt{\frac{1}{f}}}{R_e}\right)\right].D^{2.5}$$

Where the transmission factor is defined as

$$\sqrt{\frac{1}{f}} = \left[-4\log\left(\frac{K_e}{3.7D}+\frac{1.4126\sqrt{\frac{1}{f}}}{R_e}\right)\right]$$

5. Pipe Wall Thickness

$$P = \frac{2St}{D}FET$$

So

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

Where, `

P = Pipeline Design Pressure, psi,

S = Specified Minimum Yield Strength, psi

t = Nominal Wall Thickness, mm

D = Pipe Outside Diameter, mm,

F = Design Factor Obtained From Table below

LOCATION CLASS	DESIGN FACTOR, F
CLASS 1,DIVISION 1	0.80
CLASS 1, DIVISION 2	0.72
CLASS 2	0.6
CLASS 3	0.5
CLASS 4	0.4

E = Longitudinal Joint Factor Obtained From Table below

Spec. No.	Pipe class	E factor
ASTM A 53	Seam Less Electric resistance welding Furnace Butt welded: continuous weld	1.00 1.00 0.60
ASTM A 106	Seamless	1.00
ASTM A 134	Electric Fusion Arc Welded	0.8
ASTM A 135	Electric resistance welded	1.00
ASTM A 139	Electric Fusion welded	0.8
ASTM A 211	Spiral welded steel pipe	0.8
ASTM A 333	Seamless 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	1.00 1.00

	Electric flash welded Submerged arc welded Furnace butt welded	1.00 1.00 0.60

T = Temperature De-Rating Factor

Temp,°F	TEMP DERATING FACTOR,T
250 OR LESS	1
300	0.967
350	0.933
400	0.9
450	0.867

6. Looping Formula

$$X = L.\frac{\left(\frac{Q_1}{Q_2}\right)^2 - 1}{\left(\frac{1}{1+\left(\frac{D_2}{D_1}\right)^2}\right)^2 - 1}$$

Where,

X = length of the pipeline to be looped, miles

L = length of the existing pipeline, miles

Q_1 = initial gas flow rate, MMSCMD

Q_2 = final gas flow rate, MMSCMD

D_1 = existing pipeline inside diameter, inches

D_2 = looped segment inside diameter, inches

1.8. Charts/Graphs

See Appendix.

1.9 Design of Buoyancy Control

1. General

Pipelines are subjected to buoyant forces whey they encounter freestanding or flowing water, and when buried in saturated soils. The buoyant forces are counteracted by the addition of weight, such as concrete swamp weights, river weights or continuous coating. The final selection of the type and extent of buoyancy control measures is usually made on a site-specific basis. If the ditch is filled with water, a river weight or continuous concrete coating may be required to keep the pipe down.

The required amount of weight is calculated by equating the force due to the mass of the pipe and weights with the buoyant forces due to the fluid displaced by the pipe and weights. In this calculation, a factor of safety called a negative buoyancy factor is introduced to ensure that the pipe will stay down. Negative buoyancy factors between 5% and 20% are common, depending upon the fluid density of the soil/water mixture encountered and the construction methods used.

2. Assumptions

1. For river floodplains, small streams, drainage courses, swamp, muskeg, small lakes, and local depression where water will be encountered in the ditch during construction:

- Negative buoyancy: 5%
- Fluid density: 1040 kg/m^3

2. For main river channels and areas where flowing or moving water will be encountered during construction:

- Negative buoyancy: 10%
- Fluid density: 1000 kg/m^3

3. Basic Input

Pipe Outside Diameter, D	: 24in. (610mm)
Wall Thickness, t	: 11.1 mm
Length of Pipe, L	: 11.5 M
Length of Pipe with Conc. Coating	: 10.9 M
Density of Water	: 1000 kg/m^3
Density of Concrete	: 2500 kg/m^3
Assume Negative Buoyancy, N	: 10%
Steel Density (X65 Grade)	: 7810 kg/m^3

4. Equations/Formulas

1. Coating Thickness Calculation

$$T_c = 0.5\left\{\left[\frac{D^2\gamma_c - \left[D^2 - \left(D^2 - 2t\right)^2\right]\gamma_s}{\gamma_c - \gamma_F\left(1 + \frac{N}{100}\right)}\right]^{.5} - D\right\}$$

Where,

T_c = concrete coating thickness, M

D = pipe outside diameter, M

t = pipe wall thickness, M

γ_c = concrete density, kg/m^3

γ_s = steel density, kg/m^3

γ_F = fluid density, kg/m^3

2. Pipe Weight Calculation

$$M_p = \left[D^2 - (D-2t)^2\right]\frac{\gamma_s \pi}{4}$$

Where,

M_p = mass of pipe, kg/m

3. Concrete Weight Calculation

$$M_c = \left[(D+2T_c)^2 - D^2\right]\frac{\gamma_c \pi}{4}$$

Where,

M_c = mass of concrete, kg/m

4. Buoyancy Weight Calculation

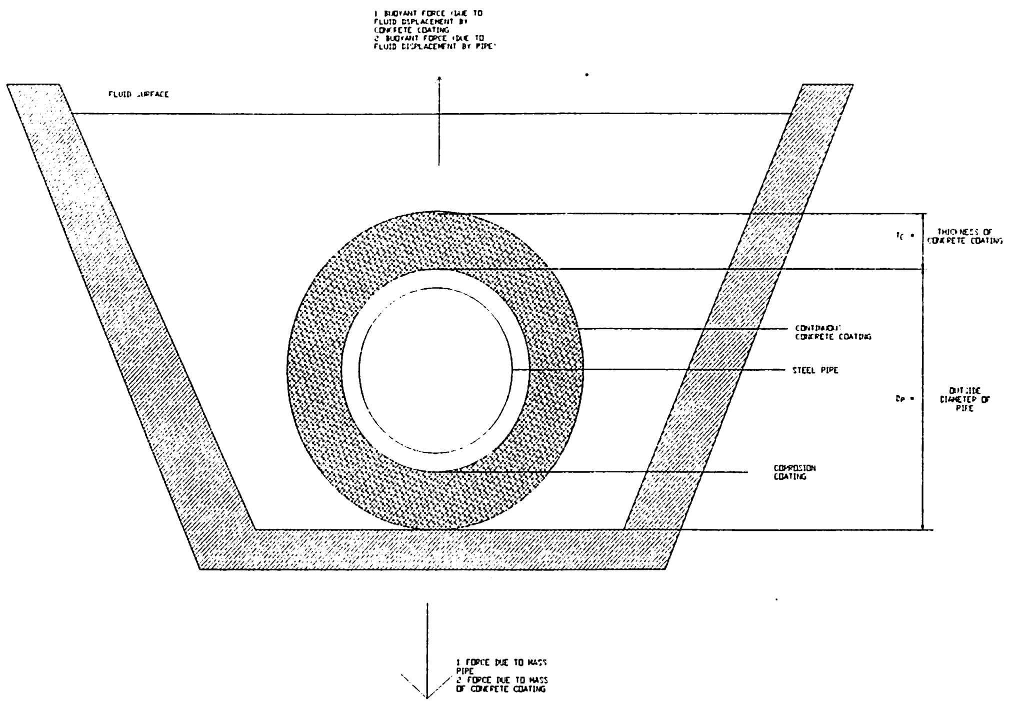
$$B_p + B_c = (D+2T_c)^2 \frac{g\gamma_F \pi}{4}$$

Where,

B_p = buoyant force acting on pipe, N/m

B_c = buoyant force acting on concrete, N/m

5. Schematic Representation of Anti-Buoyancy



CHAPTER 2

PROJECT WORK DETAILS

1. Name Of the Project - **Detail Design Of Gas Pipeline**

2. Aim of the Project

To bring out the optimal design Specification in respect of following

1. Design Of Pipe Size.
2. Design Of Buoyancy Control.

3. Basic Input

1. Design Of Pipe Size.

   1. Gas Composition

GAS COMPOSITION REPORT		
COMPONENTS (Mole %)		Lean LNG
METHANE	C1	94.742
ETHANE	C2	2.390
PROPANE	C3	0.399
BUTANE	C4	0.020
PENTANE	C5	0.009
HEXANE	C6	0.000
HEPTANE	C7	0.000
CARBON DIOXIDE	CO2	1.970
NITROGEN	N2	0.470
TOTAL MOLE		100.000

2. Gas Demand

1. At Goa	11 MMSCMD
2. At Bangalore	2 MMSCMD
3. At Chennai	3 MMSCMD

3. Pipeline Data

Throughput	16 MMSCMD
Design Pressure	93 bar
MAOP	83 bar
∅ outside (nominal)	ND 30", 28",26"
Steel grade :	API5L X60 and 70
Wall thickness calculation according to ASME B31.8 with :	
Design factor :	0.7 for class 1 0.6 for class 2 0.5 for class 3 0.4 for class 4

2. Design Of Buoyancy Control

Pipe Outside Diameter, D	: 24in. (610mm)
Wall Thickness, t	: 11.1 mm
Length of Pipe, L	: 11.5 M
Length of Pipe with Conc. Coating	: 10.9 M
Density of Water	: 1000 kg/m^3
Density of Concrete	: 2500 kg/m^3
Assume Negative Buoyancy, N	: 10%
Steel Density (X65 Grade)	: 7810 kg/m^3

4. Sources of Input

1. Design Of Pipe Size.

The Sources of Input has been taken from Gas Authority Of India limited. The following datas are assumed.

5. It is assumed for the study that the maximum gas pressure available at "Dabhol" will be $45b\,\text{arg}$.
6. The pressure at the inlet battery limit shall be considered as 93barg. At the outlet of intermediate compressor station (if any), the gas temperature will be maintained below $50°C$.
7. After this compression (if any), the maximum pipeline pressure will be increased to a maximum pressure of 93barg.
8. For gas delivery at Chennai entry points, the minimum required pressure shall be chosen as 44.14 barg.
9. The influence of internal coating on transport capacity will be studied by considering scenario with both internally coated and non coated line pipes.

2. Design Of Buoyancy Control

The Sources of Input has been taken from Gas Authority Of India limited. The following datas are assumed.

1. For river floodplains, small streams, drainage courses, swamp, muskeg, small lakes, and local depression where water will be encountered in the ditch during construction:

- Negative buoyancy: 5%
- Fluid density: 1040 kg/m^3

2. For main river channels and areas where flowing or moving water will be encountered during construction:

- Negative buoyancy: 10%
- Fluid density: 1000 kg/m^3

5. Design Steps

1. Design Of Pipe Size.

Step 1: Determination of Supply Pressure Using Pipeline Studio (Software)

The simulation results described hereafter give

- The alternative description
- For the design flow rate

1. The pressure at "Dabhol", when the pressure at "Chennai" is set to 44.14barg
2. The ultimate transport capacity is obtained for the maximum pressure drop between Dabhol and Chennai.

Each alternative description must be read with the associated Process Flow Diagram given hereafter.

1. Alternative 1

This case is representative of X70 steel grade pipeline, with epoxy internal coating. The diameter is 30 inches from Dabhol to Goa, from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 77.549barg, when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

2. Alternative 2

This case is representative of X70 steel grade pipeline, without epoxy internal coating. The diameter is 30 inches from Dabhol to Goa, from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 84.95barg, when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

3. Alternative 3

This case is representative of X60 steel grade pipeline, with epoxy internal coating. The diameter is 30 inches from Dabhol to Goa, from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 78.09barg, when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

4. Alternative 4

This case is representative of X60 steel grade pipeline, without epoxy internal coating. The diameter is 30 inches from Dabhol to Goa, from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 85.60barg, when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

5. Alternative 5

This case is representative of X60 steel grade pipeline, without epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 101.436barg, when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

6. Alternative 6

This case is representative of X60 steel grade pipeline, with epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 91.3barg when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

7. Alternative 7

This case is representative of X70 steel grade pipeline, with epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 90.6barg when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

8. **Alternative 8**

This case is representative of X70 steel grade pipeline, without epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The pressure at Dabhol is 100.509barg when the pressure at Chennai is 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

Step 2: Installation of Compressor at the Supplier End

9. **Alternative 9**

This case is representative of X70 steel grade pipeline, with epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The pressure at "Dabhol", when the pressure at "Chennai" is set to 44.14barg

The ultimate capacity to Chennai reaches 3 MMSCMD and 11 MMSCMD to Goa and 2 MMSCMD to Bangalore.

Step 3: Capacity Augmentation

1. Hydraulic simulation with one compressor station installed

In addition to the information provided in above alternatives cases, the simulation results include, for the future design flowrate.

1. The pressure at Dabhol, when the pressure at Chennai is set to 44.14barg

2. The corresponding compressor duty (mechanical power required at the compressor shaft end, not the installed compression power).
3. The Fuel Gas Consumption.

The ultimate transport capacity is obtained for the maximum pressure drop between Dabhol or Chennai.

1. Alternative 1

This case is representative of X70 steel grade pipeline, with epoxy internal coating and compressor stations at Dabhol, and intermediate compressor at 238KM. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The required pressure at Dabhol to reach the Compressor station inlet at the minimum pressure of 45barg is 94.31barg and the required pressure at the compressor station outlet (at 238 KM) to reach Chennai at the minimum pressure of 45barg is 94.3barg.

The duty of the compressor station is 14.14 MW at Dabhol and 14.30 MW at 238KM. The fuel gas rate is 0.1198 MMSCMD at Dabhol and 0.226 at 238KM.

The ultimate capacity reaches 7 MMSCMD if gas is withdrawn at Chennai.

2. Hydraulic simulation with Loop installed

1. Alternative 1

This case is representative of X70 steel grade pipeline, with epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The loop is provided in the upstream side of the section. There is no greater effect in the supplier pressure end.

2. Alternative 2

This case is representative of X70 steel grade pipeline, with epoxy internal coating. The diameter is 28 inches from Dabhol to Goa, and 26 inches from Goa to Bangalore and Bangalore to Chennai.

The loop is provided in the downstream side of the section. In this case, the pressure at the supplier end is greater than the requirement. This case is shown to understand how downstream section of the loop affect the supplier side

2. Design Of Buoyancy Control

Step 1: Coating thickness Calculation

Step 2: Pipe Weight Calculation

Step 3: Concrete Weight Calculation

Step 3: Buoyancy Weight Calculation

6. Calculations

1. Design Of Pipe Size

1.1 Determination of Diameter

$$Q_b = 16 \text{ MMSCMD}$$

$$= 16*35.31$$

$$= 564.96 \text{ MMSCFD}$$

$$= 23540000 \text{ Cu.Ft/Hr.}$$

$$G = 0.654$$

$$T_b = 520 \text{ Rankine}$$

$$P_b = 14.7 \text{ Psia}$$

$$L = 142.9151 \text{ Miles.}$$

P_1 =93 barg = 1323.46 Psia

P_2 =44.14 barg = 628.67 Psia

K_e = 5 Microns

=0.00019685 Inches

D =27.25 Inches.

$$\sqrt{\frac{1}{f}} = \left[-4\log\left(\frac{K_e}{3.7D} + \frac{1.4126\sqrt{\frac{1}{f}}}{R_e}\right)\right]$$

$$R_e = 45.\left(\frac{7356250 * 0.654}{27.25}\right)$$

$$= 7944750$$

The Regime of flow is Turbulent, since the calculated value is greater than 2000.

$$\sqrt{\frac{1}{f}} = \left[-4\log\left(\frac{0.00019685}{3.7 * 27.25} + \frac{1.4126\sqrt{\frac{1}{f}}}{7944750}\right)\right]$$

By Trail and Error Method

$$\sqrt{\frac{1}{f}} = 21$$

$$7356250 = 38.774\left(\frac{520}{14.7}\right)\left[\frac{1311.945^2 - 934.986^2 - 0}{.9 * 528 * 0.65 * 142.9151}\right]^{0.5} 21 * D^{2.5}$$

D = 27.25"

1.2 Determination of Wall Thickness

For the Pipe No. 0001

$P = 93$ bar

$= 93 * 14.22$

$= 1322.46$ bar

$D = 28$ Inches.

$S = 70000$ Psi

$F = 0.72$

$E = 1$

$T = 1$

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

$$t = \frac{1322.46 * 28}{2 * 70000 * 0.72 * 1 * 1}$$

$$t = 0.367 inch$$

For the calculated thickness, refer API 5L, to correct the standard thickness

For $t = 0.367 inch$, the standard thickness is $t = 0.374 inch$

$$t = 9.52 mm$$

For the Pipe No. 0002 and Pipe No. 0003

$P = 93$ bar

$= 93 * 14.22$

$= 1322.46$ bar

$D = 26$Inches.

$S = 70000$ Psi

$F = 0.72$

$E = 1$

$T = 1$

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

$$t = \frac{1322.46 * 26}{2 * 70000 * 0.72 * 1 * 1}$$

$t = 0.341 inch$

For the calculated thickness, refer API 5L, to correct the standard thickness

For $t = 0.341 inch$, the standard thickness is $t = 0.344 inch$

$t = 8.73 mm$

1.3 Determination of Loop Length

L = 1100 km =1760 Miles

Q_1 = 16 MMSCMD

Q_2 = 20 MMSCMD

D_1 = 27.25 inches

D_2 = 27.25 inches

$$X = L.\frac{\left(\frac{Q_1}{Q_2}\right)^2 - 1}{\left(\frac{1}{1+\left(\frac{D_2}{D_1}\right)^2}\right)^2 - 1}$$

$$X = 1760.\frac{\left(\frac{16}{20}\right)^2 - 1}{\left(\frac{1}{1+\left(\frac{27.25}{27.25}\right)^2}\right)^2 - 1}$$

$X = 528 KM$

1. Design Of Buoyancy control

1.1 Coating Thickness Calculation

$$T_c = 0.5\left\{\left[\frac{D^2\gamma_c - \left[D^2 - (D^2 - 2t)^2\right]\gamma_s}{\gamma_c - \gamma_F\left(1 + \frac{N}{100}\right)}\right]^{.5} - D\right\}$$

$$T_c = 0.5\left\{\left[\frac{.610^2 * 2500 - \left[.610^2 - (.610^2 - 2 * 0.0111)^2\right]7810}{2500 - 1000\left(1 + \frac{10}{100}\right)}\right]^{.5} - .610\right\}$$

T_c = 54 mm

1.2 Pipe Weight Calculation

$$M_p = \left[D^2 - (D - 2t)^2\right]\frac{\gamma_s \pi}{4}$$

Where,

M_p = mass of pipe, kg/m

$$M_p = \left[.610^2 - (.610 - 2 * 0.0111)^2\right]\frac{7810 * \pi}{4}$$

M_p = 163 kg/m

For 11.5 m

M_p = 1874 kg.

1.3 Concrete Weight Calculation

$$M_c = \left[(D+2T_c)^2 - D^2\right]\frac{\gamma_c \pi}{4}$$

Where,

M_c = mass of concrete, kg/m

$$M_c = \left[(.610+2*0.054)^2 - .610^2\right]\frac{2500*\pi}{4}$$

M_c = 281.46 kg/m

For 10.9 m

M_c = 3068 kg.

Total Weight = $M_c + M_p$

= 3068 + 1874

= 4942 kg.

1.4 Buoyancy Weight Calculation

$$B_p + B_c = (D+2T_c)^2 \frac{g\gamma_F \pi}{4}$$

Where,

B_p = buoyant force acting on pipe, N/m

B_c = buoyant force acting on concrete, N/m

$$B_p + B_c = (.610 + 2 * 0.054)^2 \frac{9.81 * 1000 * \pi}{4}$$

$$B_p + B_c = 3969 \text{ kg}$$

Net weight acting against buoyancy = Total Weight - Buoyancy Weight

= 4942 – 3969

= 973 kg.

Chapter 3
Discussions

1. Discussions on Different options and Narrowing down to best Options

1.1 Determination Of Pipe Diameter.

- Various alternatives have been discussed above to determine the Optimum diameter for the given throughout.
- Alternative also discuss the options of grade between X60 and X70 Grade.
- Alternative also discuss the need of internal coating. This is to reduce the friction and Power Requirement.
- Alternatives also done for future expansion by considering Looping the pipeline or by installing the compressor for the future throughput.
- From the above alternatives, the alternative 7 is selected which gives close value to our Design Pressure.
- The alternative 6 can also be selected, which is also close to our Design Pressure.
- But this alternative has one drawback, as the grade decreases, the wall thickness values increases, which lead to longer time to weld a single pipe. Hence, the labor cost.

- The cost of smaller grade pipe can be compensated with other factor while comparing cost of higher grade pipes.

- In general practice, the higher grade of X70 is selected for cross country pipeline.

1.2 Capacity Augmentation

- There are two important parameters to consider when choosing the location for a pipeline loop: temperature and pressure.

- Considering pipeline pressure, the magnitude of the pressure drop is higher at the downstream section of the pipeline because the gas has expanded.

- Hence, considering pressure alone, looping at the downstream portion of the pipeline is more efficient.

- However, temperature must also be considered. At the upstream part of the pipeline, particularly downstream of a compressor station, the gas temperature is typically much higher than in other places along the line.

- Adding a loop increase where the gas temperature is hotter increases the heat transfer from the pipeline to the immediate environment.

- This is especially true if the ground temperature is significantly less than the gas temperature.

- When higher rates of cooling occur, the pressure drop along the pipeline is considerably less.

- Therefore, it is most often recommended that under steady-state conditions, pipeline looping be in an upstream region, such as immediately downstream of a compressor station, especially if the gas is hot.

1.3 Determination of Buoyancy Weight

- The final selection of the type and extent of buoyancy control measures is usually made on a site-specific basis.

- The Factor of safety called a negative buoyancy is introduced to ensure that the pipe will stay down.

- Negative buoyancy factors between 5% and 20% are common, depending upon the fluid density of the soil/water mixture encountered and the construction methods used.

Conclusion

Chapter 4

The Design Specification for the Dabhol-Chennai Gas Pipeline are as follows

1. Throughput	-	16 MMSCMD
2. Pipe Diameter	-	28", 26"
3. Wall Thickness	-	9.52, 8.7
4. Design Pressure	-	93 barg
5. Design Temperature	-	-20 to 65 degree Celsius
6 MAOP	-	74 barg
7. Operating Pressure	-	35-60 barg
7. Rating of Pipeline System	-	600#
8. Pipe Grade	-	API 5L X70
9. Minimum Test Pressure	-	66 barg
10. Maximum Test Pressure	-	102.3 barg
11. Power Requirement	-	14.11 MW

The Design Specification for the buoyancy control of Dabhol-Chennai Gas Pipeline are as follows

1. Coating Thickness	-	54 mm
2. Pipe Weight	-	1874 kg
3. Concrete weight	-	3068 kg
4. Buoyancy Weight	-	3969 kg
5. Net weight acting against Buoyancy	-	973 kg

REFERENCES

Chapter 5

1. ASME CODE B-31 FOR PRESSURE PIPING.

2. API -1104 FOR WELDING OF PIPELINES AND OTHER RELATED FACILITIES.

3. ASME B 31.8 – GAS TRANSMISSION AND DISTRIBUTION PIPING SYSTEMS.

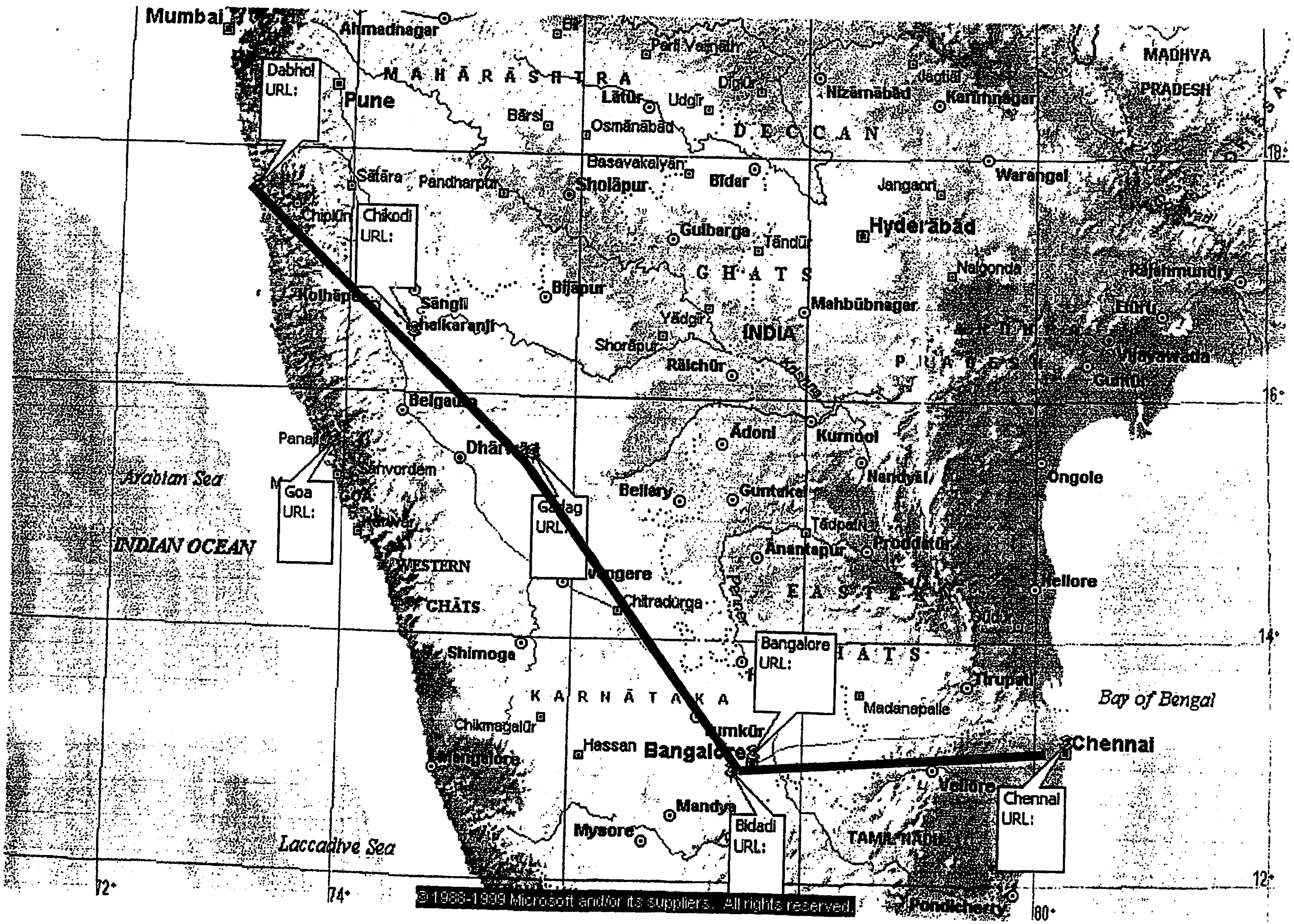
4. "PIPELINE DESIGN: A PRACTICAL APPROACH" By MOHIT POUR

5. PIPELINE AND GAS JOURNALS. ? !

6. INTERNET.

APPENDIX

Chapter 6


Dabhol
URL:
Chikodi
URL:
Goa
URL:
Gadag
URL:
Bangalore
URL:
Bidadi
URL:
Chennai
URL:
Mumbai
Ahmadnagar
Pune
MAHĀRĀSHTRA
Lātūr
Udgīr
Bārsi
Osmānābād
Nizāmābād
Karīmnagar
DECCAN
MADHYA
PRADESH
Basavakalyān
Bīdar
Warangal
Sātāra
Pandharpur
Sholāpur
Jangaon
Hyderābād
Chiplūn
Gulbarga
Tāndūr
GHATS
Nalgonda
Rājahmundry
Bijāpur
Sāngli
Mahbūbnagar
Ichalkaranji
Yādgīr
INDIA
Shorāpur
Rāichūr
Vijayawāda
Guntūr
Belgaum
Panaji
Ādoni
Kurnool
Arabian Sea
GOA
Nandyāl
Ongole
Bellary
INDIAN OCEAN
WESTERN
GHĀTS
Anantapur
Proddatūr
Nellore
Chitradurga
Shimoga
Tirupati
KARNĀTAKA
Madanapalle
Bay of Bengal
Chikmagalūr
Hassan
Bangalore
Chennai
Mangalore
Vellore
Mandya
Mysore
TAMIL NĀDU
Laccadive Sea
Pondicherry
72°
74°
80°
18°
16°
14°
12°
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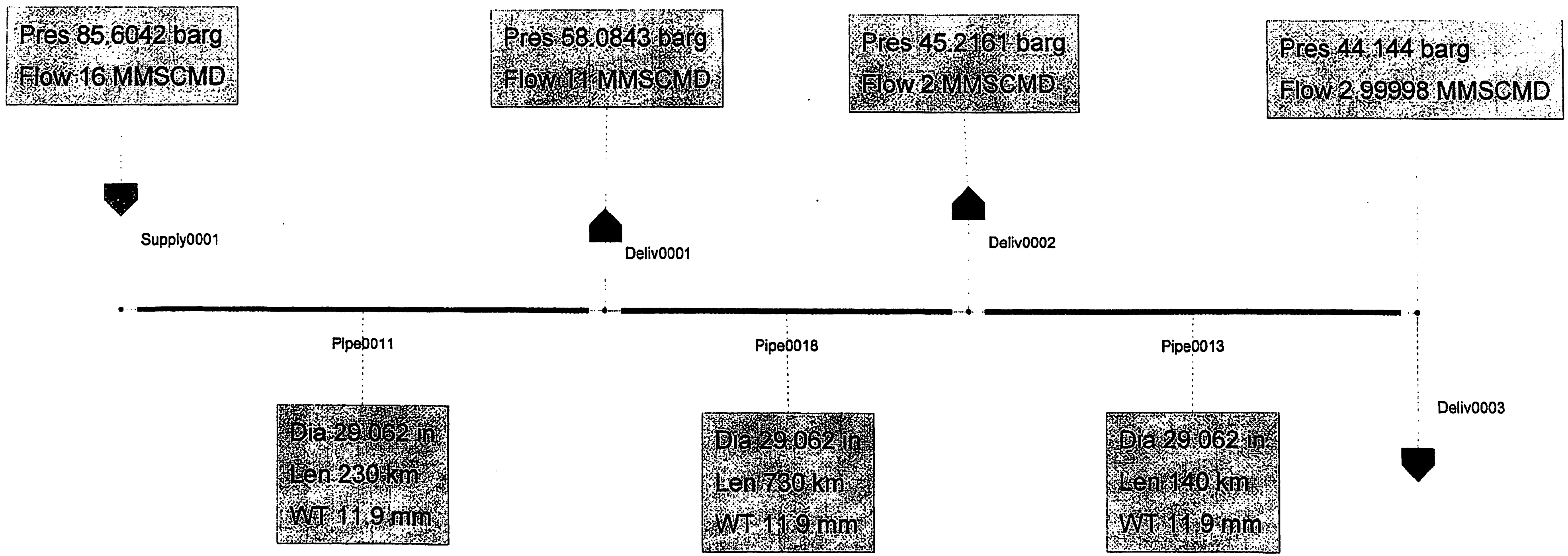
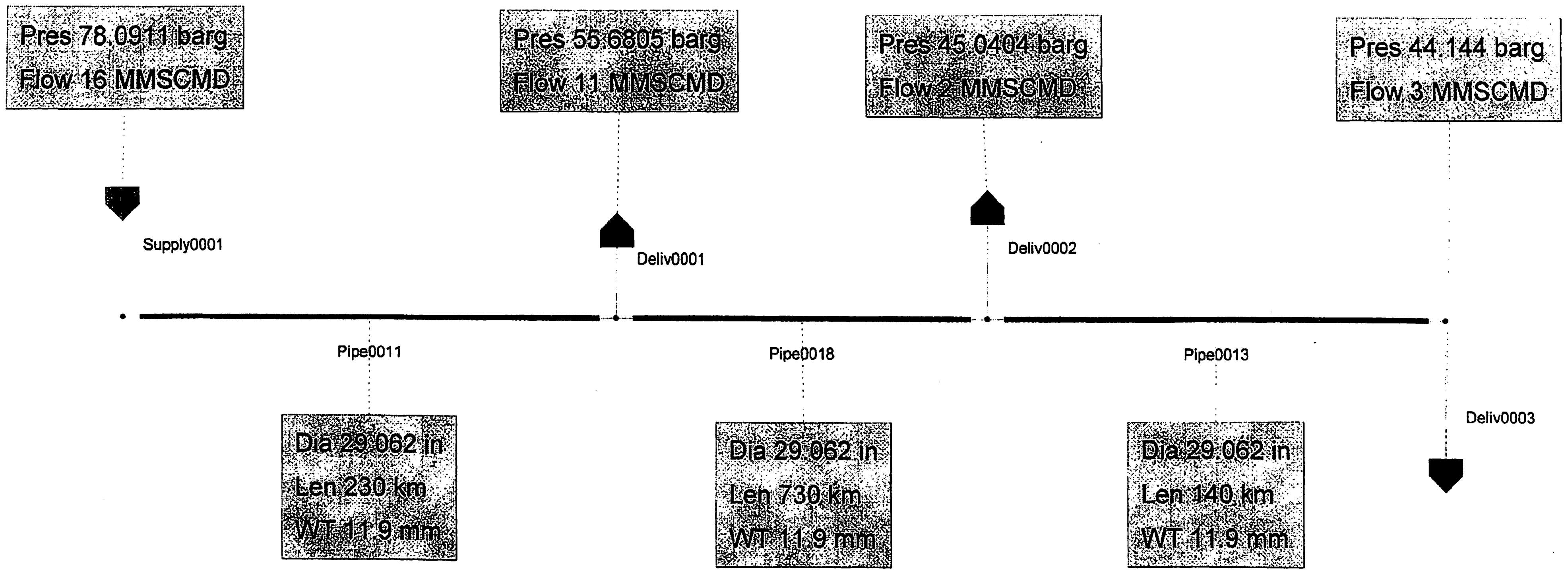
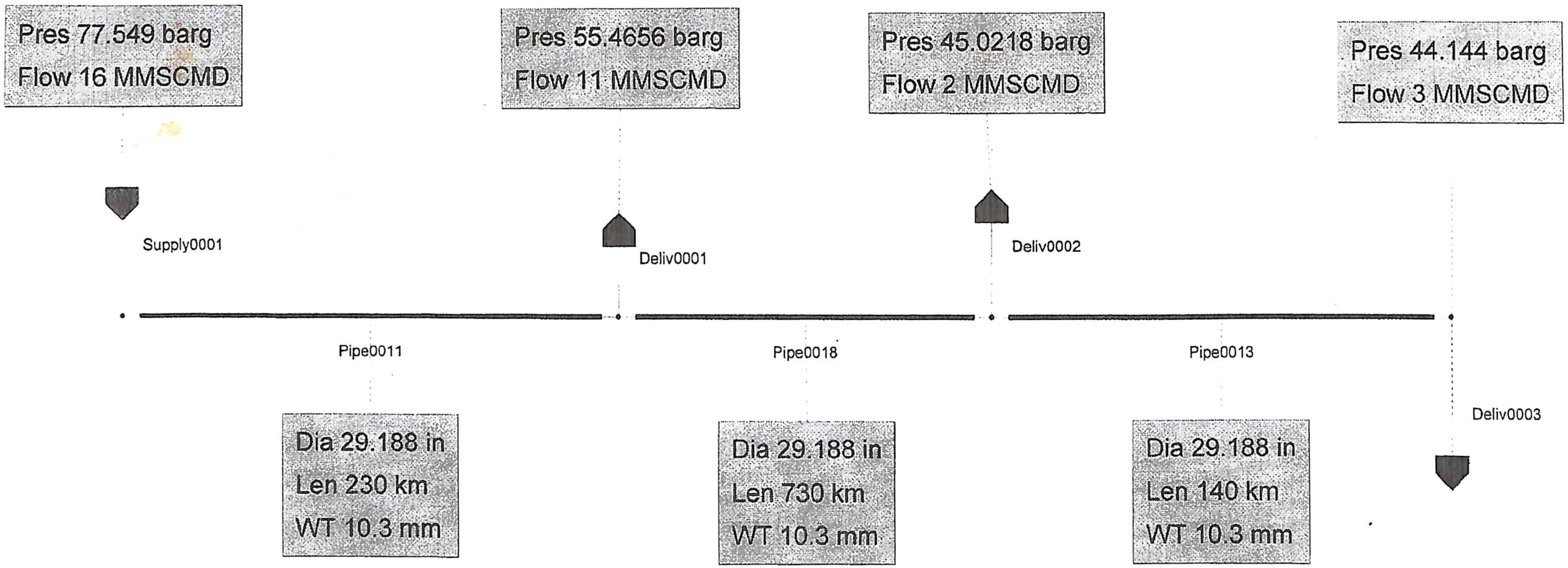
X60UnCoated-30inch

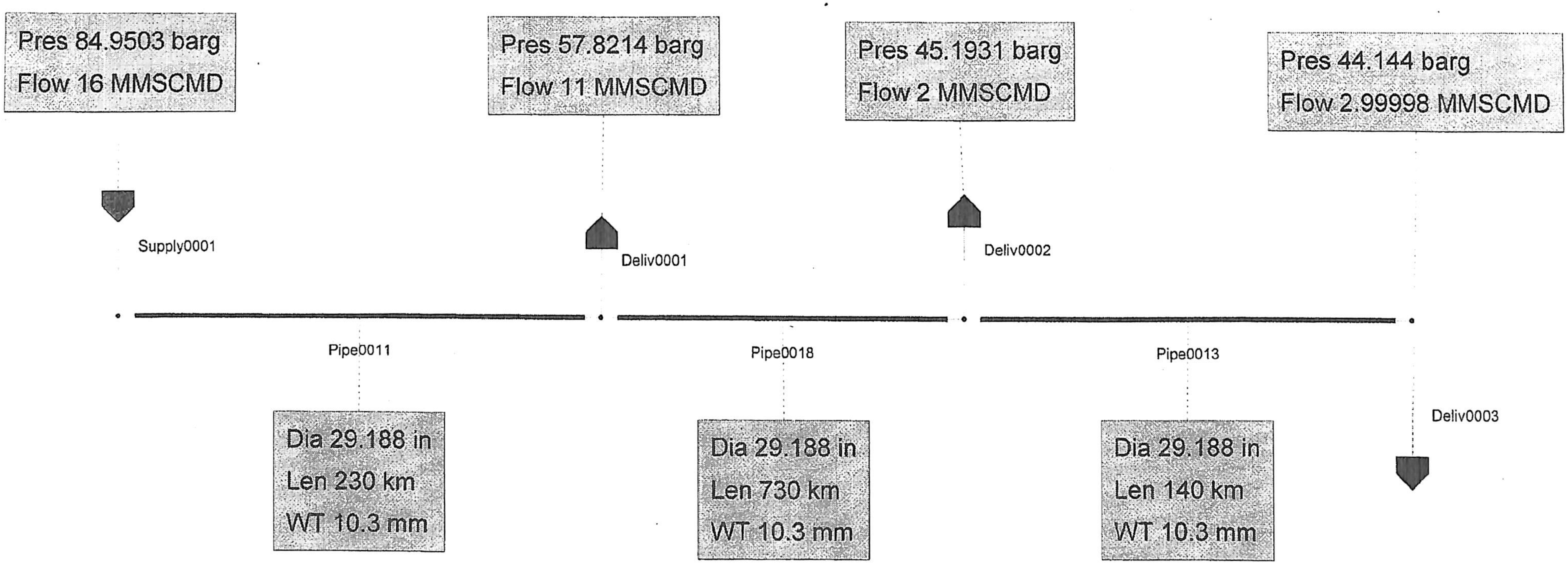



Pres 78.0911 barg
Flow 16 MMSCMD
Pres 55.6805 barg
Flow 11 MMSCMD
Pres 45.0404 barg
Flow 2 MMSCMD
Pres 44.144 barg
Flow 3 MMSCMD
Supply0001
Deliv0001
Deliv0002
Pipe0011
Pipe0018
Pipe0013
Deliv0003
Dia 29.062 in
Len 230 km
WT 11.9 mm
Dia 29.062 in
Len 730 km
WT 11.9 mm
Dia 29.062 in
Len 140 km
WT 11.9 mm

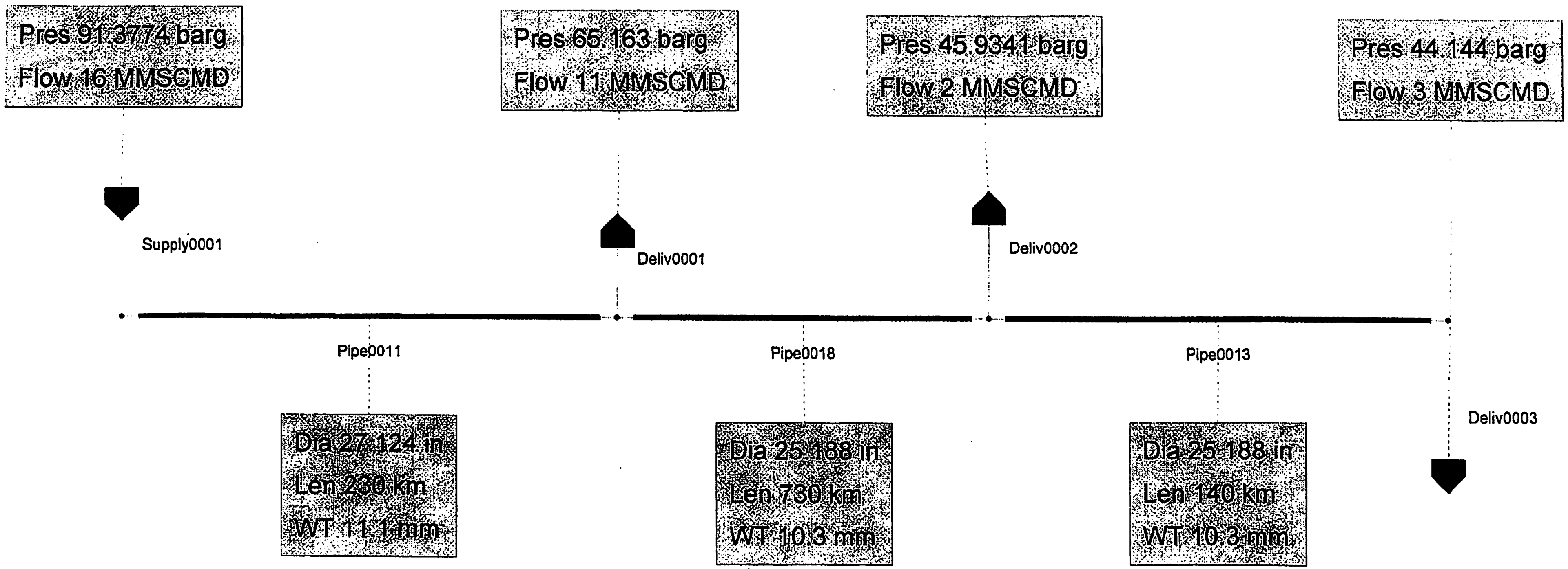


Pres 77.549 barg
Flow 16 MMSCMD
Pres 55.4656 barg
Flow 11 MMSCMD
Pres 45.0218 barg
Flow 2 MMSCMD
Pres 44.144 barg
Flow 3 MMSCMD
Supply0001
Deliv0001
Deliv0002
Deliv0003
Pipe0011
Pipe0018
Pipe0013
Dia 29.188 in
Len 230 km
WT 10.3 mm
Dia 29.188 in
Len 730 km
WT 10.3 mm
Dia 29.188 in
Len 140 km
WT 10.3 mm

X70UnCoated-30inch

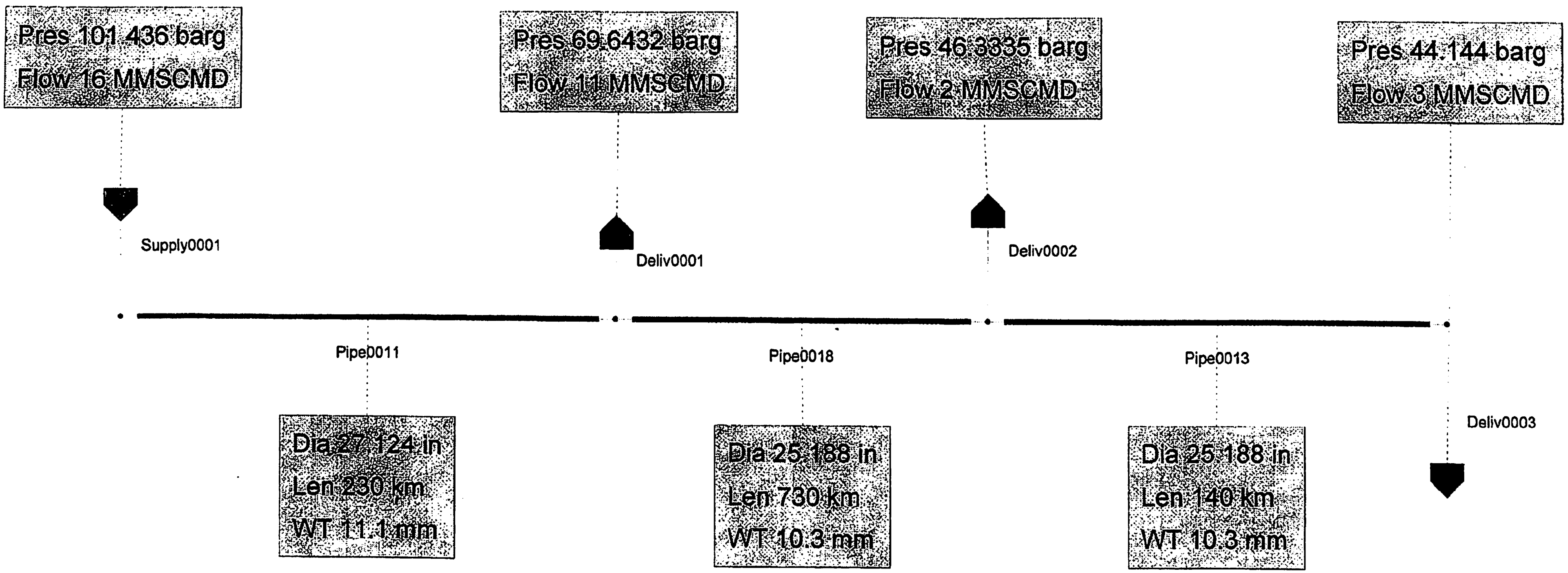


X60 Coated

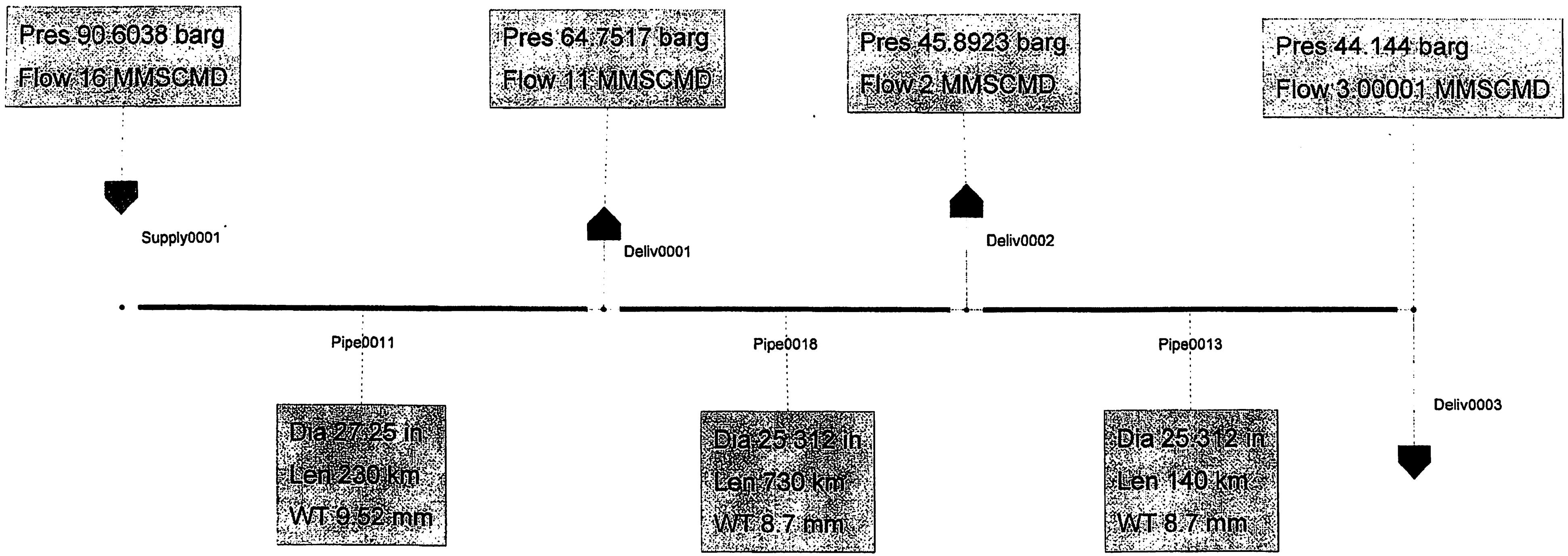


Pres 91.3774 barg
Flow 16 MMSCMD
Pres 65.163 barg
Flow 11 MMSCMD
Pres 45.9341 barg
Flow 2 MMSCMD
Pres 44.144 barg
Flow 3 MMSCMD
Supply0001
Deliv0001
Deliv0002
Pipe0011
Pipe0018
Pipe0013
Deliv0003
Dia 27.124 in
Len 230 km
WT 11.1 mm
Dia 25.188 in
Len 730 km
WT 10.3 mm
Dia 25.188 in
Len 140 km
WT 10.3 mm

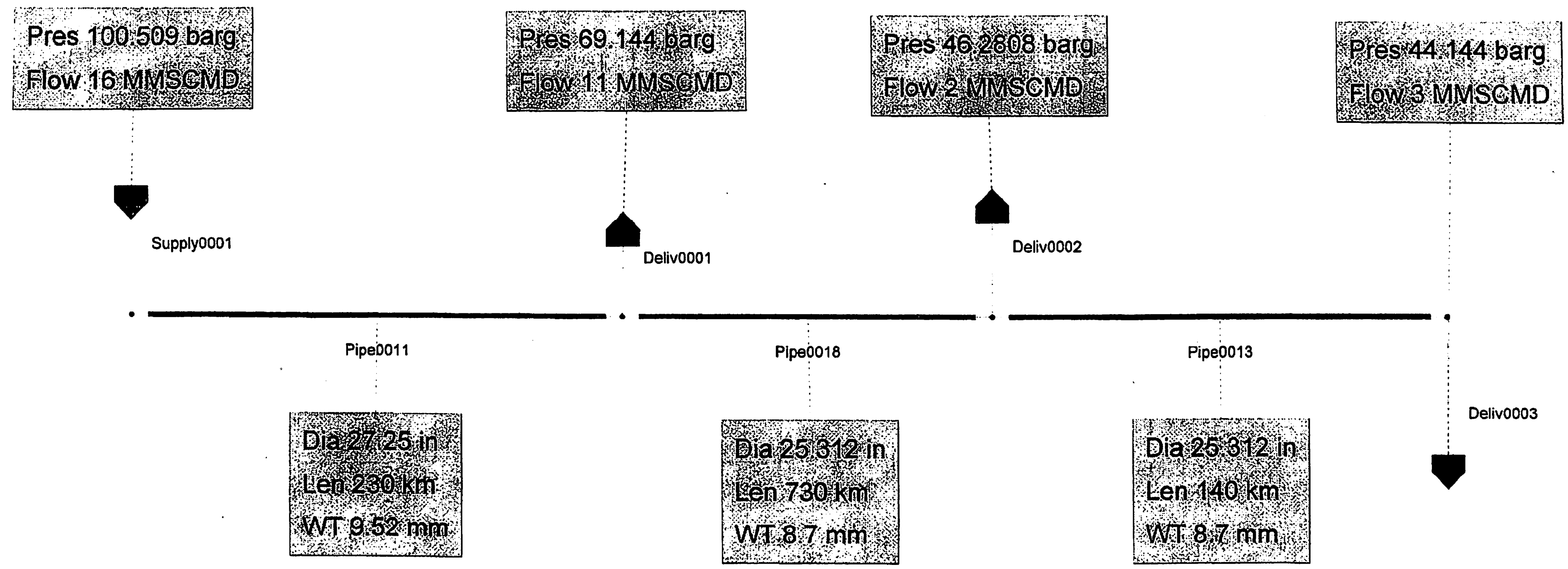
X60UnCoated

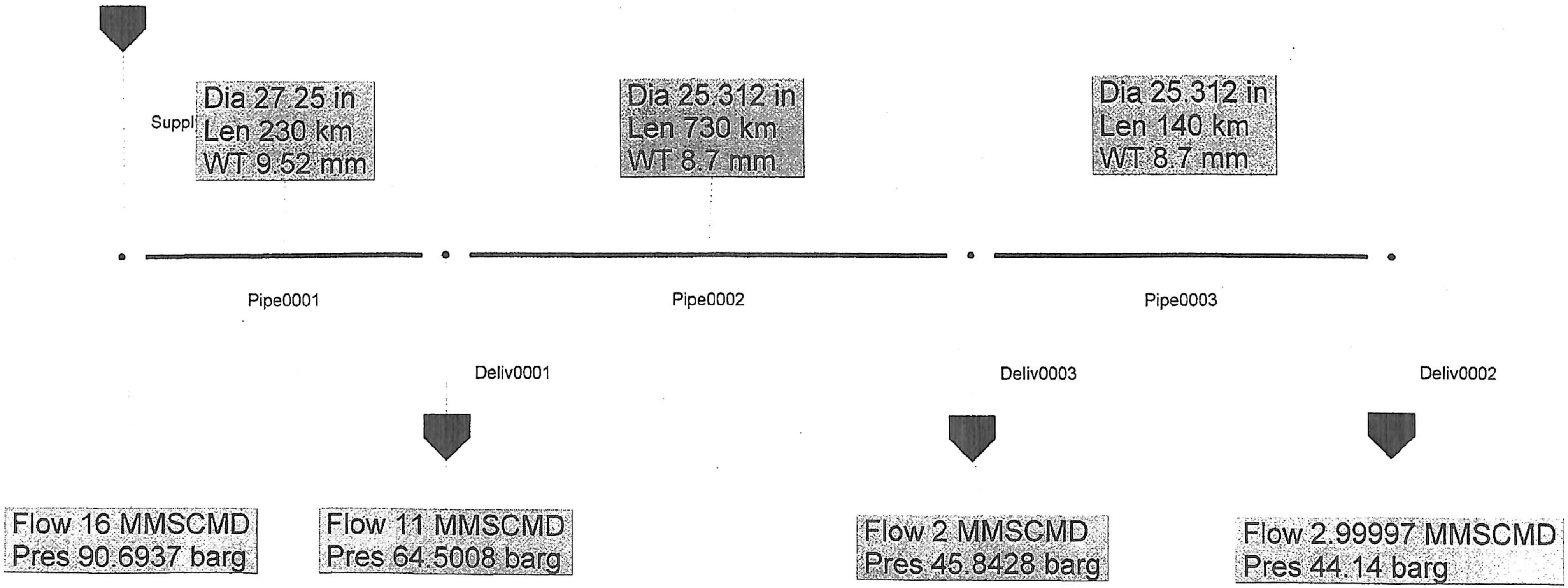


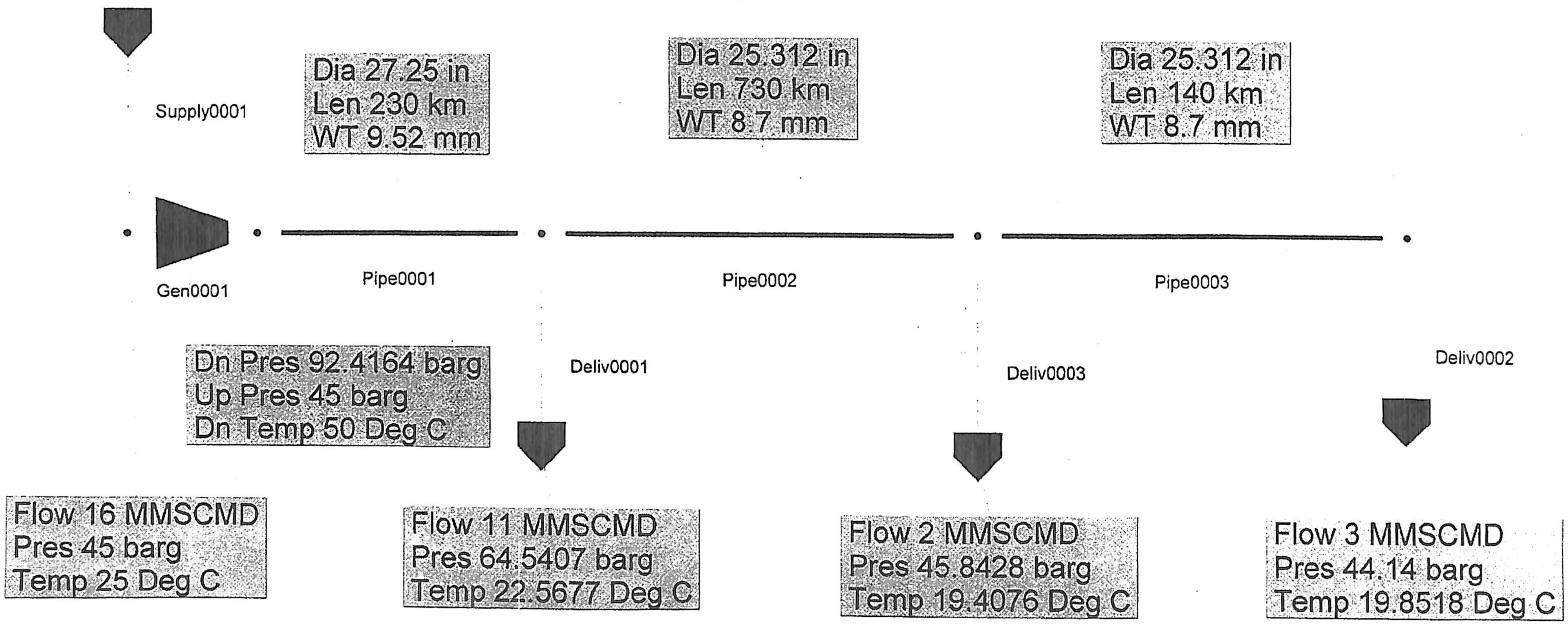
X70Coated


Pres 90.6038 barg
Flow 16 MMSCMD
Supply0001
Pres 64.7517 barg
Flow 11 MMSCMD
Deliv0001
Pres 45.8923 barg
Flow 2 MMSCMD
Deliv0002
Pres 44.144 barg
Flow 3.00001 MMSCMD
Deliv0003
Pipe0011
Dia 27.25 in
Len 230 km
WT 9.52 mm
Pipe0018
Dia 25.312 in
Len 730 km
WT 8.7 mm
Pipe0013
Dia 25.312 in
Len 140 km
WT 8.7 mm

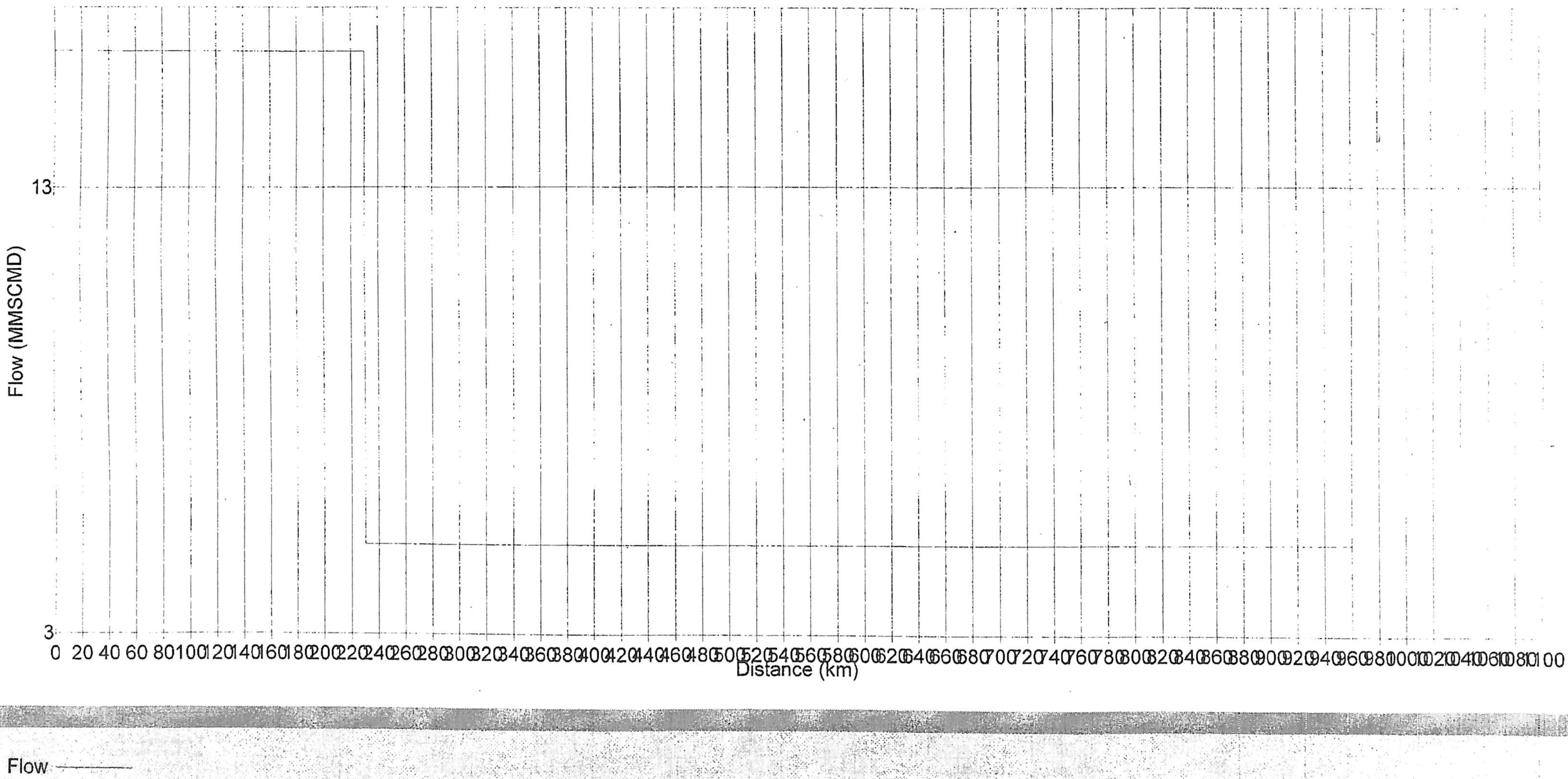
X70UnCoated



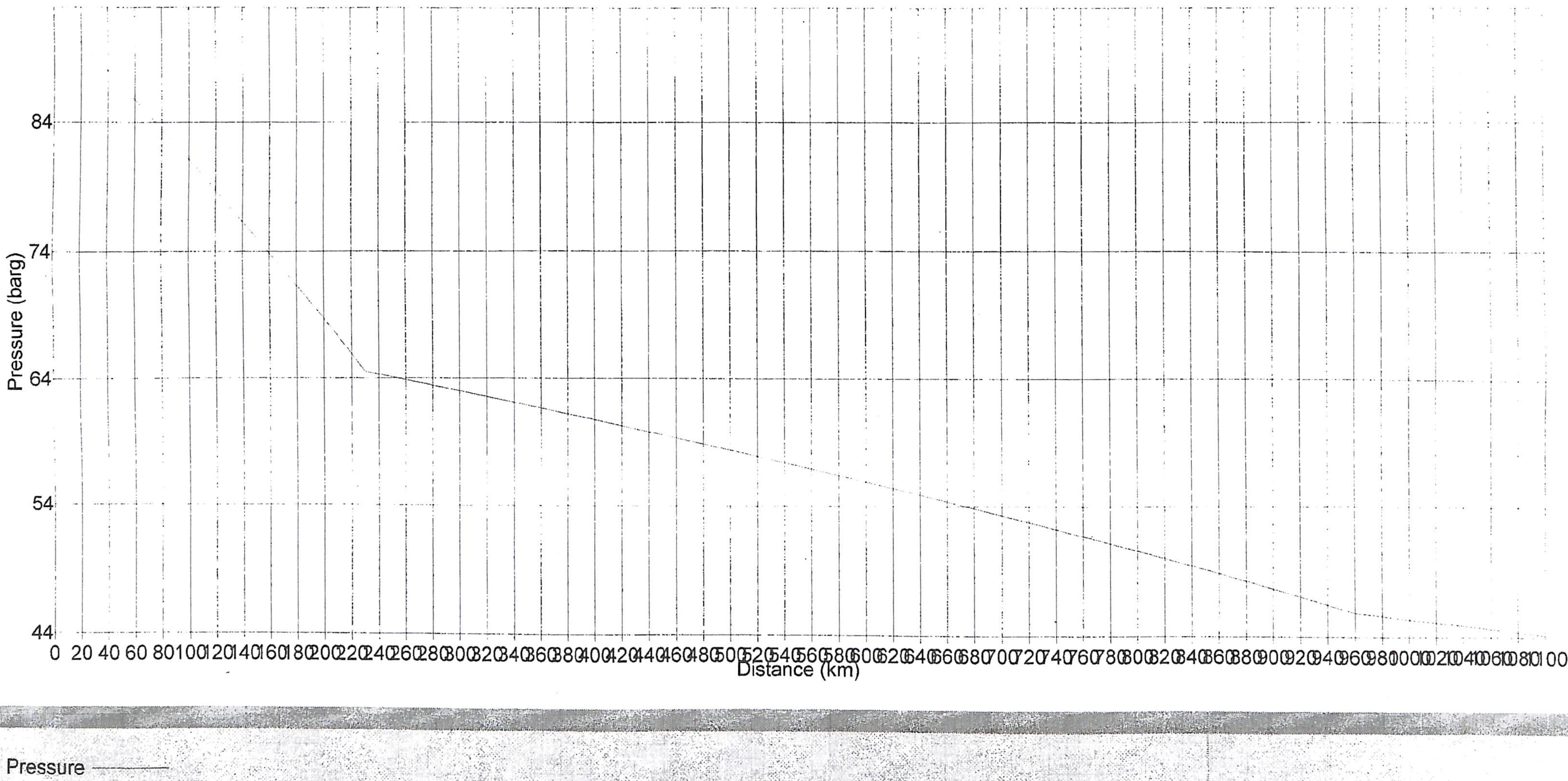

Suppl
Dia 27.25 in
Len 230 km
WT 9.52 mm
Dia 25.312 in
Len 730 km
WT 8.7 mm
Dia 25.312 in
Len 140 km
WT 8.7 mm
Pipe0001
Pipe0002
Pipe0003
Deliv0001
Deliv0003
Deliv0002
Flow 16 MMSCMD
Pres 90.6937 barg
Flow 11 MMSCMD
Pres 64.5008 barg
Flow 2 MMSCMD
Pres 45.8428 barg
Flow 2.99997 MMSCMD
Pres 44.14 barg


Supply0001
Dia 27.25 in
Len 230 km
WT 9.52 mm
Dia 25.312 in
Len 730 km
WT 8.7 mm
Dia 25.312 in
Len 140 km
WT 8.7 mm
Gen0001
Pipe0001
Pipe0002
Pipe0003
Dn Pres 92.4164 barg
Up Pres 45 barg
Dn Temp 50 Deg C
Deliv0001
Deliv0003
Deliv0002
Flow 16 MMSCMD
Pres 45 barg
Temp 25 Deg C
Flow 11 MMSCMD
Pres 64.5407 barg
Temp 22.5677 Deg C
Flow 2 MMSCMD
Pres 45.8428 barg
Temp 19.4076 Deg C
Flow 3 MMSCMD
Pres 44.14 barg
Temp 19.8518 Deg C

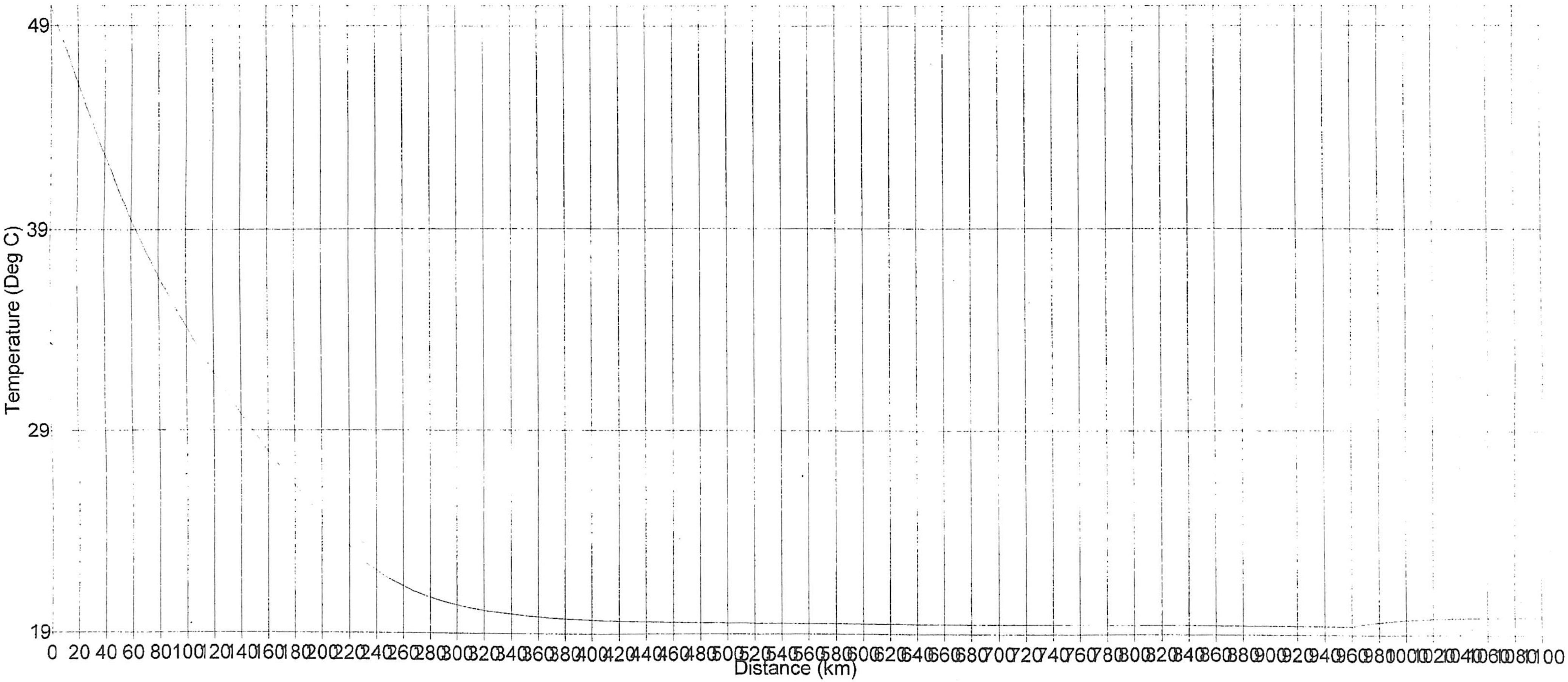
Flow Profile



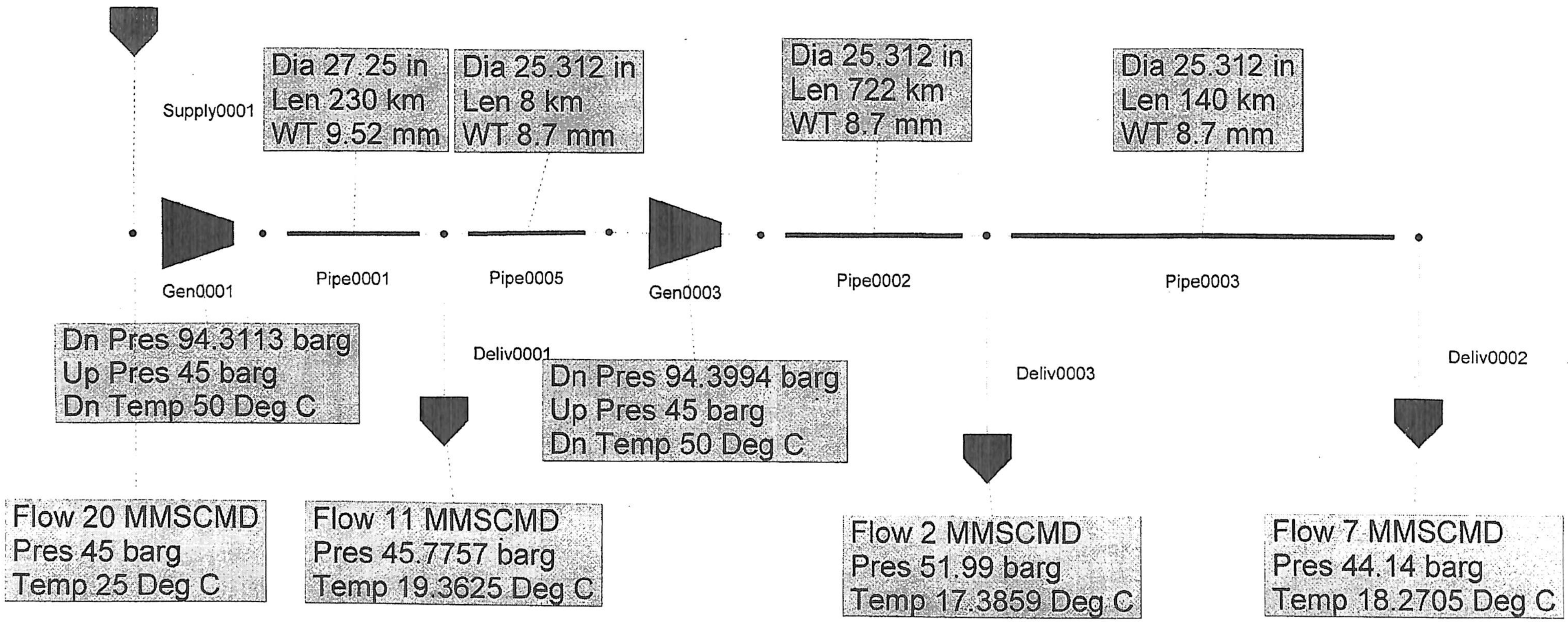
Pressure Profile

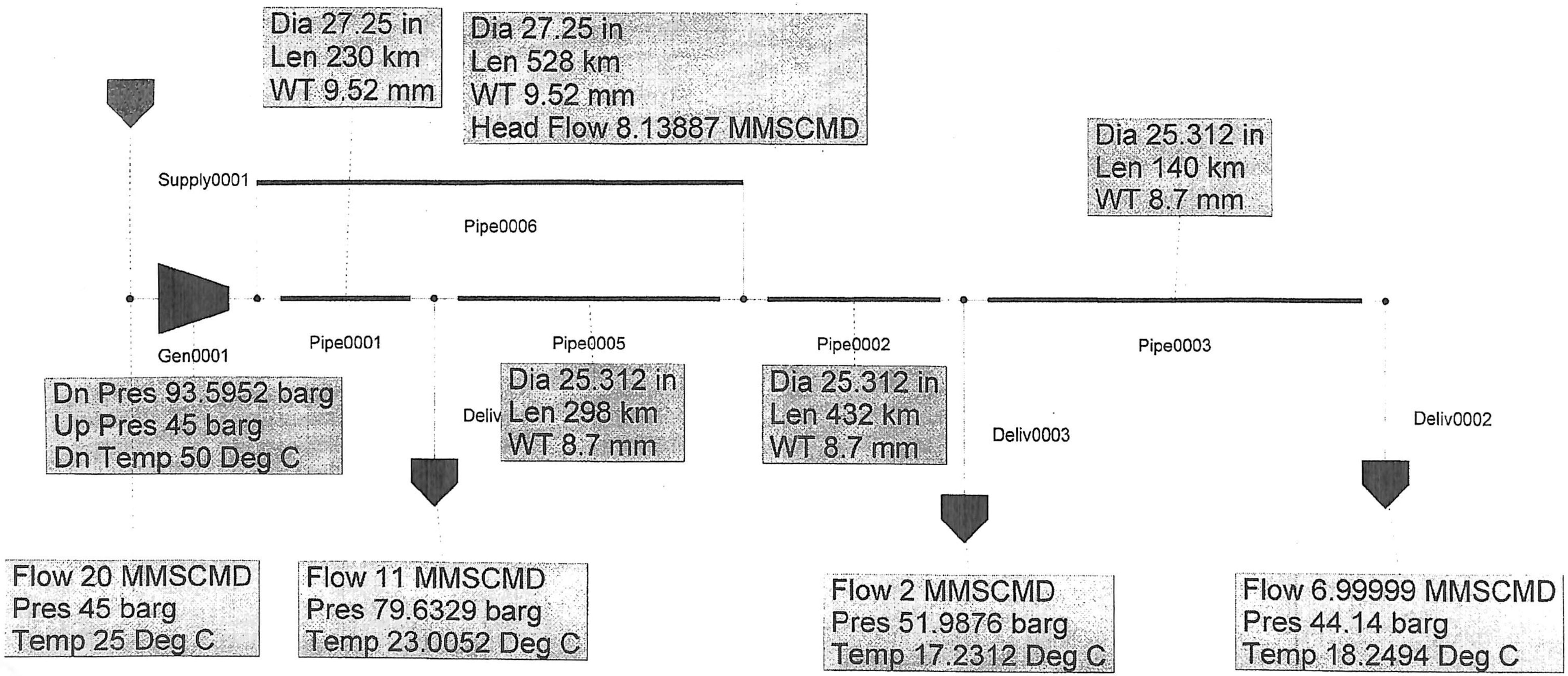


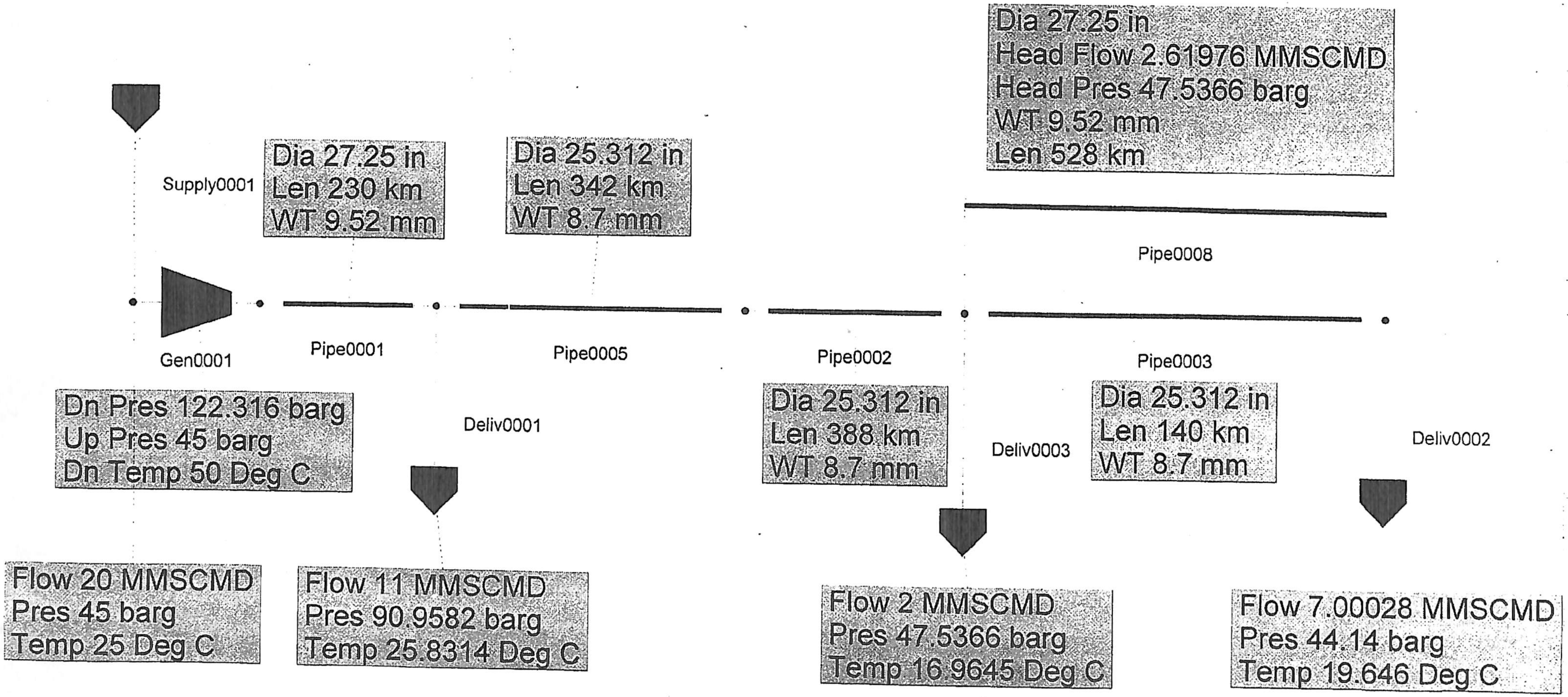
Temperature Profile



Temperature


Supply0001
Dia 27.25 in
Len 230 km
WT 9.52 mm
Dia 25.312 in
Len 8 km
WT 8.7 mm
Dia 25.312 in
Len 722 km
WT 8.7 mm
Dia 25.312 in
Len 140 km
WT 8.7 mm
Gen0001
Pipe0001
Pipe0005
Gen0003
Pipe0002
Pipe0003
Dn Pres 94.3113 barg
Up Pres 45 barg
Dn Temp 50 Deg C
Deliv0001
Dn Pres 94.3994 barg
Up Pres 45 barg
Dn Temp 50 Deg C
Deliv0003
Deliv0002
Flow 20 MMSCMD
Pres 45 barg
Temp 25 Deg C
Flow 11 MMSCMD
Pres 45.7757 barg
Temp 19.3625 Deg C
Flow 2 MMSCMD
Pres 51.99 barg
Temp 17.3859 Deg C
Flow 7 MMSCMD
Pres 44.14 barg
Temp 18.2705 Deg C


Dia 27.25 in
Len 230 km
WT 9.52 mm
Dia 27.25 in
Len 528 km
WT 9.52 mm
Head Flow 8.13887 MMSCMD
Dia 25.312 in
Len 140 km
WT 8.7 mm
Supply0001
Pipe0006
Gen0001
Pipe0001
Pipe0005
Pipe0002
Pipe0003
Dn Pres 93.5952 barg
Up Pres 45 barg
Dn Temp 50 Deg C
Deliv
Dia 25.312 in
Len 298 km
WT 8.7 mm
Dia 25.312 in
Len 432 km
WT 8.7 mm
Deliv0003
Deliv0002
Flow 20 MMSCMD
Pres 45 barg
Temp 25 Deg C
Flow 11 MMSCMD
Pres 79.6329 barg
Temp 23.0052 Deg C
Flow 2 MMSCMD
Pres 51.9876 barg
Temp 17.2312 Deg C
Flow 6.99999 MMSCMD
Pres 44.14 barg
Temp 18.2494 Deg C



Dia 27.25 in
Head Flow 2.61976 MMSCMD
Head Pres 47.5366 barg
WT 9.52 mm
Len 528 km
Supply0001
Dia 27.25 in
Len 230 km
WT 9.52 mm
Dia 25.312 in
Len 342 km
WT 8.7 mm
Pipe0008
Gen0001
Pipe0001
Pipe0005
Pipe0002
Pipe0003
Dn Pres 122.316 barg
Up Pres 45 barg
Dn Temp 50 Deg C
Deliv0001
Dia 25.312 in
Len 388 km
WT 8.7 mm
Deliv0003
Dia 25.312 in
Len 140 km
WT 8.7 mm
Deliv0002
Flow 20 MMSCMD
Pres 45 barg
Temp 25 Deg C
Flow 11 MMSCMD
Pres 90.9582 barg
Temp 25.8314 Deg C
Flow 2 MMSCMD
Pres 47.5366 barg
Temp 16.9645 Deg C
Flow 7.00028 MMSCMD
Pres 44.14 barg
Temp 19.646 Deg C