Pipeline Construction

IN ACCORDANCE TO FDP PROGRAM

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Notation scheme

α symbol represents SHALL[PS]: mandatory requirement with Process Safety.

β symbol represents SHALL: mandatory requirement without [PS].

γ symbol represents "should": a recommendation

If neither α, β or γ is mentioned, then the procedure is merely permitted.

$\therefore$ symbol indicates that the subject shall be clarified in the coming slides; otherwise, there will be no further clarification.

References (Ver. Freeze)

Document Reference	Name	Revision
SP-1208	Pipeline Construction Specification	6.0
SP-1211	Onshore Pipeline Engineering	6.0
SP-1212	Hydrostatic Pressure Testing Of New Pipelines	5.0
SP-2199	Design Class Selection	2.0
MBR-11-PDFEED-PX-7704-00001-0000	Mabrouk North East Development Project-FEED: 42TProcess Design Basis	3.0
MBR-16-105729-BA-3581-00007-0000	Method Statement For Final Hydro testing of Pipeline section	5.0
MBR-16-105729-BA-3581-00008-0000	Method Statement for Dewatering, Swabbing, Drying & Preservation of Pipeline	3.0
Test Pack No.: 21-PL-01-TP-01	Hydrostatic Test Package for DSS Pipeline 16 Inch – PL-5	-

Mabrouk North East Development Project

OBJECTIVE OF PROJECT

The major objectives of Mabrouk North East Development Project are as follows:

- To produce a 16 MMSCMD of gas with associated condensate and water from Mabrouk North East field in order to secure mid to long term gas supply.
  - MMSCMD ➔ Million Metric Standard Cubic Meter per Day
- Minimize development risks.

- 24” x 35 km – DSS Export Pipeline (Blue Line) – 1 line
- 16” x 31 km – DSS Trunk line (Red Line) - 6 lines
- 8” x 52 km – DSS Flowlines (Black Line) - 16 lines
- OHL - 27 Km – 33 KV from Mabrouk GIS

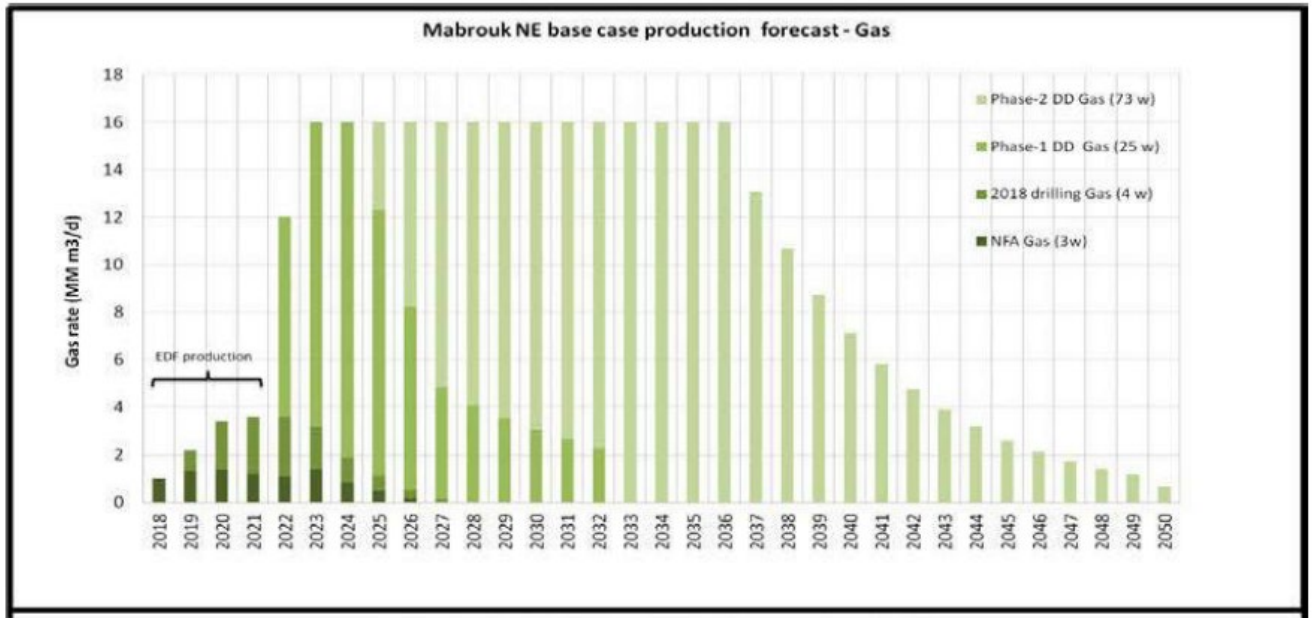
RMS-1
RMS-2
RMS-3
RMS-4
RMS-5
RMS-6
CEMS
SRCPP
24” Export Pipeline from CEMS to SRCPP (35 Km)
Saih Rawl Central Processing Plant

Cont.

Phases of project:

Phase-1 aims to bring the field on stream by 2022 and drilling total of 25 wells; (16 FEED; 9 GGE6 team)

Phase-2 of the project will start in 2024 by drilling 5-7 wells per year.



Cont.

Table 3-1: Summary of Design Capacities

Parameter	Design Capacities
Field production Gas rate MMSCMD	16.0
RMS 1/2/3/4 Gas Capacity MMSCMD (Each)	2.0
RMS 5/6 Gas Capacity MMSCMD (Each) (Design/Normal)	6.0/4.0
CGR, m3/MMSm3	290
WGR, m3/MMSm3(Max/Min)	40/10
Per Well production Gas rate MMSCMD (Test separator design gas rate required)	0.8

CGR Condensate Gas Ratio

WGR Water to Gas ratio

Table 1-1: MBRNE RMSs Details

Facility	Project Scope no. of slots	Project Scope No of Well Hook Up	Distance from common Export Manifold (km)	Test separator	IA skid	Remark
RMS-1	6	1	10.6	Future	Future	Actuated changeover valves with handwheel to be provided. Drain pit and vent system to be designed considering future test separator. Plot space to be considered for future slots/Test separator /IA skids in each RMS
RMS-2	12	2	5.4	Future	Future	
RMS-3	6	1	6.5	Future	Future	
RMS-4	12	2	2.3	Future	Future	
RMS-5	12	5	5.5	Project scope		IA to be considered for future slots/test separator.
RMS-6	12	5	8.4			
Common export Manifold	6	4(Production headers from RMS1/2/3/4/5/6)	34.9 (From SRCPP)	Not Applicable		Piping spool to be provided for future Depletion compressor

IA Instrument Air

CODES AND STANDARDS

PL (Policy) - Statement of PDO's attitude in response to a business need – provides the course of action stating intentions and principles – Mandatory

CP (Code of Practice) - Translates a policy into practical activities to be executed repeatedly - Provides rules and an overview of the required Procedures & Guidelines – Mandatory

SP (Specification) - Prescribes requirements to be fulfilled by a product, process or service in line with a Code of Practice - Provides rules and an overview of the required Procedures & Guidelines. DEM1 denotes that the SP contains AI-PSM elements – Mandatory

PR (Procedure) - Formal description for executing an activity to achieve a result in accordance with the specification - Describes the purpose & scope of an activity and the specific way the activity is to be performed to achieve a satisfactory result – Mandatory

Cont.

DEP (Shell Design & Engineering Practice) - Sets the recommended standard for good design and engineering practice and thereby achieves maximum technical and economic benefit from standardization. DEM1 denotes that the DEP contains AIPSM elements – Mandatory when DEP is specified. **DEP version 42** shall be used in FEED.

Materials Handling

According to SP-1208 Sec.2.3.4 :

Pipe shall not be allowed to **drop or strike** objects which may **damage** the **pipe** and/or **coating** but shall be lifted, moved and lowered from one position to another by suitable equipment.

For **lifting**, **non-abrasive wide nylon pipe slings** or special lifting hooks equipped with a non-metallic bevel protectors curved to fit the curvature.

Pipes shall be protected against **truck beds** and side metallic posts by means of non-metallic soft materials.

Pipe ends should have **non-metallic endcap** to avoid any contaminant [entrance] from external sources (such as sand, water, salt, solids).

Cont.

According to SP-1208 Sec.2.3.5 [β] :

Ground surfaces to be used for stacking of pipe shall be **reasonably flat**.

Stacked pipes shall be raised above ground surfaces and prevented from movement by **berms of screened sand** covered by **polyethylene sheeting** or by using **timber** covered with non-metallic soft materials.

The bottom layer of pipes shall be **wedged or clipped**.

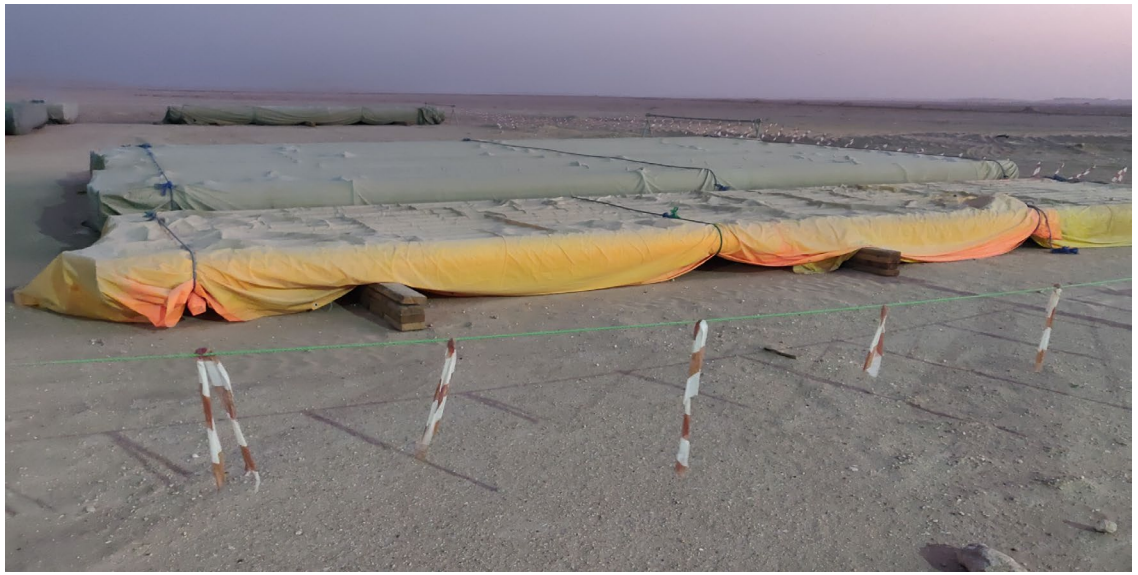
Pipes of different **diameter**, **wall thickness**, **grade** or **manufacturer** shall be stacked separately, and shall be marked.

All **externally coated** pipes shall be stacked during transport and storage using **rubber**.

Pipes shall not be stacked higher than **3.5 m**.

Pipes shall be stacked in such a way that **no water is retained inside the pipe** during storage.

Wedged pipes stack



Pipeline routing: 1. Survey

The surveyor uses an original benchmark (x,y,z)

The original point will be used as datum for:

- Other benchmarks (off-construction site)
- Other benchmarks for each construction site

The surveyors utilize surveying equipment and PDO Earth.

Cont. Survey

In accordance to SP-1211 sec. 4.2.2 the following data should be obtained and considered:

1. Population and building densities.
2. Topographical data.
3. Records of any existing special features.
4. Soil investigation for foundation design.
5. Soil resistively for cathodic protection design.
6. Environmental data.
7. Existing facilities and CP systems.
8. Buried pipelines and cables.
9. Over head high voltage power lines.

Cont. Survey

According to SP-1208 Sec. 2.4.1.2 :

The Company shall survey the route for the pipeline and prepare route maps from which the centerline of the pipeline shall be staked out.

The construction survey shall adopt the same marks and benchmarks as used in the Engineering design unless otherwise approved by the Company.

Pipeline routing: 2. Classifications

Classifications:

A. Fluid categories.
B. Location classifications.
C. Criticality classifications.
D. Design classifications.
E. Wadies classifications.
F. Health and safety consequences classifications.

Cont. [A] Fluid Categories Classes

Fluid Categories as per ASME codes (SP-1211 Sec. 2.1):

A. **Non-flammable water-based fluids**. Example: water, (as in water injection / disposal / supply lines).

B. **Flammable fluids** that are liquids at ambient temperature and at atmospheric pressure conditions [STP]. Example: stabilized crude oil (such as **M**ain **O**il **L**ine).

C. **Flammable multiphase liquids**. Example: unstabilised crude (as in interfield headers / pipelines) and crude (as in flowlines).

D. **Flammable multiphase** fluid which are **gases** at [STP] ambient temperature and atmospheric pressure conditions (such as gas flowlines / pipelines, Gas lift network lines, export natural gas lines, etc.).
   - # Liquid petroleum gas and anhydrous ammonia

E. **Critical sour fluids** as defined by SP-1190-1.

Design codes as per fluid classification:
- Categories A, B, and # ➔ASME B31.4 + SPs.
- Categories C,D, and E ➔ ASME B31.8 + SPs.

Cont. [B] Location Class

Location Class is an onshore area that extends **¼ mile** (400 meters) zone along to pipeline route with pipeline route centered along the zone for continuous 1-mile (1.6 kilometers) of pipeline length.

Location classes as per B31.8:

1. **Location Class 1 (MBR)**: It is any 1-mile (1.6-km) section that has $\leq \mathbf{10}$ buildings intended for human occupancy.
2. **Location Class 2 (MBR)**: It is any 1-mile (1.6-km) section that has $\mathbf{10} < \boldsymbol{Buildings} < \mathbf{46}$ intended for human occupancy.
3. **Location Class 3**: It is any 1-mile (1.6-km) section that has $\geq \mathbf{46}$ buildings intended for human occupancy except when a Location Class 4 prevails.
4. **Location Class 4**: It includes areas where **multistory** $(\geq \mathbf{4}\ \boldsymbol{floors})$ buildings are prevalent, where **traffic is heavy** or dense, and where there may be **numerous other utilities underground**.

Cont. [C] Criticality Class; SP-1211

As Per SP-1211 Sec. 3.4/4.5/:
Pipeline criticality is related to the risks as the combination of two parameters namely**, susceptibility to failure** and **consequence of failure**.

Dependent on risk matrix (See [F])

Gas flowlines from gas wells SHALL [PS] not be installed aboveground.

Class 2 and Class 3 pipelines may be installed above ground.

Pipeline criticality class	Class – 1 Div. 2
Pipeline location class	Class – 1 & 2

Table A1.1 – Pipeline Classification based on Risk Assessment Matrix

		SUSCEPTIBILITY TO FAILURE	PIPELINE CRITICALITY CLASS			
SUSCEPTIBILITY CLASS	H	Very susceptible to degradation	CLASS 2	CLASS 1	UNACCEPTABLE	UNACCEPTABLE
	M	Susceptible to degradation under normal conditions	CLASS 2	CLASS 1	CLASS 1	UNACCEPTABLE
	L	Susceptible to degradation under upset conditions	CLASS 3	CLASS 2	CLASS 1	CLASS 1
	N	Not susceptible under any foreseen conditions	CLASS 3	CLASS 3	CLASS 2	CLASS 1
CONSEQUENCE CATEGORY		Economic value (USD)	<100K	0.1 – 1 M	1 – 10 M	> 10 M
		Health and Safety	Minor Injury	Major Injury	Permanent total disability OR upto three fatalities	More than three fatality
		Environment	Minor Effect	Localised Effect	Major Effect	Massive Effect
CONSEQUENCE CLASS			L	M	H	E

Cont.

A.1.2. Susceptibility to Failure Classification

The following predominant failure modes that are relevant to PDO operations are considered:

- Internal corrosion
- External corrosion
- Corrosion Cracking (SSC, SCC, HIC, SOHIC)
- Third party damage
- Mechanical/construction damage

Table A1.2 - Susceptibility to failure Classification for Various Materials

MATERIAL	INTERNAL CORROSION	EXTERNAL CORROSION	CORROSION CRACKING	THIRD PARTY DAMAGE	MECHANICAL & CONSTRUCTION DAMAGE
Duplex SS	Class N	Class L	Class L	Class L or N	Class L

Cont. [D] Design Class

As per SP-2199 Sec. 3.3 :

There are 3 different Design Classes used to describe the levels of capability in each of the performance categories:

Class 1 – Minimum cost and minimum flexibility.

Class 2 – Intermediate in flexibility and cost.

Class 3 – Maximum flexibility, highest cost.

3.5 Plant Availability and Sparing

As per Define Phase Design Class Workshop conducted as a part of FEED scope Ref.[4]:

- The project facilities are classified as satellite facilities (Class 1) which sets an availability target in the range of 85 – 90% as per SP-2199.

		Design Classes		
		Design Class 1	Design Class 2	Design Class 3
Performance Categories	Design capacity	No margin	10% margin	20% margin
	Expandability	None	Plot space	Tie-ins / Sized for future
	Capacity Utilization (Availability)	85 - 90%	90 – 95%	> 95%
	Operability / Maintainability	• Minimum turndown capability • Not designed to handle feed variability • Designed to accommodate a narrow range of rate and composition uncertainty • Minimum flexibility for online maintenance – would require shutdown to maintain	• Some turndown capability provided • Selected units will have flexibility to handle feed variability • Designed to accommodate a limited range of rate and composition uncertainty • Some flexibility for online maintenance	• Significant turndown capability • All units will have flexibility to handle feed variability • Designed to accommodate a broad range of rate and composition uncertainty • Significant flexibility for online maintenance
	Energy Efficiency / Carbon Management	Minimum energy efficiency considerations	Energy efficiency designs implemented which meet PB guidelines economic assessment criteria	Best available technology implemented for energy efficiency

	Portfolio	Capacity	Capacity Utilization	Expandability	Energy Efficiency
	Class 1	No margin	85 - 90%	None	Minimum
	Class 2	10% margin	90 - 95%	Plot space	Meets PB guidelines
	Class 3	20% margin	> 95%	Tie-ins / sized for future	Best available technology
A	Oil satellite	Class 1	Class 1	Class 1	Class 1
B	Gas satellite	Class 1	Class 1	Class 2*	Class 1
C	Oil hub	Class 1	Class 2	Class 1	Class 2
D	Gas hub	Class 1	Class 3	Class 2*	Class 2
E	Steam system for EOR	Class 1	Class 2	Class 1	Class 2
F	Chemical system for EOR	Class 1	Class 1	Class 1	Class 2
G	Utilities (non HC)	Class 1	Class 3	Class 1	Class 2
H	Power plants	Class 1	Class 1 (plant) Class 3 (system)	Class 1	Class 3

Cont. [E] Wadis Classes

As per SP-1208 Sec. 2.9.3.3 :

Wadis may be classified based on judgement and careful evaluation of the crossing location with due consideration to wadi's width, bed slope, past discharge history and erosion potential at the crossing location.

1. **Type 'A'** wadis are those where **low velocity** flow is expected after heavy rains.
2. **Type 'B'** wadis are those where erosion due to **high velocity** flow is expected after heavy rains.
3. **Type 'C'** wadis are those where **heavy erosion** due to **high velocity flow** is expected after heavy rains combined with the existence of **large stones and boulders**.
4. **Type 'D'** wadis – for Type 'C' wadis, in case of **high H2S levels** (critical sour asper SP-1190) and MOL (Main Oil Line) / SOGL(South Oman Gas line) pipelines

Cont. [F] Health and Safety Consequence

Method Statement For Final Hydro testing of Pipeline section; pages 10/11:

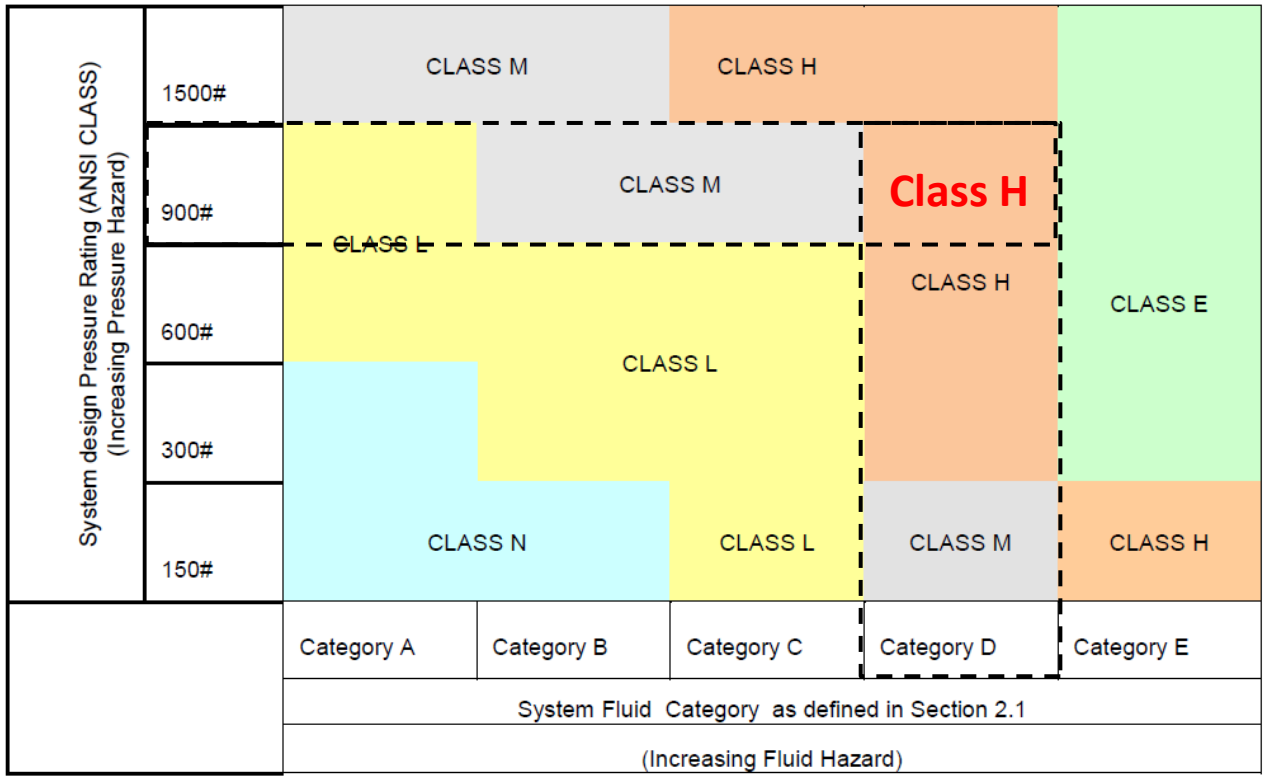
ASME/ANSI -Flange rating	900#
Pipeline material specification	DSS (Duplex Stainless Steel)

SP-1211 (Table A1.5):

H	Permanent total disability OR upto three fatalities	From an accident or occupational illness (poisoning, cancer).

D. Flammable multiphase fluid which are **gases**

Table A1.4 - Health and Safety Consequence Classification



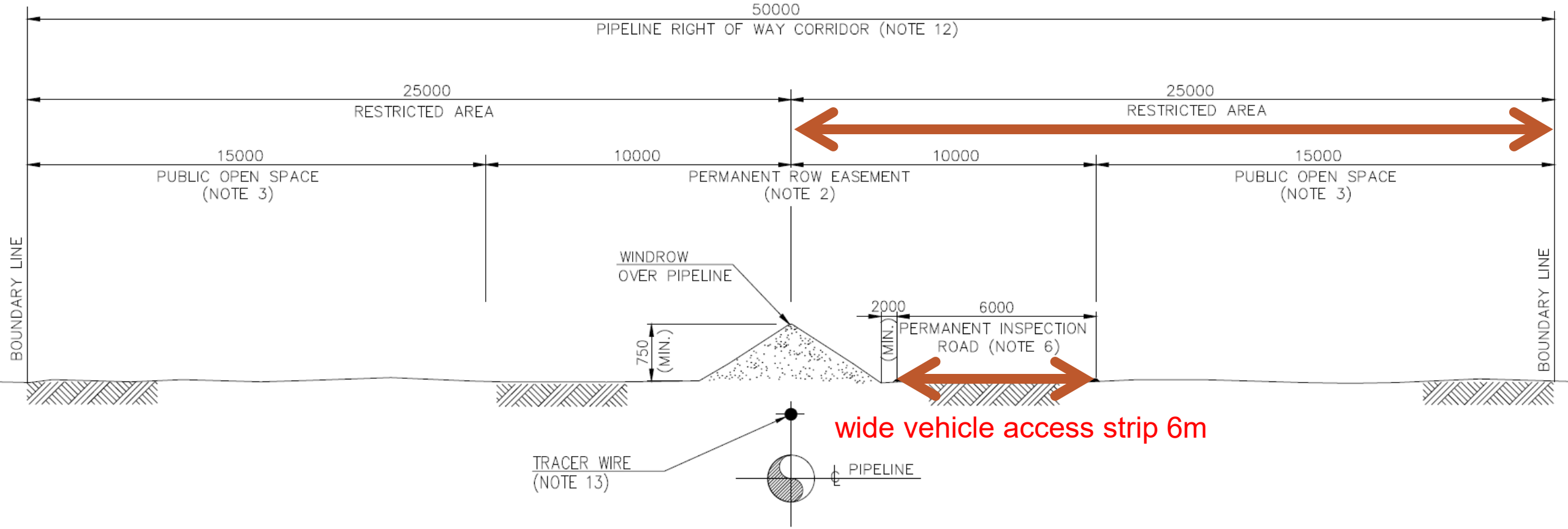
Pipeline routing: 3. ROW

According to SP-1208 Sec. 2.4.1.3 :

The Right-of-Way for the pipeline is a corridor of **50 meters** overall width.

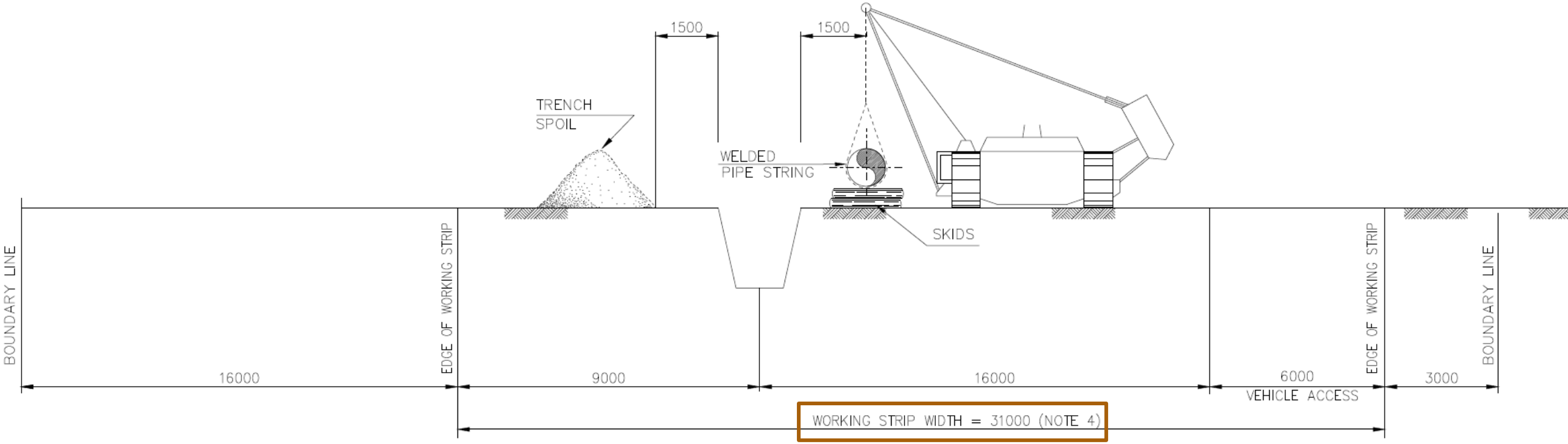
The "**Restricted Area**", a strip of land **25 meters wide** on either side of the pipeline measured from the centerline of the pipeline.

Contractor may make use of a **Working Strip**, having a width of **31 meters.**



wide vehicle access strip 6m

SP-1208 :TYP-3-0001-001



SP-1208 : TYP-3-0002-001

Cont.

According to SP-1208 Sec. 2.4.1.4 (Planning/Approvals) :

Contractor should notify the Company **7 days** in advance before start of work.

Work near live pipelines shall comply with the requirements of **GU-501.**

Pipeline routing: 4. Clearing and Grading

According to SP-1208 Sec. 2.4.2.2 (Definitions) :

‘Clearing’ shall mean but is not necessarily limited to the **cutting and disposal** of **trees**, **farm crops**, *bushes* and **undergrowth**

‘Grading’ shall mean but is not necessarily limited to **removal and disposal** of **rock**, **sand dunes**, **tree stumps** and **roots**.

‘Point of Intersection’ [PI] shall mean a point in which the **centerline of the straight sections** of the pipeline route **changes direction in the horizontal plane**. In general such a point will be outside the actual pipeline centerline because of the bending radius to be applied.

Cont.

According to SP-1208 Sec. 2.4.2.5 :

The Working Strip **should be cleared over its entire width**, **unless restricted** by the terrain or other features shown on the drawings. Contractor shall carry out all operations within the limits of the Working Strip and **shall not operate within 25 meters from existing pipelines without** Company **approval**.

According to SP-1208 Sec. 2.4.2.7 :

Contractor shall **grade off high points** and **fill low points** to allow the pipe to be bent and laid within the limits set forth herein with due regard to the minimum radius of bends allowed and **shall drill, blast, and excavate rock or other material which cannot be graded off** with ordinary grading equipment.

Pipeline routing: Stacking

According to SP-1208 Sec. 2.4.2.3 :

The centerline of the pipeline shall be staked by the Contractor with **markers** [bury] **visible by binoculars** or **survey equipment**.

- Reference markers are established at the Points of Intersection, perpendicular to the previous pipeline direction, at 25 meter steps from the pipeline centerline.
- The markers are angle-iron profiles or wooden posts with sequential numbers, starting with no. 1 at start point of the pipeline.

Markers in the **centerline of the pipeline at distances of maximum 100** meters for straight line sections and **maximum 10 meters for horizontal bends**, but in any case **not less than one at the center of every bend**.

Two construction markers shall be installed **at every existing marker location** or at **least every 500 meters** except where these have already been provided at Points of Intersection.

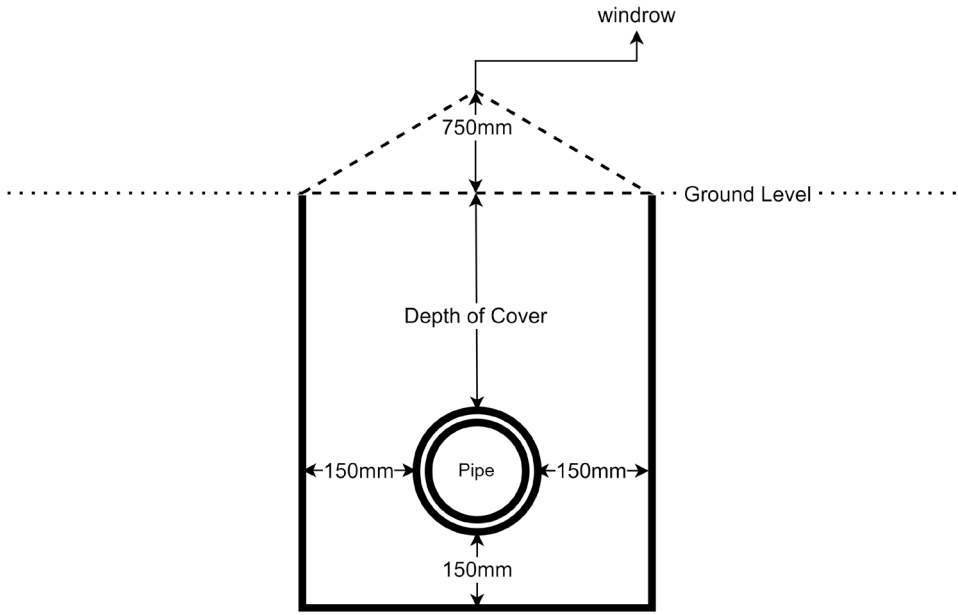
The distance from **construction marker to pipeline centerline shall be 25 meters** wherever possible.

Pipeline routing: 5. Trenching

According to SP-1211 Sec. 4.5 (table 3):

TABLE 3 RECOMMENDED MINIMUM COVER FOR ONSHORE PIPELINES

LOCATION CLASS (as defined in ASME B 31.8)	MINIMUM COVER (M) (Note 1)	
	IN NORMAL GROUND	IN ROCK, REQUIRING BLASTING OR ROCK CUTTING (note 4)
Location Class 1	0.6	0.50
Location Class 2	0.90	0.60
Location Class 3, 4 and Flood Plain	1.2	0.90
Public and private roads, Wadi, live stock passage crossings	1.50	1.50



Minimum depth of cover shall be measured from the top of the pipe the top of the undisturbed surface of the soil or top of graded Working Strip whichever is smallest.

Cont.

In areas where the **risk** of interference by mechanical excavators is high, **a warning tape** should be installed in the trench above the pipeline to further lower the risk.

According to SP-1208 Sec. 2.4.2.4 :

Trenching or other excavation within **2m from any underground services** shall be by **hand** only.

According to SP-1208 Sec. 2.4.3.3 :

Blasting classification

1. More that 50m
2. Less than 50m and more than 20m
3. Less than 20m

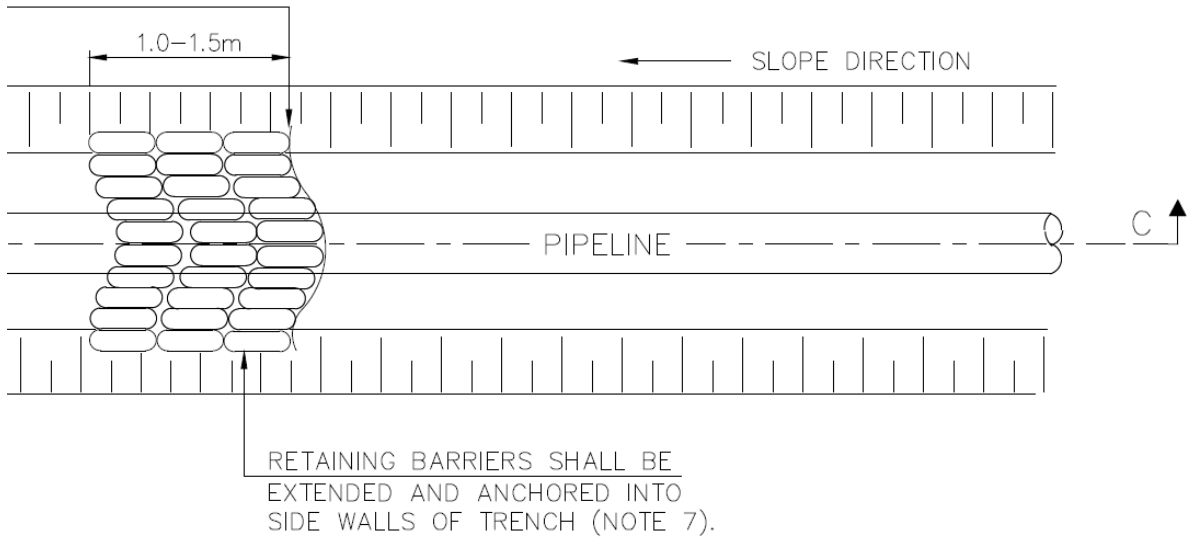
Cont.

For depth of cover purposes, rock in trench is defined as the rocky part of the specified trench which cannot be removed by ditching machines, rock plough, back hoe or ripper, to be decided after two passes of a D9 Caterpiller tractor.

Cont.

Trenches having a longitudinal slope of more than 10% shall be provided with structures or retaining barrier(s)

TABLE RETAINING BARRIER SPACING	
SLOPE %	SPACING C/C L1 m
< 10	NIL
> 10 ≤ 35	60–48m
> 35 ≤ 60	48–36m
> 60 ≤ 80	36–24m
> 80 ≤ 100	24–16m



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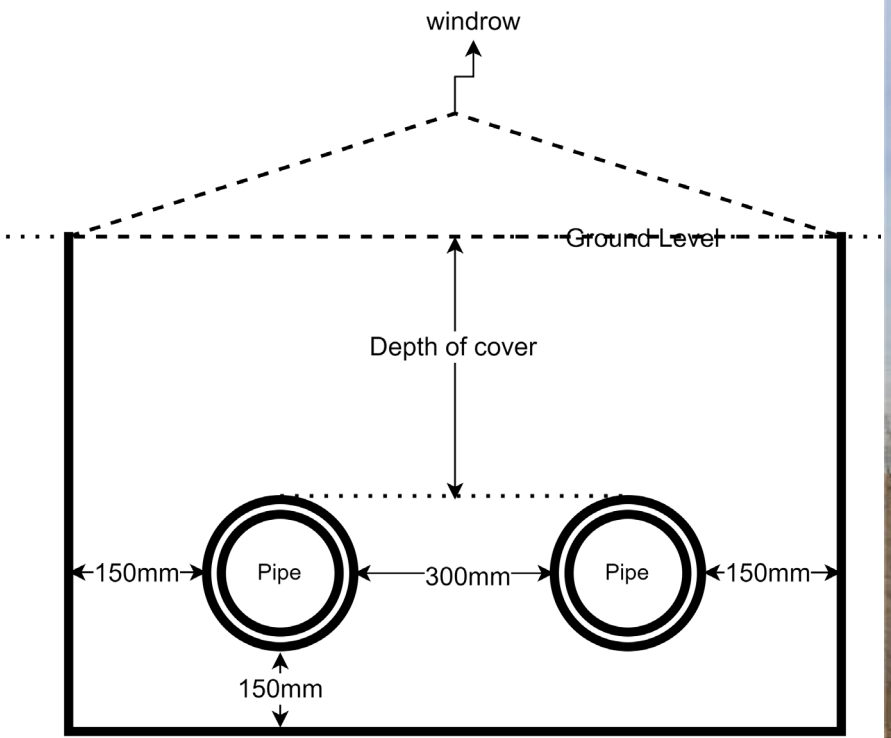
windrow
Ground Level
Depth of cover
150mm
Pipe
300mm
Pipe
150mm
150mm


HIGH PERFORMANCE
- finer dug material and faster backfilling
- high precision and clean trenches
LOW IMPACT ON ENVIRONMENT
- minimum volumes of removed material
- minimum collateral damages
LOW POLLUTION
- less machines on job site
- Tier4 f standard
MANY SOILS
- digging attachments suitable for soils from dirt to hard rock
SAFE
- operator's protection
- no blasting
- no swinging arms
HIGH EFFICIENCY
- same volume dug with less machines
- easier job site management

Pipeline routing: 6. Stringing

All the pipes and the parts arranged in the sequence as they labeled from manufacture to ease identifying and retrieving defect parts should they occur.

According to SP-1208 Sec. 2.5.2 :

No pipe shall be strung before the trench is excavated to full depth.

Pipe shall not be placed directly on the ground but on wooden skids with proper protective padding or sand bags.

Dragging, skidding or dropping of the pipe is not permitted.

Length of individual pipe strings should not exceed **1 km**.

Bending

Cold bend is the process of bending pipes on site utilizing “bending machine” without heating.

Procedure:

1. AFC shall specify the locations where the cold bend shall be preformed.
2. Preform the calculations in accordance to SP-1211 Sec.4.3.8. **[∵]**
3. Marking the bend center and steps of bend.
4. Inserting the marked pipe into bending machine over the rolling rack.
5. Inserting the mandrel and locating at the bending step, and expanding it.
6. Press (bending force)
7. Relief mandrel from pneumatic pressure and move into next step using side crane. Bending angel shall be verified intermittently.
8. Check visually for any coating damage, wrinkles, and ripples.
9. Preform gauging test. If it fails gauging test, the pipe considered defected and shall be replaced.

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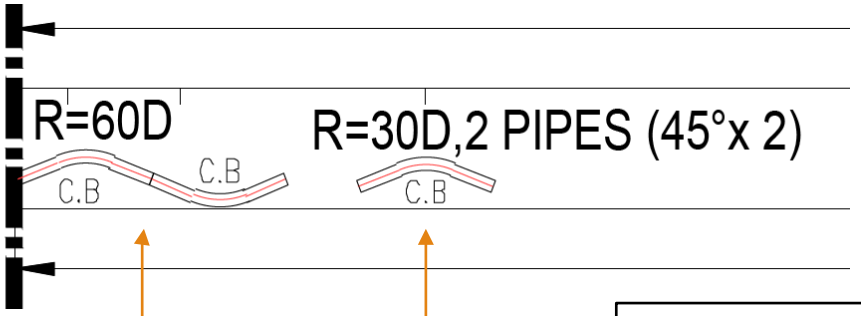
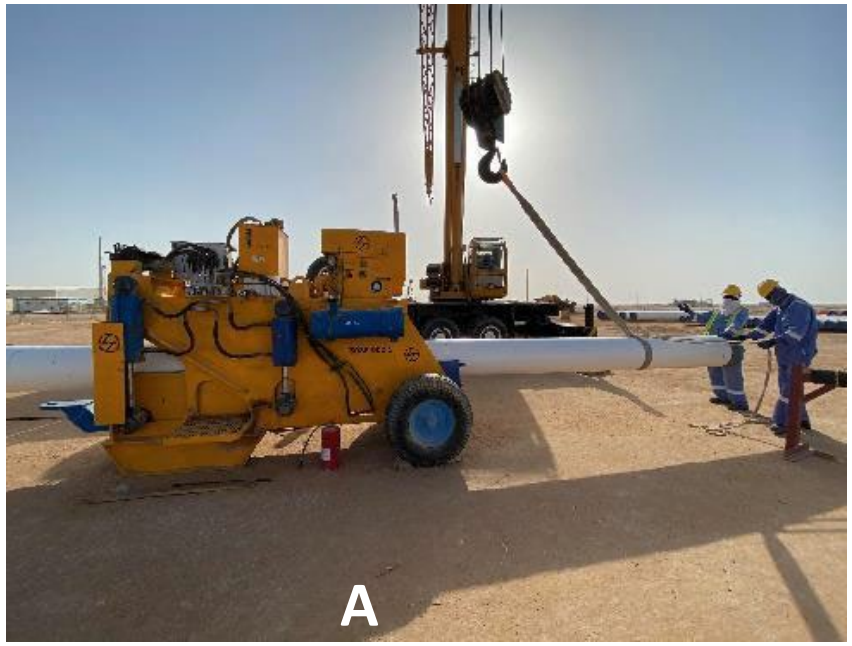
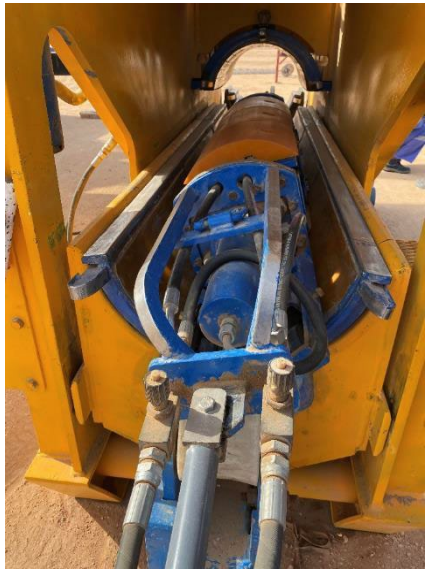


AFC alignment sheet: radii 60D, 2 pipes, 2 bending locations; one on each pipe

AFC alignment sheet: radii 30D, 2 pipes with 45˚degree angle, 2 bending locations; one on each pipe



A➔ Bending machine
B➔ Neutral axis
C➔ Steps marks
D➔ Mandrel insertion



A

B

C

D

E

F

A➔ Mandrel: a tool inserted inside the pipe to prevent ovalities, and it operates using hydraulic force.
B➔ Bending machine.
C➔ Crane.
D➔ Abney level: non-digital degrees measurement tool.
E➔ Protractor: measures the angle automatically without the user having to read it from a scale.
F➔ Gauge: a tool to verify the absence of ovalities and defects in the bend.

Cont.

In general, the minimum bending radii should not be less than:

- 25 D for pipe NPS of less than 8”
- 30 D for pipe NPS of 8” to 16”
- 40 D for pipe NPS of over 16”

Pipe outer diameter

$$D := 16\ \text{in}$$

Degrees in (θ)D

$$\theta := 60\ \text{deg}$$

Step length per dgree (S)

$$S := \left|\theta \cdot D\right| = 0.4256\ \text{m}$$

Step length per 1/2 degree (s, 1/2 deg)

$$S_{.5} := \frac{S}{2} = 0.2128\ \text{m}$$

Degrees of bending

$$Degree := 90\ \text{deg}$$

Bend length needed

$$B := S \cdot \frac{Degree}{1\ \text{deg}} = 38.3023\ \text{m}$$

Length of the pipe

$$L_p := 11.750\ \text{m}$$

Spool Length

$$Spool := L_p - 2\ \text{m} - 2\ \text{m} = 7.75\ \text{m}$$

Number of steps

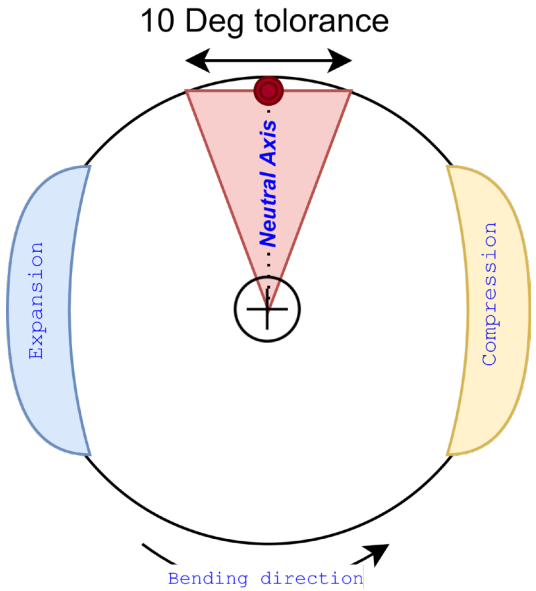
$$DPP := \frac{Spool}{S} = 18.2104$$

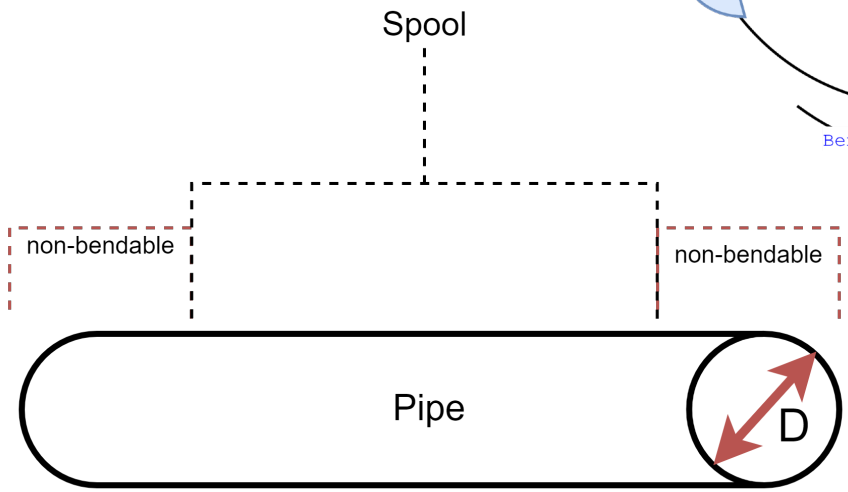
Number of pipes

$$NOP := \frac{B}{Spool} = 4.9422$$

Round number of pipes to a natural number

$$\text{round}\left(NOP,\ 0\right) = 5$$





Cont.

See Graphical User Interface GUI in appendix 1

Bend thinning calculations shall be performed. Recommended formula for calculating bend thinning is as below.

bend thinning % = 50/(n+1)%

t_b = (1-bend thinning) x t

where,

t= nominal thickness.

n= inner bend radius/pipe outer diameter.

t_b = pipe wall thickness after bending.

ε: Bending strain in outer fibre

$$\varepsilon := \frac{D}{\frac{2 \cdot \theta \cdot D}{\text{deg}}} = 0.0083$$

t: nominal thickness

$$t := 10.5 \text{ mm}$$

Inner bend radius

$$R_i := \frac{\left(\theta \cdot D\right)}{1 \text{ deg}} - \frac{D}{2} = 24.1808 \text{ m}$$

Ratio

$$n := \frac{R_i}{D} = 59.5$$

Bend thinning percentage

$$BT := \frac{50}{\left(n + 1\right)} = 0.8264$$

Pipe wall thickness after bending

$$t_b := \left(1 - \frac{BT}{100}\right) \cdot t = 10.4132 \text{ mm}$$

Diffrence between original thickness and thickness after bending at expansion

$$\Delta t := t - t_b = 0.0868 \text{ mm}$$

Inner diameter

$$ID := D - 2 \cdot t = 385.4 \text{ mm}$$

Guaging plate diameter

$$GPD := 97.5 \text{ \%} \cdot ID = 375.765 \text{ mm}$$

$10.4132\ \text{mm} > 7.557\ \text{mm} = 1$

ASME B31.4 LINE PIPE WALL THICKNESS CALCULATION - Elastic
(Restrained Pipe Section)

Spread sheet No. S11 Ver : 2012-5

DESCRIPTION: PL 16 inch Production Pipeline from RMS to STN S31803 DF= 0.72

	Input Data			METRIC UNITS			IMPERIAL UNITS		WT SOP, ASME B31.4, Other Ref
9	Construction Mode			BURIED			BURIED		Above Ground (A/G) or BURIED
10	Line Pipe Material	API 5LC		LC65-2205			S31803 DSS	Welded/SMLS	Pipeline Design Data Summary Sheet
11	NPS Pipe Size	NPS				=	16		As above
12	Outside Diameter of Pipe	D	=	406.40	mm	=	16.000	in	
13	Design Pressure	P	=	120.00	bar	=	1740.5	psi	Pipeline Design Data Summary Sheet
14	Max Operating Temp. (Max Design temp if applicable)	T2	=	110.00 *	°C	=	230.0	°F	As above
15	Min Operating Temp. (Min Design temp if applicabl	T2min	=	-20.00	°C	=	-4.0	°F	As above
16	Installation Temperature	T1	=	21.00	°C	=	69.8	°F	SP1211
17	Buried Restrained Temperature Differential	ΔT	=	-89.0	°C	=	-160.2	°F	WT SOP
18	Specified Min. Yield Strength (line pipe material)	S	=	448.16	Mpa	=	65000	psi	API 5LC
19	Modulus of Elasticity	E_s	=	1.9992E+05	Mpa	=	2.900E+07	psi	Sandvic Data
20	Material Expansion Coefficient	α	=	1.31E-05	mm/mm/°C	=	7.30E-06	in/in/°F	402.2.1
21	Poisson's Ratio	ν	=	0.3		=	0.3		402.2.3
22	Design Factor (Hoop Stress)	F	=	0.72		=	0.72		SP1211, 4.3.2, Table 1
23	Design Factor (Combined Stress)	k	=	0.9		=	0.9		SP1211, 4.3.5, Table 2
24	Longitudinal Joint Factor	E	=	1.0		=	1		Table 403.2.1-1
26	Corrosion Allowance	t_{corr}	=	0.0	mm	=	0.000	in	Pipeline Design Data Summary S
27	Pipeline Class			CLASS 1					
28	Is Pipeline is MOL or SOGL?			NO					
29									
30	Nominal Wall Thickness Based On Hoop Stress								
31	Wall Thickness due to Hoop Stress		=	7.557	mm	=	0.298	in	PD/(2*S*F*E*T) 841.1.1, (a)
32	Wall Thickness due to Hoop Stress+CA		=	7.557	mm	=	0.298	in	
33	Selected Wall Thk		=	10.5	mm	=	0.413	in	

Based on location class (Generally 0.72 for Desert, 0.6 at Station)

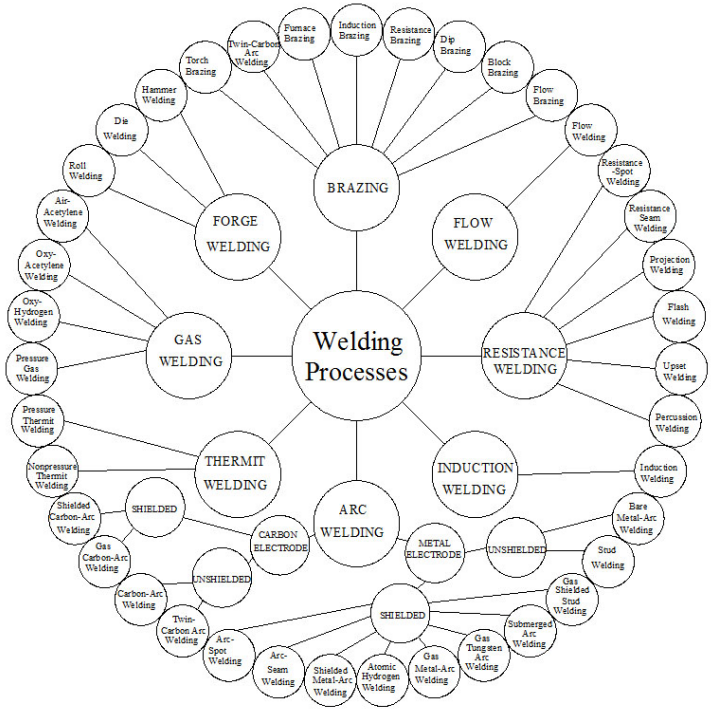
* On summery data sheet, the Max. operation T is 107 C; see slide # 91

Welding

Welding is one of the processes that its integrity cannot be verified until it's delivered.

Methods of welding:

1. GTAW/TIG
2. SMAW: Shielded metal arc welding
3. SAW: Submerged-arc welding
4. FCAW: Flux-cored arc welding
5. GMAW/MIG: Gas metal arc welding
6. Electro Slag Strip Cladding



Welding Process Requirements

Cont. Materials

Heat input is determined by current (Amp) and Voltage (V).

The welding method could be automatic or manual.

1	Cleaning	Preheating	Interpass Temp	Post heating	PWHT	Purging	HEAT INPUT
CABON STEELS	Wire brush/ Grind	100° C When thickness is more than 20 mm	250 ° C	Not required	Required When thickness more than 20mm	Not required	2.5 KJ/mm
LTCS	Wire brush/ Grind	100 C When thickness is more than 20 mm	250 °	Not required	Required When thickness more than 20mm	Not required	2.5 KJ/mm
Alloys steels (Cr-Mo Steels)	Wire brush/ Grind	150-200° C When thickness is more than 20 mm	350 ° C	Required for 300° C for 30 to 60 mins.	Required When thickness more than 13mm	When Cr > 5%	2.5 KJ/mm
STAINLESS STEELS	Cleaning with Acetone both joint and filler wires	Not required	150° C	Not required	Not required	Required. Oxygen content shall not be more .5%	2.0 KJ/mm
DUPLEX STAINLESS STEELS	Cleaning with Acetone both joint and filler wires	Not required	150° C	Not required	Not required	Required. Oxygen content shall not be more 50 ppm	2.0 KJ/mm
SUPER DUPLEX STAINLESS STEELS	Cleaning with Acetone both joint and filler wires	Not required	100 ° C	Not required	Not required	Required. Oxygen content shall not be more 50 ppm	1.5 KJ/mm
INCONEL ALLOYS	Cleaning with Acetone both joint and filler wires	Not required	100° C	Not required	Not required	Required. Oxygen content shall not be more 50 ppm	1.5 KJ/mm

Cont.

Automatic welding components:

1. Control box.
2. Welding bug: the component responsible for welding.
3. Welding power source.
4. Spool holder.
5. Gas mixing system.
6. Communication and supervision module/software.
7. Welding wire (feeding wire).

Cont.

Manual welding components:

1. Welding machine.
2. Remote control.
3. Grinding machines.
4. Gas cylinders.
5. Pneumatic claps.

Tie-ins

According to SP-1208 Sec. 2.8.4 :

Tie-ins shall take place in the trench.

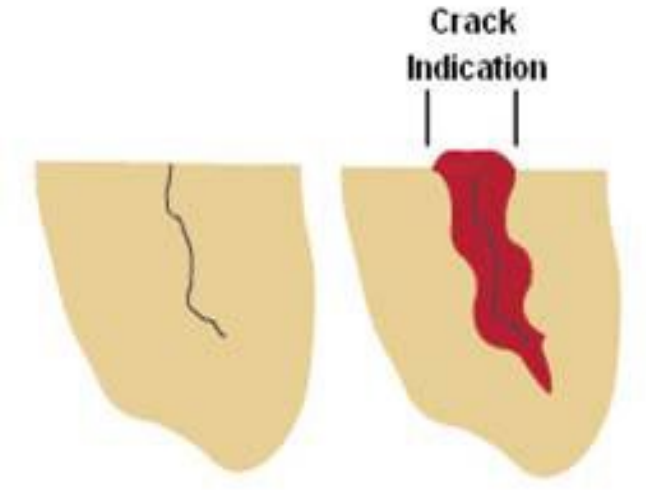
For tie-ins outside the trench, holding and lowering operations shall be undertaken in such a manner as to minimize stresses in the pipe and therefore avoid movement of the pipe from the skids, for safety reasons.

Due consideration shall be given to ambient temperature changes throughout the day and the resultant pipe length changes/stresses.

Non-Destructive Tests: 1. PT

Penetrant Testing, or PT, is a nondestructive testing method that builds on the principle of Visual Inspection.

PT increases the “seeability” of small discontinuities that the human eye might not be able to detect alone.



Cont. PT

Works on:

Almost any material that has a relatively smooth, non-porous surface on which discontinuities or defects are suspected.

Doesn’t work on:

1. Components with rough surfaces, such as sand castings, that trap and hold penetrant.
2. Porous ceramics
3. Wood and other fibrous materials
4. Plastic parts that absorb or react with the penetrant materials.
5. Components with coatings that prevent penetrants from entering defects.

Cont. PT

Working principles:

I. In penetrant testing, a liquid with high surface wetting characteristics is applied to the surface of a component under test.

II. The penetrant “penetrates” into surface breaking discontinuities via capillary action and other mechanisms.

III. Excess penetrant is removed from the surface and a developer is applied to pull trapped penetrant back the surface.

IV. With good inspection technique, visual indications of any discontinuities present become apparent.

Cont. PT

Procedure of PT:

1. Pre-clean
2. Penetrant Application
3. Excess Penetrant Removal
4. Developer Application
5. Inspect/Evaluate
6. Post-clean

Non-Destructive Tests: 2. RT

Radiography test uses penetrating radiation that is directed towards a component.

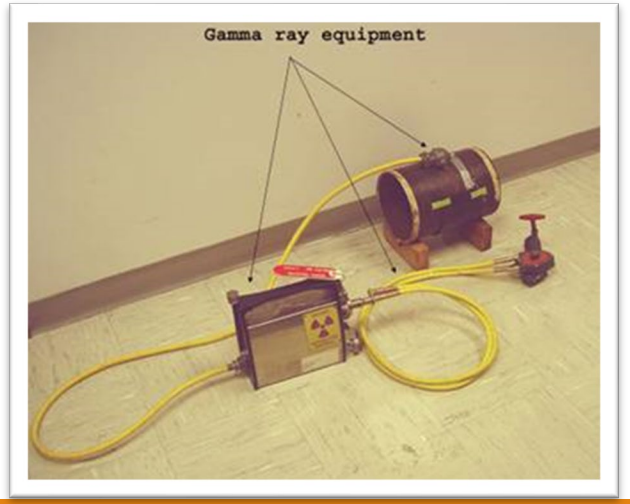
Working principles:

1. The component stops some of the radiation. The amount that is stopped or absorbed is affected by material density and thickness differences.
2. These differences in “absorption” can be recorded on film, or electronically.
3. Higher energy radiation can penetrate thicker and more dense materials.
4. The radiation energy and/or exposure time must be controlled to properly image the region of interest.

Cont. RT

Types of radiation source:

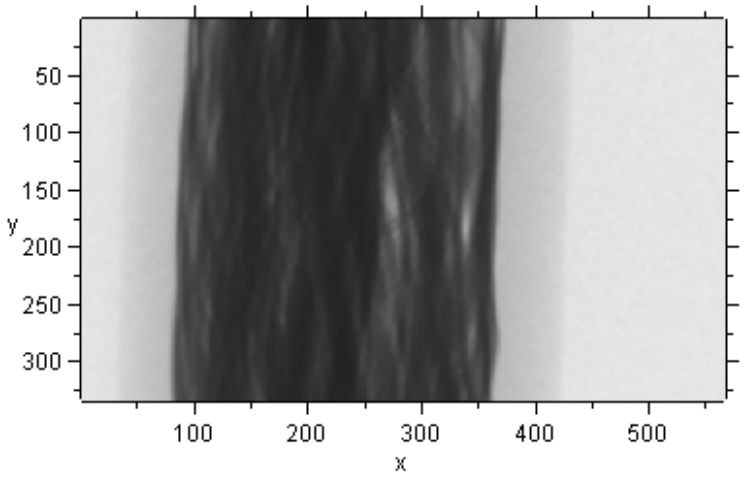
1. X-ray: produced by an X-ray generator system. These systems typically include an X-ray tube head, a high voltage generator, and a control console.
2. Gamma: produced by a radioisotope artificially produced, where it has an unstable nuclei that does not have enough binding energy to hold the nucleus together. The spontaneous breakdown of an atomic nucleus resulting in the release of energy and matter is known as radioactive decay.



Cont. RT

Imaging Modalities:

1. Film Radiography [∵]
2. Real Time Radiography
3. Computed Tomography (CT)
4. Digital Radiography (DR)
5. Computed Radiography (CR)



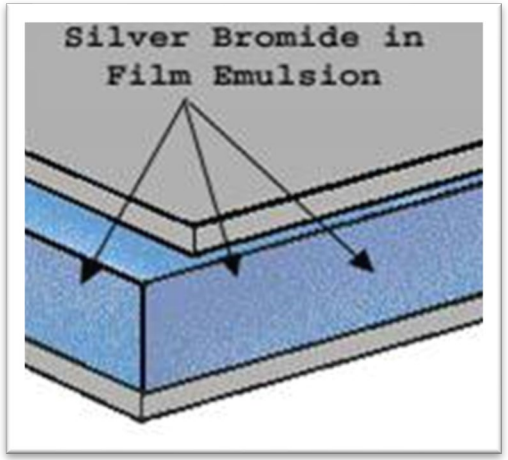
Cont. RT

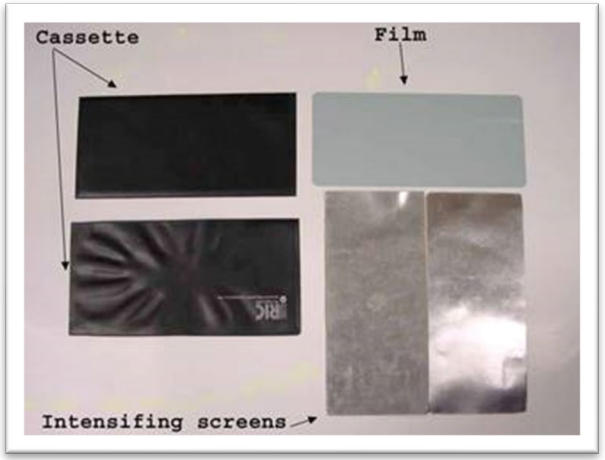
Film radiography:

Film contains microscopic material called silver bromide.

Once exposed to radiation and developed in a darkroom, silver bromide turns to black metallic silver which forms the image.

Once exposed to radiation and developed in a darkroom, silver bromide turns to black metallic silver which forms the image.





Cont. RT

Film must be protected from visible light. Light, just like x-rays and gamma rays, can expose film. Film is loaded in a “light proof” cassette in a darkroom.

This cassette is then placed on the specimen opposite the source of radiation. Film is often placed between screens to intensify radiation.

In order for the image to be viewed, the film must be “developed” in a darkroom. The process is very similar to photographic film development.

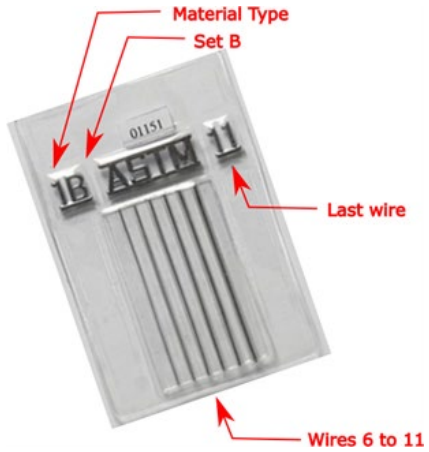
Cont. RT

Image Quality Control:

Various tools called **Image Quality Indicators (IQIs)** are used for this purpose.

Some IQIs contain artificial holes of varying size drilled in metal plaques while others are manufactured from wires of differing diameters mounted next to one another.

Quality typically being determined based on the **smallest hole or wire diameter** that is reproduced on the image.



Non-Destructive Tests: 4. UT

Ultrasound test is sound with high frequency that penetrates the test material and its damping will give indication of defects.

Working principles of ultrasonic waves:

I. Ultrasonic waves can be reflected, refracted, and focused.

II. Reflection and refraction occurs when sound waves interact with interfaces of differing acoustic properties.

III. In solid materials, the vibrational energy can be split into different wave modes when the wave encounters an interface at an angle other than 90 degrees.

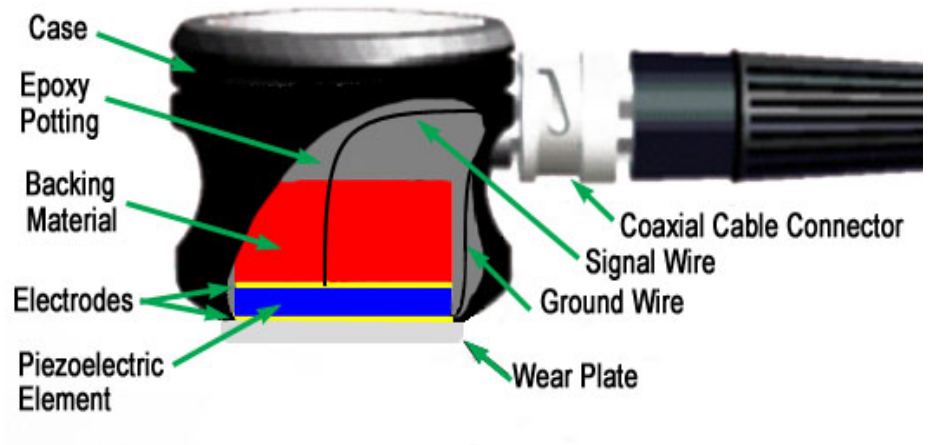
IV. Ultrasonic reflections from the presence of discontinuities or geometric features enables detection and location.

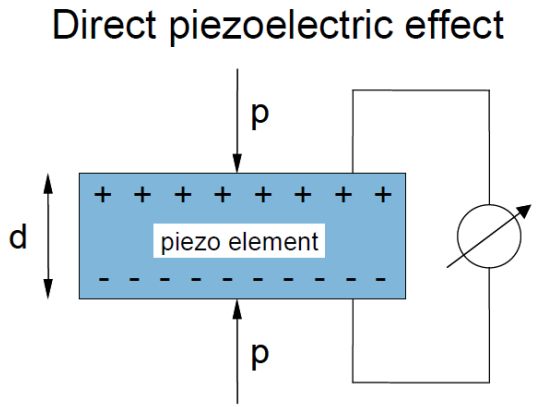
V. The velocity of sound in a given material is constant and can only be altered by a change in the mode of energy.

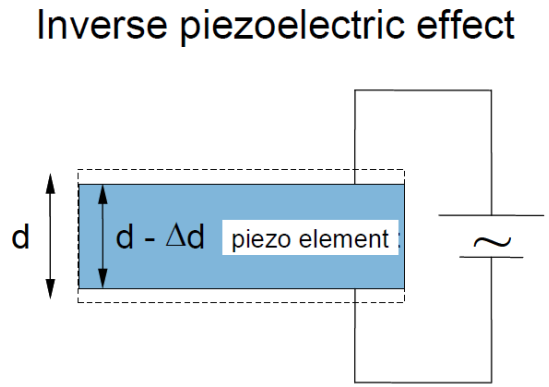
Cont. UT

Ultrasonic waves source:

Ultrasound is generated with a transducer. A piezoelectric element in the transducer converts electrical energy into mechanical vibrations (sound), and vice versa.







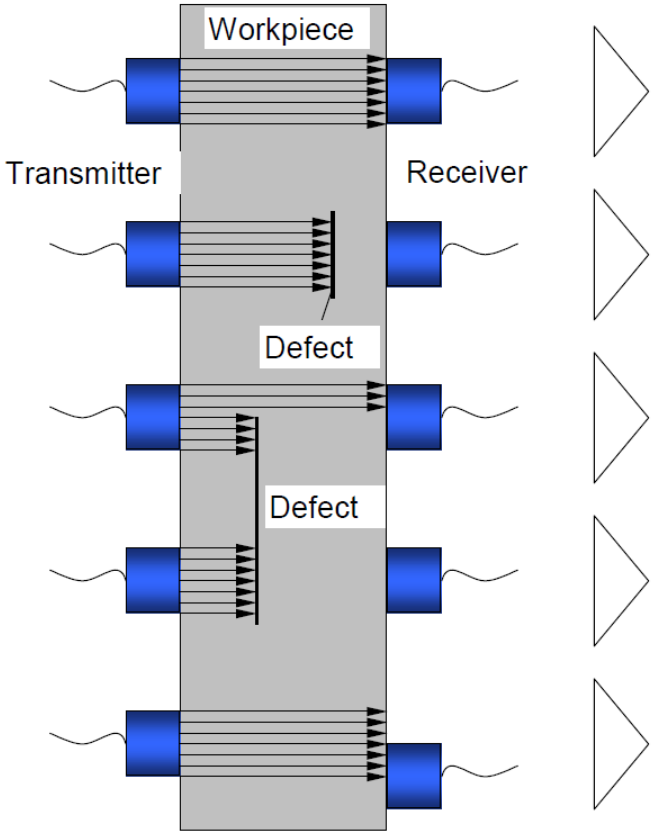
Cont. UT

Ultrasonic testing techniques:

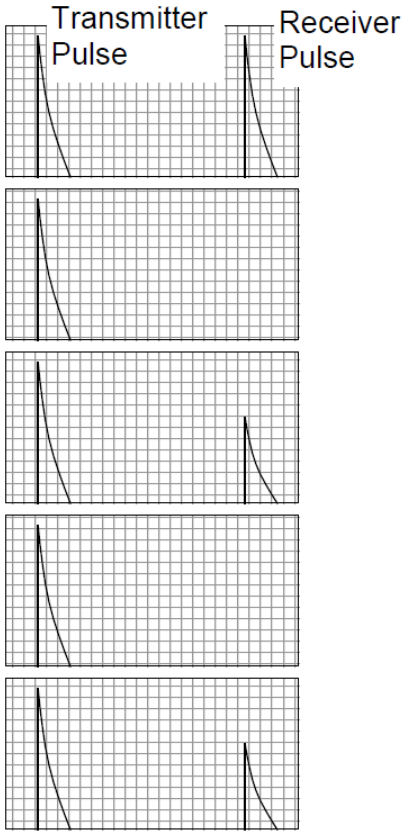
1. Pulse-echo and Through Transmission. [⋱]
   (Relates to whether reflected or transmitted energy is used)
2. Normal Beam and Angle Beam.
   (Relates to the angle that the sound energy enters the test article)
3. Contact and Immersion.
   (Relates to the method of coupling the transducer to the test article)

Cont. UT

Through-Transmission:

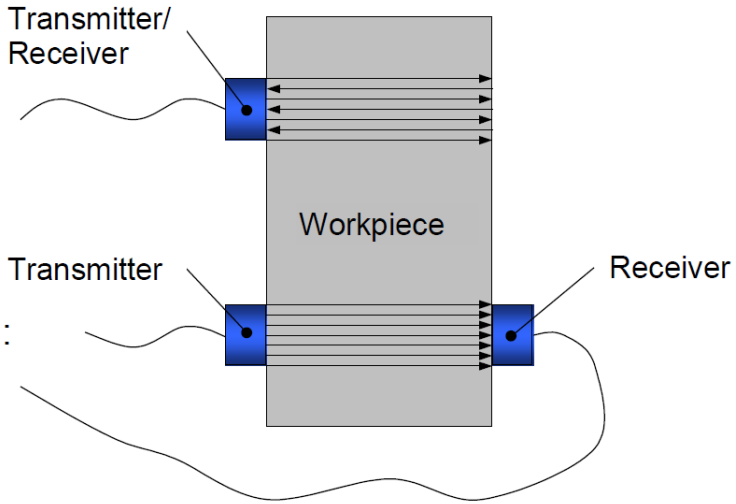


A-scan



Pulse-Echo:

Through-Transmission:

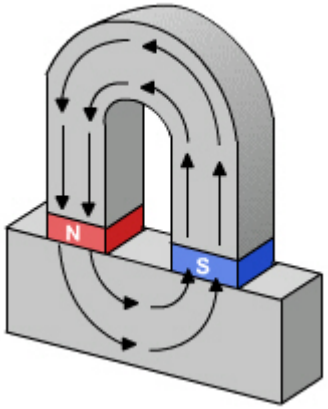


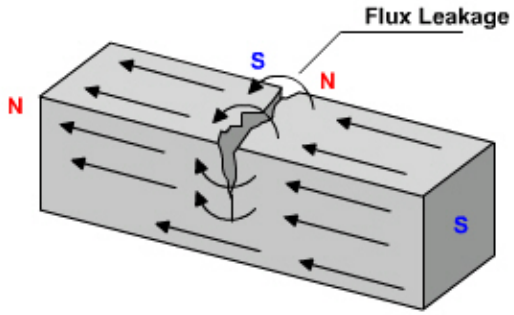
Non-Destructive Tests: 5. MT

Magnetic particle inspection can detect both production discontinuities (seams, laps, grinding cracks and quenching cracks) and in-service damage (fatigue and overload cracks).

Working principle:

A ferromagnetic test specimen is magnetized with a strong magnetic field created by a magnet or special equipment. If the specimen has a discontinuity, the discontinuity will interrupt the magnetic field flowing through the specimen and a leakage field will occur.

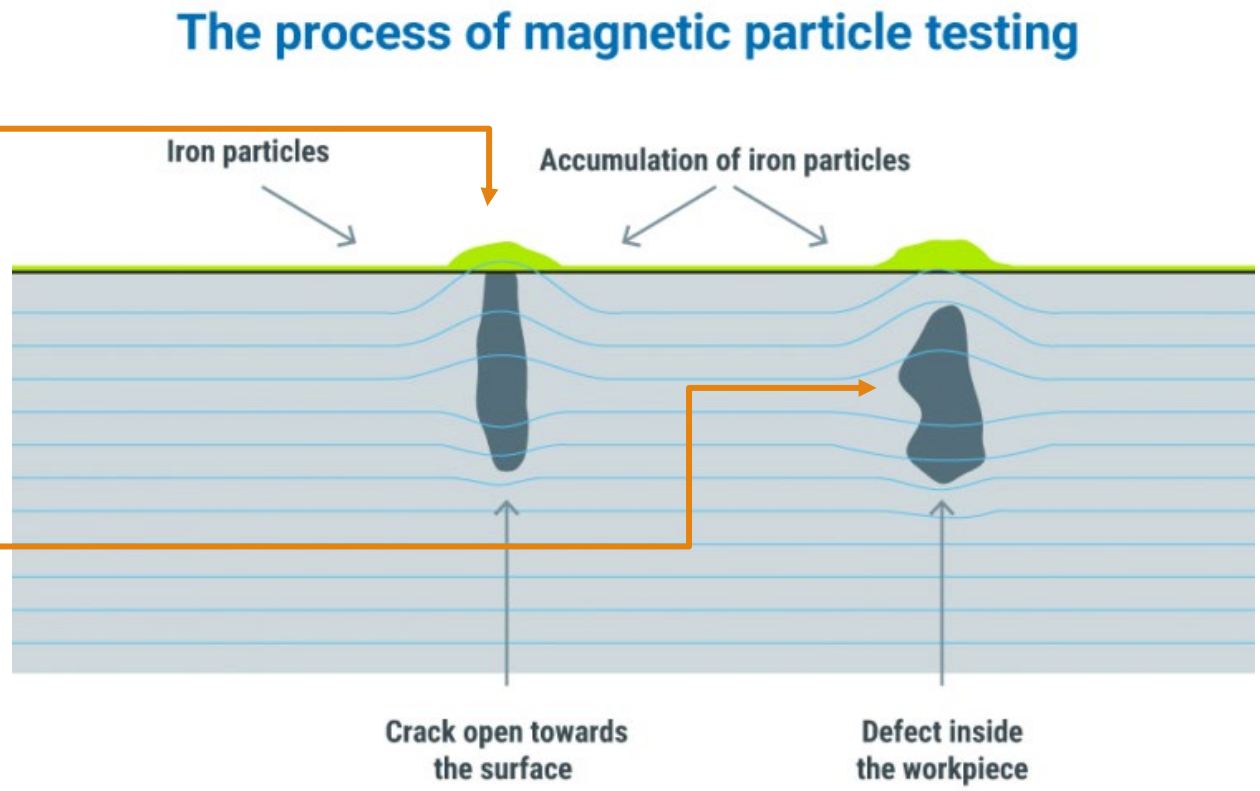




Cont. MT

Applying UV for better visibility

Maximum detectable defect depth is $0.6\ \text{in} = 15.24\ \text{mm}$

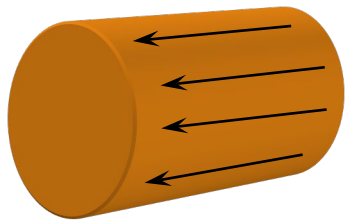


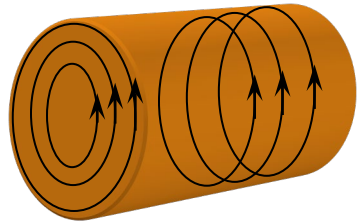
Cont.

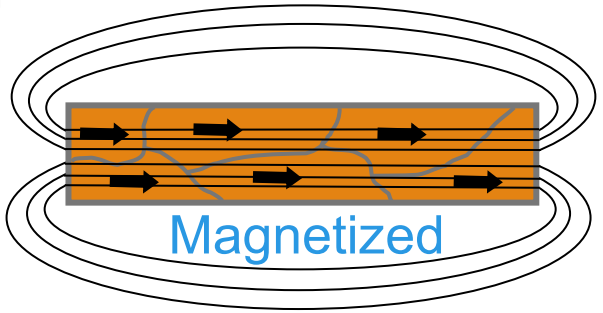
Cont. MT

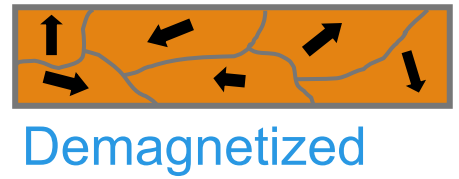
Procedure of MT:

1. Component pre-cleaning
   - No contaminations e.g. oil and dry
2. Introduction of magnetic field
   - longitudinal magnetic field or circular magnetic field
3. Application of magnetic media:
   - Wet or Dry
4. Interpretation of magnetic particle indications
5. Demagnetization (if required)









Non-Destructive Tests: 6. VT/BT

Visual testing or Boroscopic testing is a non-destructive test that depends on the experts' visual inspection. Usually used to spot oxidization for welds.

Procedure of BT:

Inserting boroscope inside the pipe and using live video feed or recordation to inspect the weld.

Cont. VT/BT


PLATE: 01

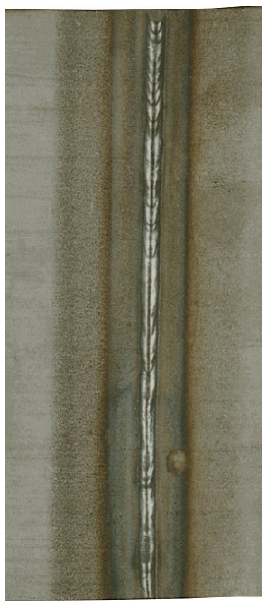


PLATE: 02


PLATE: 03

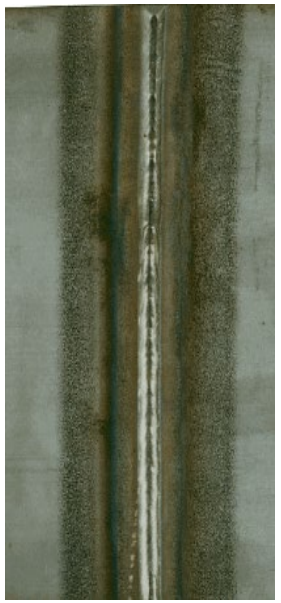


PLATE: 04


PLATE: 05


PLATE: 06

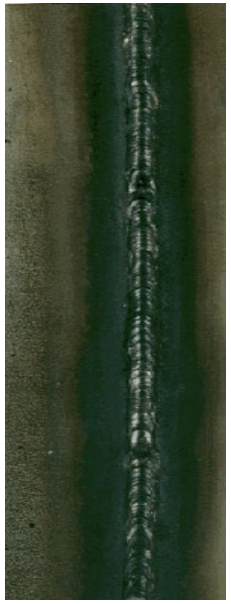


PLATE: 07

PLATE 1: ACCEPTABLE; VERY GOOD RESULT; NO DISCOLOURATION

PLATE 2: ACCEPTABLE; WELD FREE OF SIGNIFICANT OXIDATION

PLATE 3: ACCEPTABLE; SLIGHT DISCOLOURATION; WELD SHINY, NO SCALE PRESENT

PLATE 4: ACCEPTABLE; SLIGHT DISCOLOURATION; WELD SHINY, NO SCALE PRESENT

PLATE 5: UNACCEPTABLE; OXIDE LAYER PRESENT (GREY COLOUR) ON AND NEAR WELD; LACK OF PROPER BACK-PURGING

PLATE 6: UNACCEPTABLE; OXIDE LAYER PRESENT (GREY COLOUR), WELD BURNED; LACK OF PROPER BACK-PURGING

PLATE 7: UNACCEPTABLE; EXTREMELY BAD RESULT; VERY HEAVY OXIDE LAYER PRESENT - THIS MAY DEVELOP WHEN WELDING WITH COATED ELECTRODES (SMAW) OR WITH TIG WELDING (GTAW) WITH SEVERE LACK OF BACK-PURGING

Non-Destructive Tests: 7. HT

A holiday test is an inspection method used to detect discontinuities in painted/coated surfaces using specialized tools and equipment.

Working principle:

Holiday tests work on the concept of electrical conductivity. Metal substrates are excellent conductors of electricity, and therefore allow current to flow through them. On the other hand, many coatings are poor conductors of electricity and resist the flow of electricity.

Holiday test types:

- Ring Type.
- Brush Type.

Field joint coating HSS

A heat-shrink sleeve is a corrosion protective coating for pipelines in the form of a wraparound or tubular sleeve that is field applied.

Procedure:

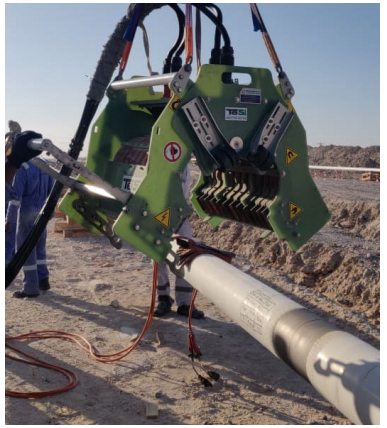
1. Measure $T_{air}, T_{pipe}, humidity, dew\ point;$
   - Pipe temperature shall be more than 3 C above ambient dew point.
   - Humidity as per table in Appendix 1
2. Blasting;
   - 100 psi
   - Deadman handle

$$100\ \mathrm{psi} = 6.8948 \cdot 10^{5}\ \mathrm{Pa}$$

$$100\ \mathrm{psi} = 6.8948\ \mathrm{bar}$$

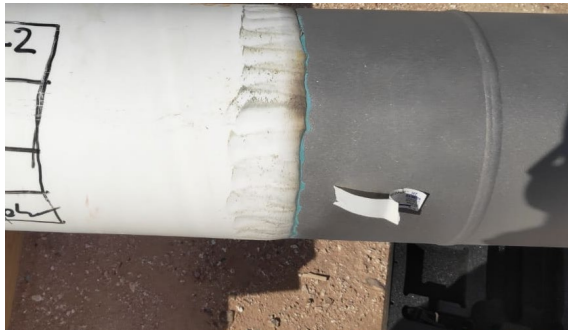
Cont.

3. Random check of:
   - Salt contamination shall be less than $2\ {}^{\mu g}/_{cm^2}$; Steps Appendix 1
   - Dust cleanness test as per ISO-8501 [A]
   - Roughness test with profile $50\ to\ 100\ microns$ $[B]$
4. Pre-heat to $75 \leq T[°C] \leq 85$ using induction heating coil. [C]
5. Mixing the two fluids .
6. Applying epoxy on the joint.
7. Measuring wet film thickness $100 \leq P[\mu m] \leq 300$.
8. Post-heat to $170 \leq T[°C] \leq 190$.



[C]

[A]



[B_1]

[B_2]

Cont.

9. Installing HSS, as per requirements;
   - Overlap $50mm$
   - Gap at down $50mm$
10. Visual testing.
11. Peel test [D]
    - $^{1}/_{100}$ or $^{1}/_{shift}$
    - 1 minuet
    - Acceptable values
12. Holiday test with $V_{Max} = 25\ KV$

[D_1]

[D_2]


elcometec

Pre-padding

According to SP-1208 Sec. 2.8.2 :

All trenches shall be pre-padded **(150 mm below the invert of the pipe)** before lowering in of pipe string.

Contractor shall use mobile screening plants with $[\boldsymbol{\beta}]\ sieve_{MaxSize} = 5\ x\ 5\ mm.$

The installed padding material shall be free of sharp rocks, stones, metal parts, roots, clods, etc.

Shall consist mainly of sandy material;

$$\geq 75\%\ wt \Rightarrow 0.06 \leq size[mm] \leq 3.00$$
$$\leq 25\%\ wt \Rightarrow 3.00 \leq size[mm] \leq 5.00$$

Lowering

According to SP-1208 Sec. 2.8.3 :

Welded pipe strings shall be lowered-in **within three weeks** duration of completion of joint coating or as [specified] by heat shrink sleeves manufacturer whichever is less.

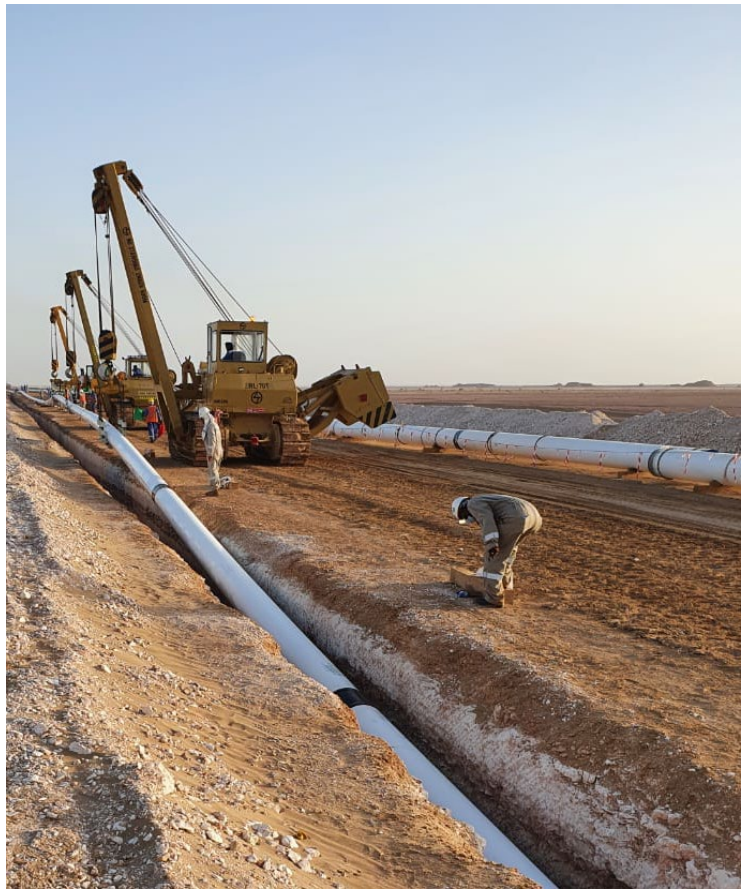
Immediately before commencing the lowering-in operation, the coating shall be checked for holiday.

Only side booms shall be used for the lowering operation with requirements;

- Minimum 3 side booms.
- Wide non-abrasive slings or belts.

The trench shall be maintained in a dry condition during lowering-in and backfill operations.

Cont.



Post-padding

According to SP-1208 Sec. 2.8.3.7/8 :

Shall be placed around and above the pipe, so as to fill the trench to a depth of **[min] 300 mm above the crown** of the pipe.

No pipe shall be left overnight in the trench without sand padding.

At any point around the pipe $150 \leq d[mm] \leq 300$

Where the trench has been **excavated through** or **along drive-ways**, **walk ways**, **roads**, etc. and at **live stock passage ways** and other locations indicated on the drawings, the sand padding shall be thoroughly **compacted by watering** and Company approved hand tools, to achieve a **compacted sand fill around the pipe and up to 300 mm above the crown** of the pipe.

Back-filling

According to SP-1208 Sec. 2.8.5 :

The trench shall not be backfilled until the Company has approved the sand padding around and above the pipe and has approved starting the backfilling operation.

The material used for initial backfill shall be from the screening plant or other loose material **not greater than 100 mm** in diameter.

In case of wadi crossings, the backfilling material is:

$$\geq 75\%\ wt \Rightarrow 200 \leq size[mm] \leq 300$$
$$\leq 25\%\ wt \Rightarrow size[mm] \leq 200$$

Post-backfilling: Windrow

According to SP-1208 Sec. 2.8.5.4:

The remaining excavated material shall be neatly crowned over the trench (the windrow), except in wadi areas.

On either side of road crossings, the windrow shall be tapered from full height to ground level to improve the visibility of drivers on the ROW.

Livestock Passageways

According to SP-1208 Sec. 2.8.7:

Livestock passageways shall be installed at **intervals** of approximately **2 km**.

Shall be constructed with a **minimum of 1.5 m cover**.

The **width** of the live stock passage shall be **2.5 m**.

Compaction of the livestock passageways shall be such that the passing of light vehicles will not have any detrimental effect on the passageway.

Road and Wadi crossing

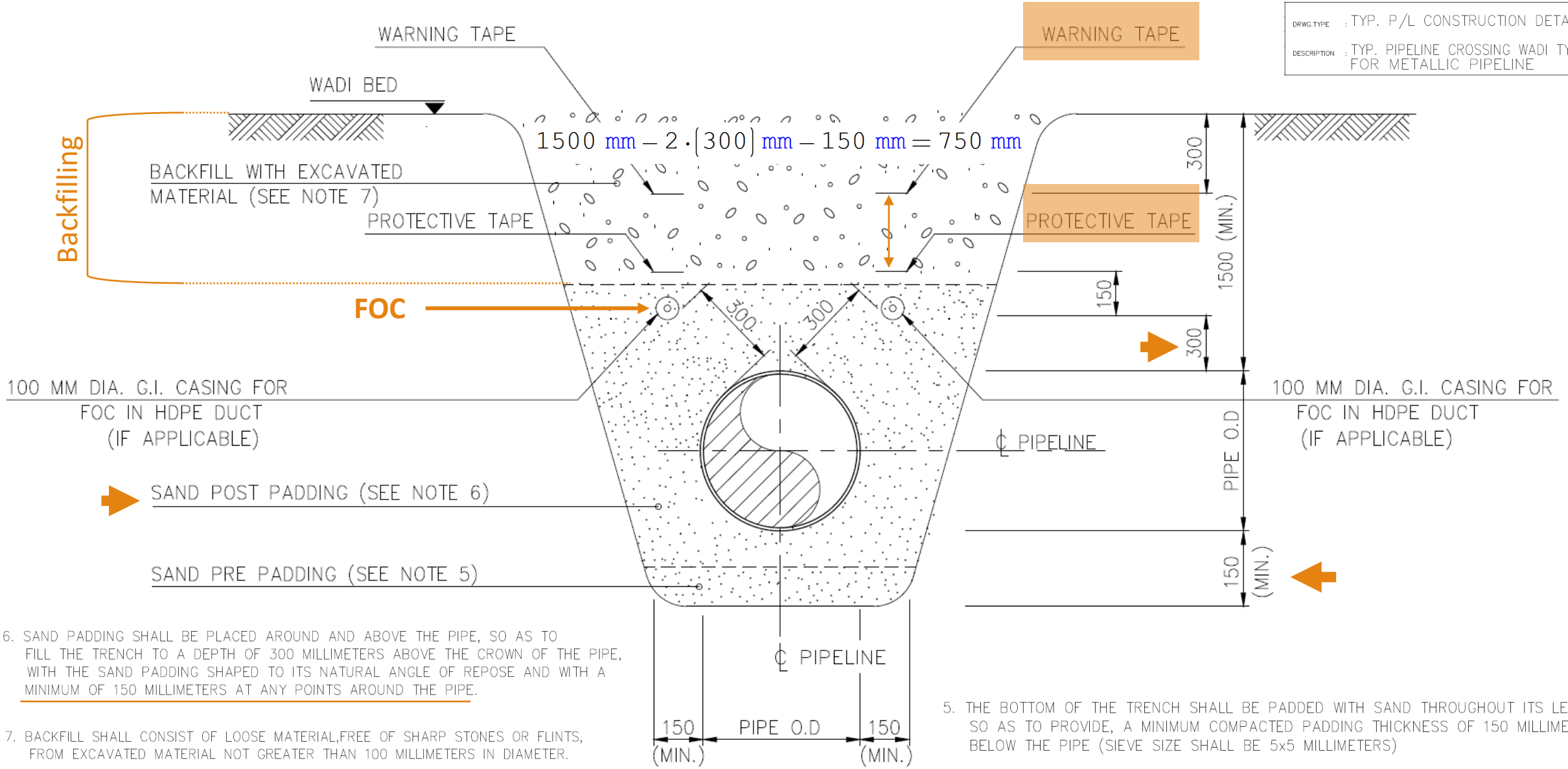
According to SP-1208 Sec. 2.8.5.5/6 :

Trenches crossing ditches shall be backfilled with the material excavated from the trench at the location.

The initial backfill shall be thoroughly compacted by mechanically tamping the material into place.

DRWG.TYPE : TYP. P/L CONSTRUCTION DETAILS

DESCRIPTION : TYP. PIPELINE CROSSING WADI TYPE–"A" FOR METALLIC PIPELINE



6. SAND PADDING SHALL BE PLACED AROUND AND ABOVE THE PIPE, SO AS TO FILL THE TRENCH TO A DEPTH OF 300 MILLIMETERS ABOVE THE CROWN OF THE PIPE, WITH THE SAND PADDING SHAPED TO ITS NATURAL ANGLE OF REPOSE AND WITH A MINIMUM OF 150 MILLIMETERS AT ANY POINTS AROUND THE PIPE.

7. BACKFILL SHALL CONSIST OF LOOSE MATERIAL,FREE OF SHARP STONES OR FLINTS, FROM EXCAVATED MATERIAL NOT GREATER THAN 100 MILLIMETERS IN DIAMETER.

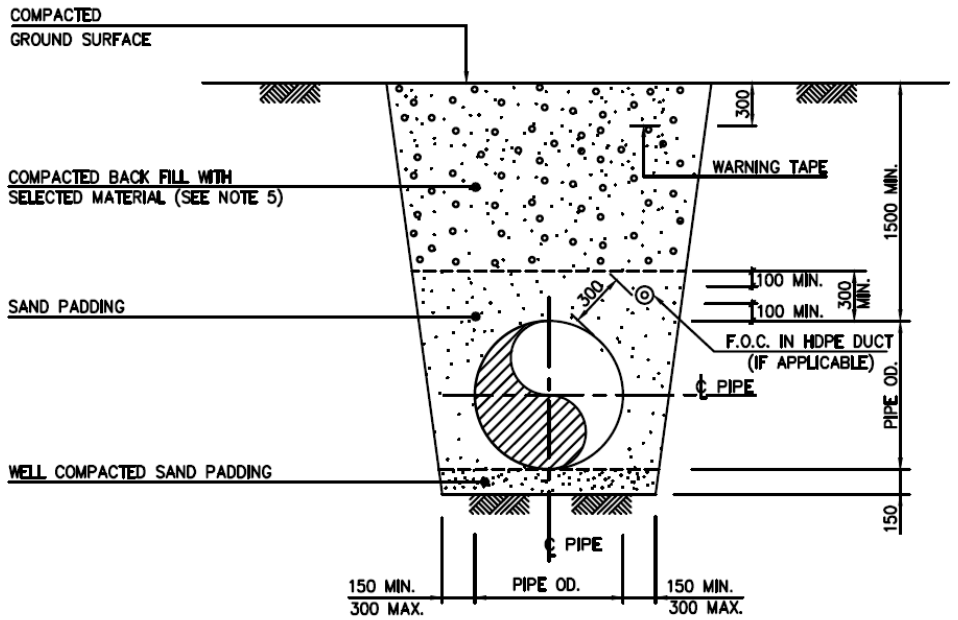
5. THE BOTTOM OF THE TRENCH SHALL BE PADDED WITH SAND THROUGHOUT ITS LENGTH, SO AS TO PROVIDE, A MINIMUM COMPACTED PADDING THICKNESS OF 150 MILLIMETERS BELOW THE PIPE (SIEVE SIZE SHALL BE 5x5 MILLIMETERS)

SECTION A–A

Cont.

DRWG.TYPE : TYPICAL P/L CONSTRUCTION DETAILS

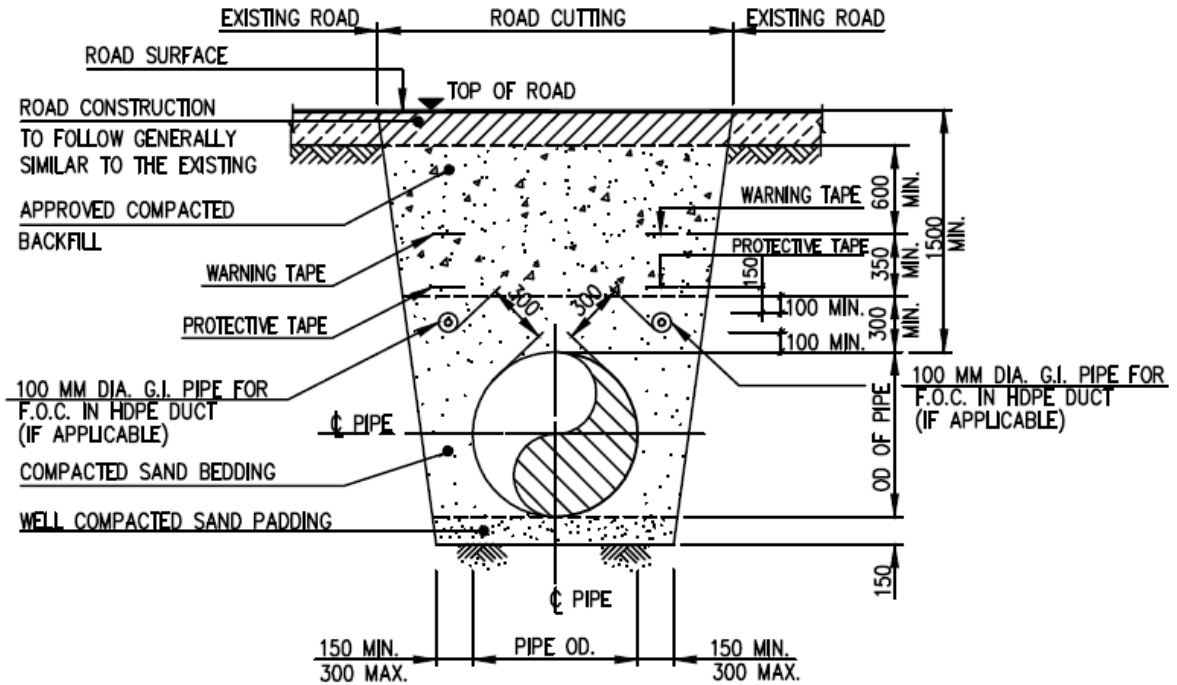
DESCRIPTION : LIVESTOCK PASSAGE WAY CROSSING FOR METALLIC PIPELINES



SECTION A–A

DRWG.TYPE : TYP. P/L CONSTRUCTION DETAILS

DESCRIPTION : TYP. GRADED ROAD CROSSING FOR METALLIC PIPELINE



SECTION B–B
(SCALE N.T.S)

Permeant marks

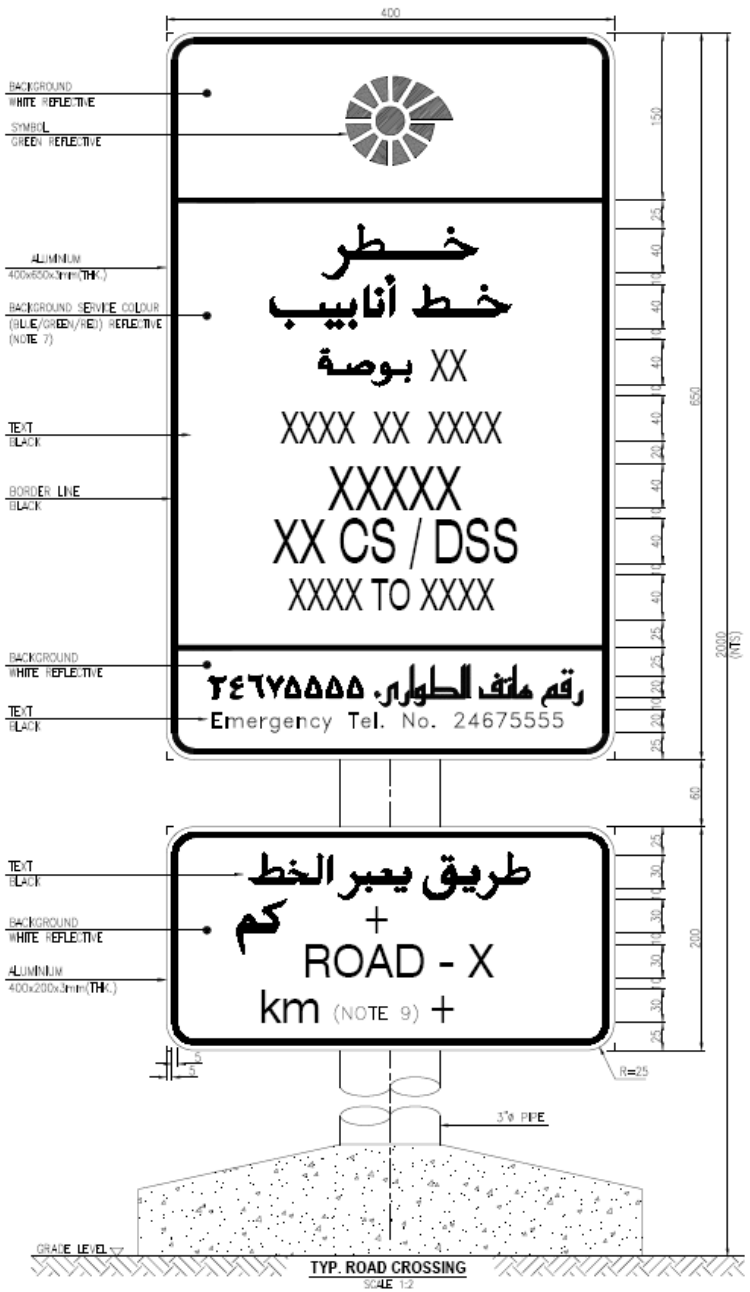
According to SP-1208 Sec. 2.11.2 :

The Contractor shall supply and install permanent pipeline markers along the buried pipeline route as close as possible to the windrow(Max 3m).

Pipelines marker shall be installed only at every Km and at road crossing.

Color coding of the background of the pipeline markers shall be as follows:

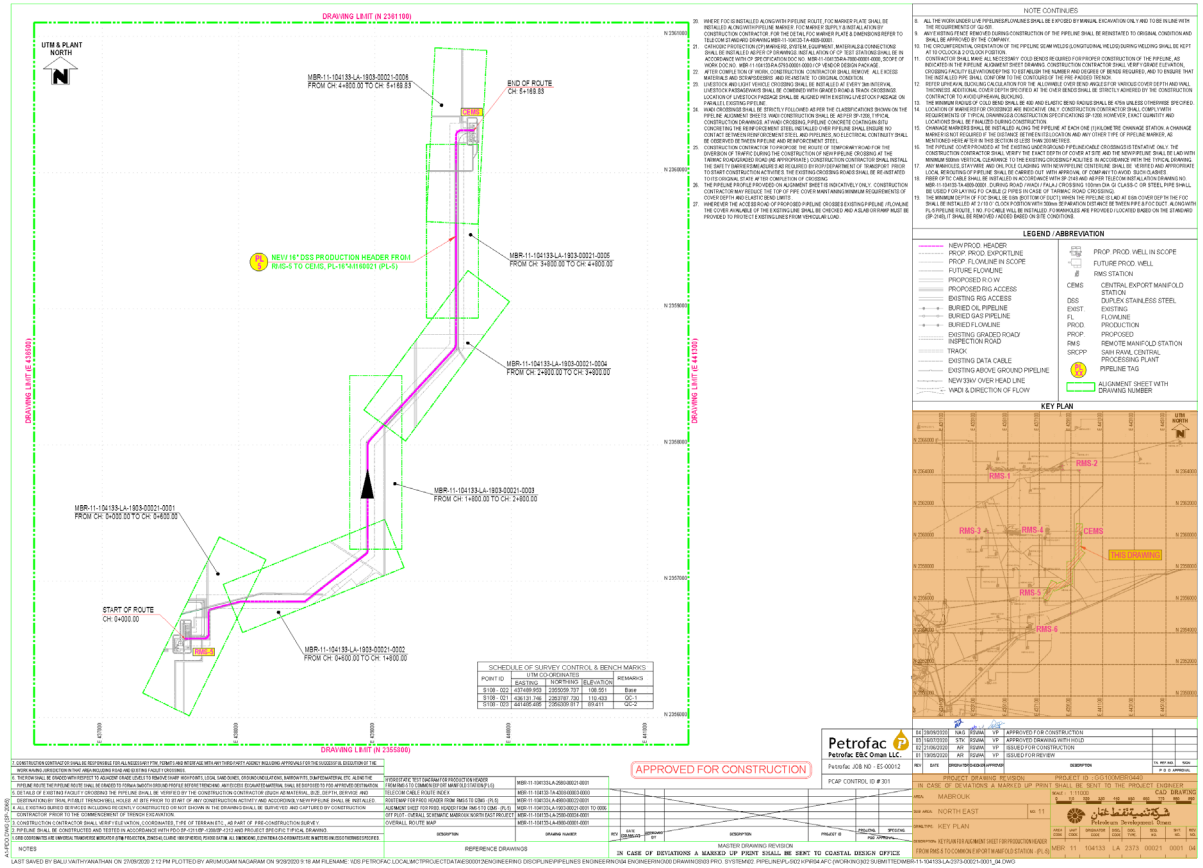
- Crude / Condensate : red
- Gas : blue
- Water : green
- Instrument Air : blue with white stripes

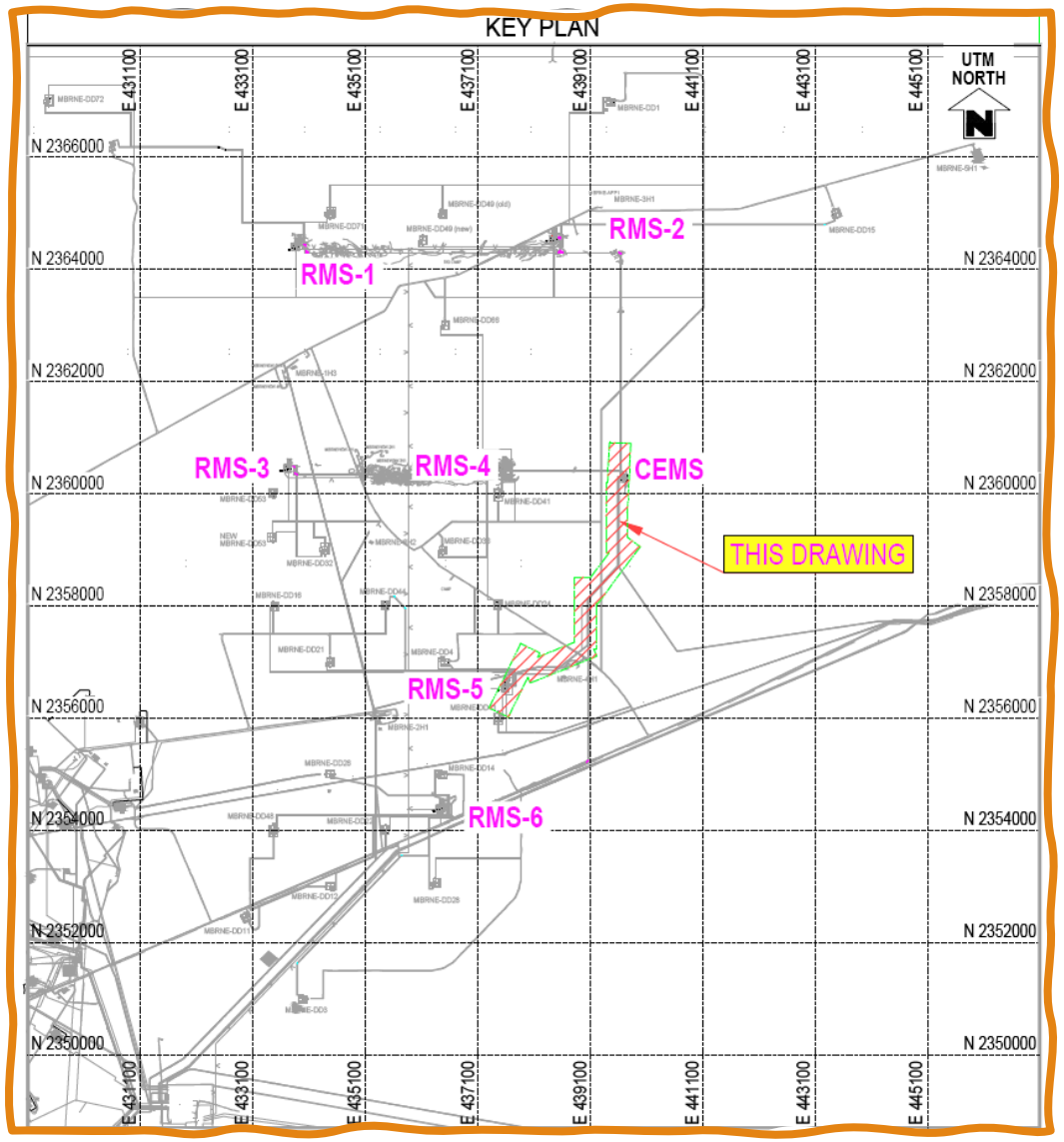


PIPELINE MARKER

Case Study: PL-05

HYDROTEST





PROJECT DRAWING REVISION PROJECT ID : GG100MBR0440

IN CASE OF DEVIATIONS A MARKED UP PRINT SHALL BE SENT TO THE PROJECT ENGINEER

AREA:	MABROUK	SCALE : 1:11000	CAD DRAWING
SUB AREA:	NORTH EAST	NO: 11	
DRWG.TYPE:	KEY PLAN		
DESCRIPTION:	KEY PLAN FOR ALIGNMENT SHEET FOR PRODUCTION HEADER FROM RMS-5 TO COMMON EXPORT MANIFOLD STATION - (PL-5)		

0 110 220 330 440 550 660 770 880 990

شركة تنمية نفط عمان
Petroleum Development Oman

AREA CODE	UNIT CODE	ORIGINATOR CODE	DISC. CODE	DOC. TYPE.	SEQ. NO.	SHT. NO.	REV. NO.
MBR	11	104133	LA	2373	00021	0001	04

Reference:
MBR-16-105729-BA-3581-00007-0000_05 - Method Statement For Final Hydro testing of Pipeline section; pages 10/11.

Applicable to all Ø16“ pipelines.

Parameter	Design Data
Nominal pipeline size	16 inch / 406.4 mm
Approximate length of pipeline	(5.184 + 5.516 +4.312+2.334+5.169+8.35) = 30.865 km (Approx.)
Fluid / Service	HC Gas + Condensate + Water
Pipeline design code	ASME B31.8
Type	Bulk/Production Header Pipelines
From - To	RMS-01 to RMS- 02 RMS-02 to Export Manifold RMS-03 to RMS-04 RMS-04 to Export Manifold RMS-05 to Export Manifold RMS-06 to Export Manifold
Design Life	25 Years
Construction philosophy	Buried
Pipeline criticality class	Class – 1 Div. 2
Pipeline location class	Class – 1 & 2
Design Pressure	120 Bar
Pipeline Design Factor	0.72 0.90 (For Hydro Test) 1.0 (For combined stress)
Hydrostatic strength test pressure	204.18 barg
Min. Hydrostatic test pressure(1.25XDP)	150 barg
Leak Tightness test pressure (1.1xDP)	132 barg
Min. /Max. design temperature for A/G pipeline sections	-20°C/110 °C
Min. /Max. design temperature for U/G pipeline sections	-20 °C/110 °C
ASME/ANSI -Flange rating	900#
Pipeline material specification	DSS (Duplex Stainless Steel)
Material Grade	LC65-2205 (S31803)
Specified Min. Yield Strength(SMYS)	448 MPa
Max. minus Mill thickness tolerance for WT	0.21 mm
Corrosion allowance for line pipe	0.0 mm
Wall thickness for Pipeline	10.5mm @ 0.72 DF
Pigging philosophy	Offline Pigging facilities.
Number of bulk header	6

Reference :PIPELINE/FLOWLINE DESIGN DATA SUMMARY SHEET

(1) TAG / PL#	(2) Buried	(3) SIZE (Inch) NPS	(4) TYPE / Nos	(5) FROM	(6) TO	(7) km	(8) Wall Thk 1 (mm)	(9) Wall Thk 2 at Rd Cross, Stn (mm)	(10) Metal ID Max / Min (mm)	(11) Material Grade	(12) Flange Rating (lbs)	(13) Fluid
PL-16"-M160021 (PL5)	Yes	16	Production Header	RMS-5	Export Manifold (CEMS)	5.169	10.50	10.50	385.4 / 385.4	LC65-2205 (S31803)	900	HC Gas + Condensate + Water

(14) Design Pres (kPa G)	(15) Min Design Temp A/G (Deg C)	(16) Max Design Temp A/G (Deg C)	(17) Min Design Temp B/G (Deg C)	(18) Max Design Temp B/G (Deg C)	(19) Design Code	(20) Valve Material	(21) Corr. Allow. (mm)	(22) Line Coat Internal	(23) Line Coat Ext	(24) CP	(25) Launcher Size	(26) Receiver Size	(27) Launcher Tag No	(28) Receiver Tag No	(29) From PEFS Dwg No	(30) To PEFS Dwg	(31) Install	(32) Remarks	(33) Rev
12000	-20	110	-20	110	ASME B31.8	DSS	0.0	NIL	3LPP	Yes	-	-	-	-	MBR-11-104133-PX-2365-00014-0003	MBR-11-104133-PX-2365-00024-0001	Yes		

12000 kPa = 120 bar

Notes:

1) Design life 25 years for all lines
2) All lines shall be designed for sour service application and materials shall comply with DEP 39.01.10.12-Gen, DEP 39.01.10.11-Gen, DEP 30.10.02.11-Gen, DEP 30.10.02.31-Gen and SP-2161.
3) Pipeline criticality classification (ref SP-1211, Table A1.1) = Class 1.
4) Location class for all lines with design code ASME B31.8=Class 1 Div 2 (Ref SP-1211,Table1).
5) Location class Design Factor is 0.72 along the pipeline/flowline route and 0.6 at road crossings and station area.
6) DSS Buried sections of metallic lines shall be protected by Impressed Current Cathodic Protection as per DEP 30.10.73.10-Gen., SP-1128 & SP-1130.
7) Permanent Pigging facilities are not required for DSS. However, removable spool arrangement shall be provided to facilitate offline pigging using temporary / mobile Pig Trap.
8) Maximum Operating Temperature is 107 deg C.

List of equipment

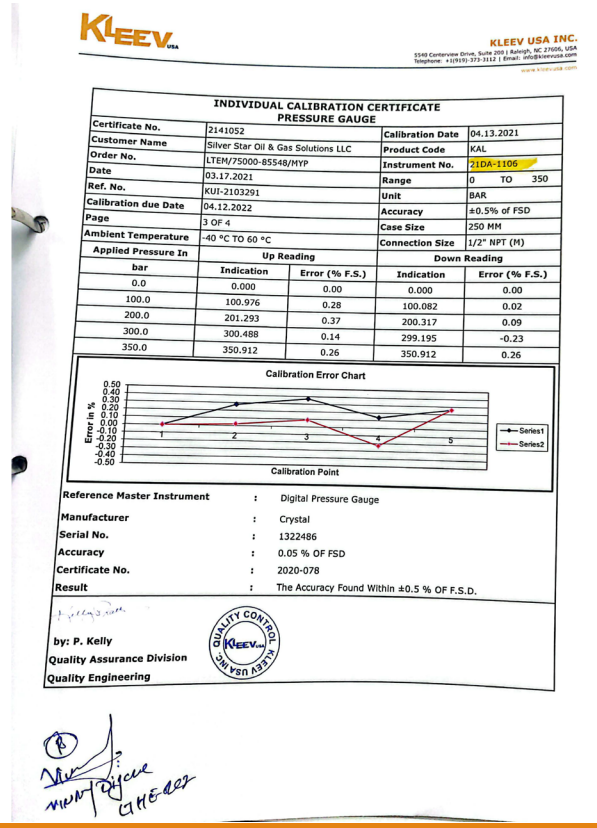
SL No.	Equipment Name	Specification	Qty	Remarks
1	Water filling pump	Diesel engine driven, Horizontal spilit Casing centrifugal pump, Flow Capacity: 200 - 300 M3 / HOUR, Max Head - 200 mtr / 20 bar	1 no	
2	Pressurising pump	Diesel engine driven, High pressure Multiplunger Reciprocating Pump, Max Pressure -300 Bar, Capacity :30- 50 LPM	1 no	
3	Water Storage / Break tank	Capacity - 60 cubic metre , Inlet / outlet end - 6"x150# with inbuilt filter SS mesh 50 micron	1 no	
4	M/L Test Headers	For water filling, strength test, leak test and de-watering purpose. Size - 8", 16",24"	1 set of each dia	Pretested at 1.25 xTP
5	Test Cabin Unit	With Air condition & Heating facility	1 no	
6	Pressure Relief valve	Set at 3 % above the test pressure	1 no	
7	Dosing / Chemical injection pump	Electrical driven pump, Capacity : 250-300 LPH at 20 barg	1 no	
8	Welding machine	Diesel operated, Dual welder type	1 no	
9	Crane truck	7 ton	1 no	
10	Excavator	20 ton	1 no	
11	Mobile crane	Capacity - 50 ton	1 no	
12	Power generator	85-125 KW	1 no	
13	Utility pick up	Double door	4 nos	

SL No.	Instrument Name	Specification	Range	Qty
1	Dead Weight Tester (DWT)	Dead Weight tester (DWT) single piston (Mechanical),Reading division 0.01 bar, Accuracy +/- 0.05 % , measuring Increment of 0. 2 bar with calibration certificates and with box, Weight material - SS, Operating medium - Oil along with tool and weight box, with calibration certificates	02 - 400 Barg	1 no
2	Pressure Chart Recorder	Pressure Chart Recorder Single pen, Reading division 2 bar ,1/2" end fitted NPT, Mechanical Type, 24 hrs cycle,12" Chart size with wall mount, Accuracy +/- 0.05 % of full scale division Including calibration certificate along with 1 box circular recording chart (1 box contain - 100 chart) and 2 box of recorder pen (Blue)	0 - 300 Barg	1 no
3	Temperature Chart Recorder	Temperature Chart Recorder Single pen, Range : 0 to 100 deg. ,Reading division 0.5 deg with 3 meter tube sensor metal SS Piston ,Mechanical type , 24 hrs cycle ,1/2" end fitting NPT (M), including calibration certificate along with 1 box of circular recording chart (1box- 100 chart)	0 - 100 °C	1 no
4	Portable Digital Temperature Indicator	Portable Digital Temperature Indicator, Range 0 to 60 °C, Accuracy : -/+ 0.2 °C , Reading division / Resolution 0.1 deg with 2 pin connector	0 - 60 °C	5 no
5	RTD Sensor	RTD Sensor, Range 0 to 60 °C, Accuracy : -/+ 0.2 °C, Resistance accuracy : -/+ 0.08 Ohms	0 - 60 °C	10 no
6	Master Pressure gauge	Master Bourdon Pressure gauge, Range: 0-400 Bar, Accuracy +/- 0.25 % FS, SS Body, connection 1/2" BSP (M) , Dial 10" , Least count - 1 bar	0 - 300 Barg	5 no
7	Pressure Gauge	Pressure Gauge, Range : 0-40 Bar, Dial size - 6 inch, Accuracy +/- 0.25 % FS, SS Body, connection 1/2" BSP	0 - 40 Barg	6 no
8	Pressure Gauge	Pressure Gauge, Range : 0-20 Bar, Dial size - 6 inch, Accuracy +/- 0.25 % FS, SS Body, connection 1/2" BSP	0 - 20 Barg	6 no
9	Digital Stroke Counter	Digital Stroke Counter with proximity switch, Range : 6 - 8 digits along with TC	6 Digit	4 no
10	Water Flow meter 6"	Water Flow meter 6", Qmax : 400 m3/hour, Pmax : 20 bar, Accuracy : (-) 1%,Both side flange end 150#.	400 m3/hr	4 no
11	Water Flow meter 2"	Water Flow meter 2" ,Qmax : 60 m3/hour, Pmax : 20 bar, Accuracy : (-) 2%,Both side flange end 150#.	60 m3/hour	4 no
12	Beaker 1000 ML	Measuring beaker PP, plastic, capacity - 1000 ML With graduated scale	0-1000 ML	4 no
13	Beaker 2000 ML	Measuring beaker PP, plastic, capacity - 2000 ML With graduated scale	0-2000 ML	4 no
14	Beaker 5000 ML	Measuring beaker PP, plastic, capacity - 5000 ML With graduated scale	0-5000 ML	4 no
15	Glass thermometer	Laboratory Glass Thermometer, Range : (-10) to 50 deg. Resolution: 0.5 °C	- 10 to 50 °C	2 no


"PRESSURE CAN KILL, SO TREAT WITH SKILL"
CAUTION
HYDROTEST IN PROGRESS
NOTICE
ONLY AUTHORIZED PERSONNEL SHALL OPERATE THIS EQUIPMENT

Safety measures and equipment calibration

All instrumentation shall be provided along with **valid calibration certificate**. The certificates shall not be older than **6 months** at the start of testing.



KLEEV USA INC.

INDIVIDUAL CALIBRATION CERTIFICATE
PRESSURE GAUGE

Certificate No.	2141052	Calibration Date	04.13.2021
Customer Name	Silver Star Oil & Gas Solutions LLC	Product Code	KAL
Order No.	LTEM/75000-85548/MYP	Instrument No.	21DA-1106
Date	03.17.2021	Range	0 TO 350
Ref. No.	KUI-2103291	Unit	BAR
Calibration due Date	04.12.2022	Accuracy	±0.5% of FSD
Page	3 OF 4	Case Size	250 MM
Ambient Temperature	-40 °C TO 60 °C	Connection Size	1/2" NPT (M)

Applied Pressure In	Up Reading		Down Reading	
bar	Indication	Error (% F.S.)	Indication	Error (% F.S.)
0.0	0.000	0.00	0.000	0.00
100.0	100.976	0.28	100.082	0.02
200.0	201.293	0.37	200.317	0.09
300.0	300.488	0.14	299.195	-0.23
350.0	350.912	0.26	350.912	0.26

Calibration Error Chart

Error in %

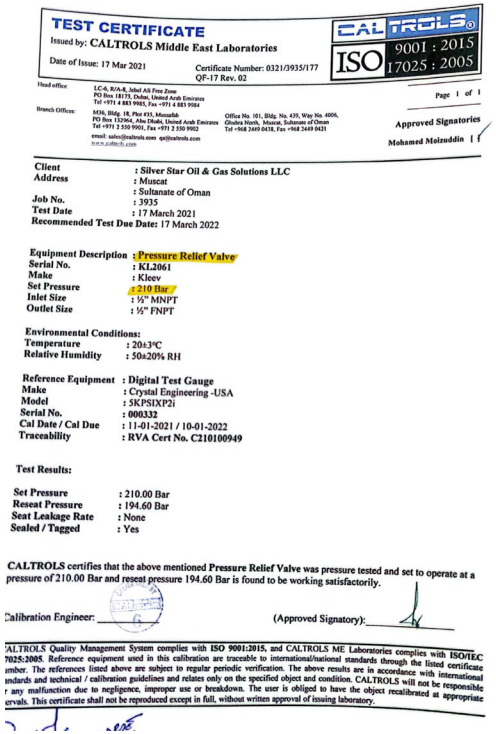
Calibration Point

Series1
Series2

Reference Master Instrument	:	Digital Pressure Gauge
Manufacturer	:	Crystal
Serial No.	:	1322486
Accuracy	:	0.05 % OF FSD
Certificate No.	:	2020-078
Result	:	The Accuracy Found Within ±0.5 % OF F.S.D.

by: P. Kelly
Quality Assurance Division
Quality Engineering

QUALITY CONTROL KLEEV USA INC



TEST CERTIFICATE

Issued by: CALTROLS Middle East Laboratories

Date of Issue: 17 Mar 2021

Certificate Number: 0321/3935/177
QF-17 Rev. 02

CALTROLS ISO 9001 : 2015 17025 : 2005

Approved Signatories
Mohamed Moizuddin

Client : Silver Star Oil & Gas Solutions LLC
Address : Muscat
: Sultanate of Oman
Job No. : 3935
Test Date : 17 March 2021
Recommended Test Due Date: 17 March 2022

Equipment Description : Pressure Relief Valve
Serial No. : KL2061
Make : Kleev
Set Pressure : 210 Bar
Inlet Size : ½" MNPT
Outlet Size : ½" FNPT

Environmental Conditions:
Temperature : 20±3°C
Relative Humidity : 50±20% RH

Reference Equipment : Digital Test Gauge
Make : Crystal Engineering -USA
Model : SKPSIX2P2I
Serial No. : 000332
Cal Date / Cal Due : 11-01-2021 / 10-01-2022
Traceability : RVA Cert No. C210100949

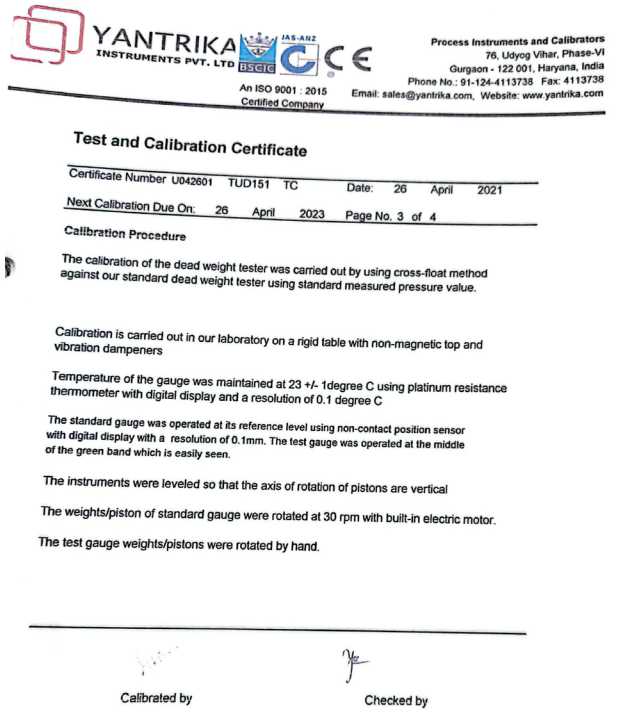
Test Results:

Set Pressure : 210.00 Bar
Reseat Pressure : 194.60 Bar
Seat Leakage Rate : None
Sealed / Tagged : Yes

CALTROLS certifies that the above mentioned Pressure Relief Valve was pressure tested and set to operate at a pressure of 210.00 Bar and reseat pressure 194.60 Bar is found to be working satisfactorily.

Calibration Engineer: (Approved Signatory):

CALTROLS Quality Management System complies with ISO 9001:2015, and CALTROLS ME Laboratories complies with ISO/IEC 17025:2005. Reference equipment used in this calibration are traceable to international/national standards through the listed certificate number. The references listed above are subject to regular periodic verification. The above results are in accordance with international standards and technical / calibration guidelines and relates only on the specified object and condition. CALTROLS will not be responsible for any malfunction due to negligence, improper use or breakdown. The user is obliged to have the object recalibrated at appropriate intervals. This certificate shall not be reproduced except in full, without written approval of issuing laboratory.



YANTRIKA INSTRUMENTS PVT. LTD

An ISO 9001 : 2015 Certified Company

Process Instruments and Calibrators
76, Udyog Vihar, Phase-VI
Gurgaon - 122 001, Haryana, India
Phone No.: 91-124-4113738 Fax: 4113738
Email: sales@yantrika.com, Website: www.yantrika.com

Test and Calibration Certificate

Certificate Number U042601 TUD151 TC Date: 26 April 2021

Next Calibration Due On: 26 April 2023 Page No. 3 of 4

Calibration Procedure

The calibration of the dead weight tester was carried out by using cross-float method against our standard dead weight tester using standard measured pressure value.

Calibration is carried out in our laboratory on a rigid table with non-magnetic top and vibration dampeners

Temperature of the gauge was maintained at 23 +/- 1degree C using platinum resistance thermometer with digital display and a resolution of 0.1 degree C

The standard gauge was operated at its reference level using non-contact position sensor with digital display with a resolution of 0.1mm. The test gauge was operated at the middle of the green band which is easily seen.

The instruments were leveled so that the axis of rotation of pistons are vertical

The weights/piston of standard gauge were rotated at 30 rpm with built-in electric motor.

The test gauge weights/pistons were rotated by hand.

Calibrated by

Checked by

Cont.

Mabrouk NE Pipeline Construction DNNS5 ☐Production-Coordinator GGO1Q; ☐CPP Gas-Operation-Supervisor GGO14q; ☐MBK_BK-Control-Room GGO141Q; ☐Al Badwawi, Abdullah GGO141Q; ☐CPP-Control-Room GGO141Q; ☐Maintenance Coordinator GGO4Q; ☐Maintenance Supervisor Electrical GGO42Q; + 28

Hydro test Pressurization notification alert for PL-02 x 16" (RMS-02 to CEMS)

This message was sent with High importance.

PL-02 RMS-02 to CEMS.png
.png File

Team,

With the reference to the below email, tomorrow (06-12-2021), we are going to start pressurization around at 11:00 AM of the hydro test section **PL-02 x 16" (RMS-02 to CEMS)**
Any crews who are working on or near area to stop/suspend their job **from 11:00 AM (06-12-2021) to 08:00 AM (08-12-2021).**
All safety precaution will be taken care .
Please find the attached location.
Please circulate the information to adjacent contractors and Rigs who are working near area.

Regards,

Abdullah

L&T Hydrocarbon Engineering

MABROUK NORTH EAST DEVELOPMENT PROJECT

Contract No :C3100000161

Petroleum Development Oman

Doc. No. : MBR-16-105729-BA-3581-00005-0000

SAFETY CHECK LIST

Format No: MRB-MPF-138
Rev.05

Line Dia & Name : 16" DSS PIPELINE x PL-05

Test Pack No. : 21-PL-01-TP-01

Test Section No. : 16"x PL-05 From : KP 0 FT 01A To : KP 5 FT 11

Date : 18-Sep-2021

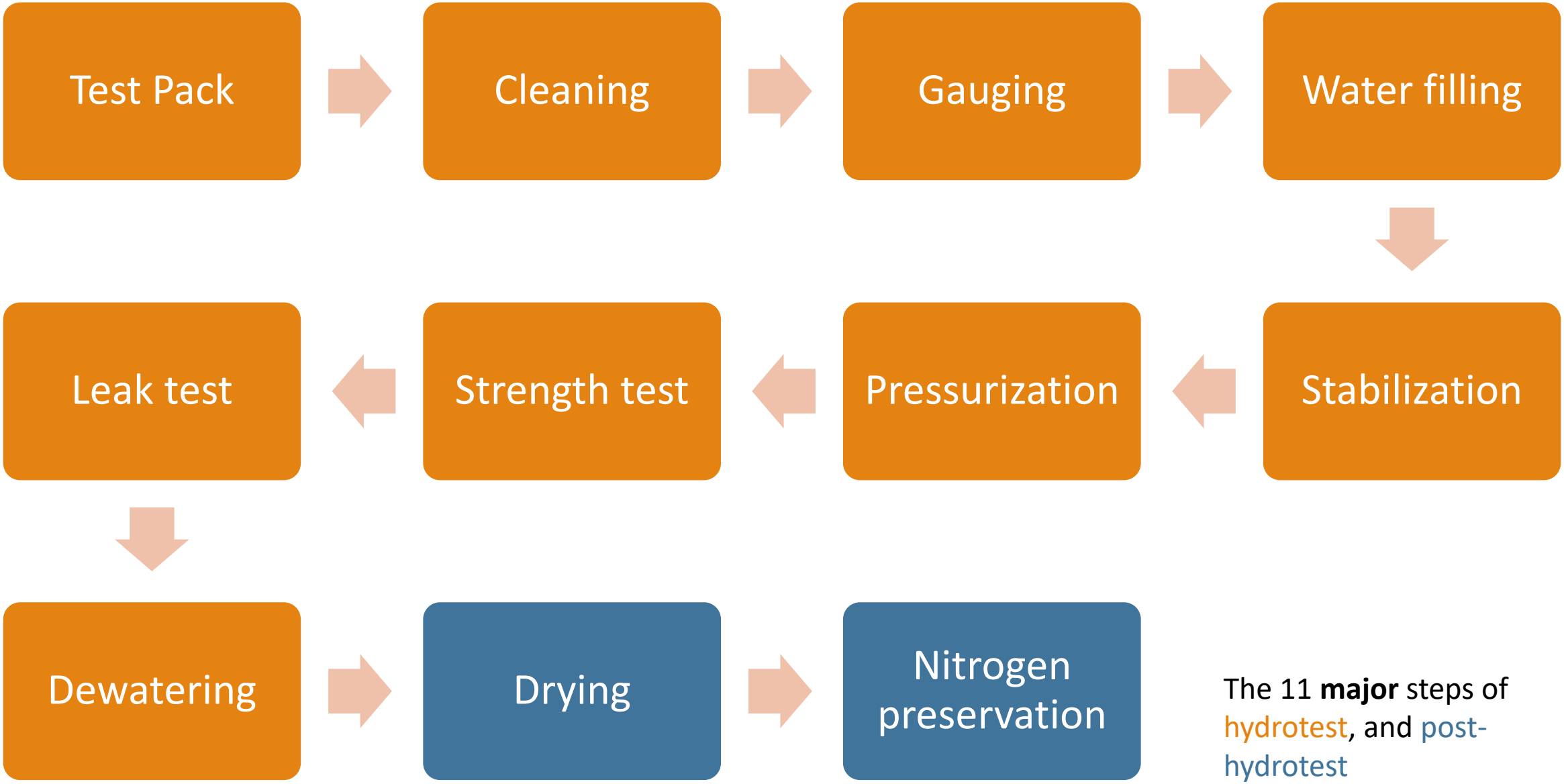
		YES	NO
1	Take the work permit / NOC from the users in concern area	√	
2	The test section has been isolated from all other pipeline sections.	√	
3	Is a copy of the hydrotest pack available in the area ?	√	
4	Is adequate water disposal arrangement made ?	√	
5	Check Housekeeping standards are acceptable at the filling end and receiving end.	√	
6	Check the conditions of the tools and tackles to be used.	√	
7	Check that the lighting arrangements are adequate and the condition of the electrical wiring circuit boards, conduit etc. are acceptable and safe.	√	
8	Check that test areas at each end of the test section have been cordoned off with stakes and bunting tape.	√	
9	Check that standby vehicle, communication system. first aid boxes. etc. are available	√	

Sequence of activities

1. Temporary pig traps made of carbon steel shall be connected to the test section through DSS line pipe pup piece only. (Please refer attached sketch in appendix-E)
2. Dis-similar welding will be carried out through approved WPS.
3. Air pigging – cleaning & Gauging
4. Cut the temporary weld joint and remove the Pig traps
5. Weld the main test header with the test section & complete the required NDT.
6. Water filling, Hydro Testing (4 hrs. + 24 hours) and Bulk dewatering / Transfer wherever applicable.
7. Cut the main test header weld joint and remove it from the test section.
8. Weld the pig trap with the test section.

Cont.

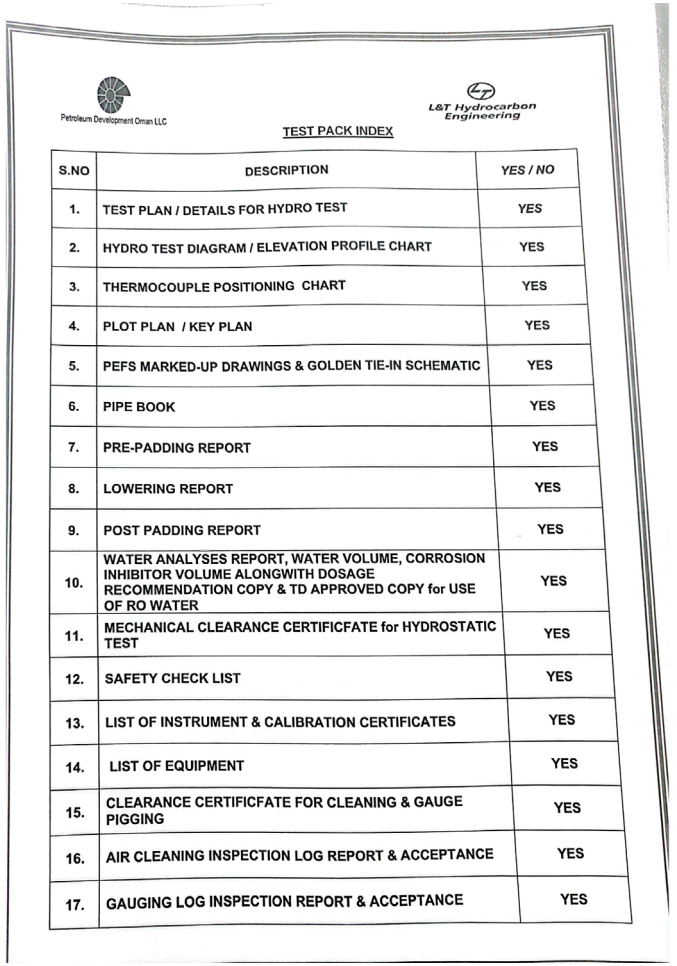
9. Complete two dewatering runs to remove the balance water from the test section. (First & Second dewatering runs). These pig runs may be carried out with using oil free compressor only.
10. Swabbing using foam pigs as per approved procedure.
11. Removal of pig traps but cutting the temporary weld joints.
12. Golden tie-in weld with flange at both ends.
13. Every station's battery limit flange end weld joint will be consider itself a "Golden weld Joint"
    (Please refer attached annexure-I Golden Joint tentative plan and marked-up PEFS)
14. Golden tie in welding as per pre agreed & identified allocation, NDT & Clearance for further activities.
15. Install the permanent valve on both end at the station flange end.
16. Drying. (With Air drying unit, as per Swabbing & Drying procedure)
17. Final drying and N2 preservation from permanent station valve flange to station valve flange.



The 11 **major** steps of hydrotest, and post-hydrotest

Test Pack

Contains all the information regrading the hydrotest.

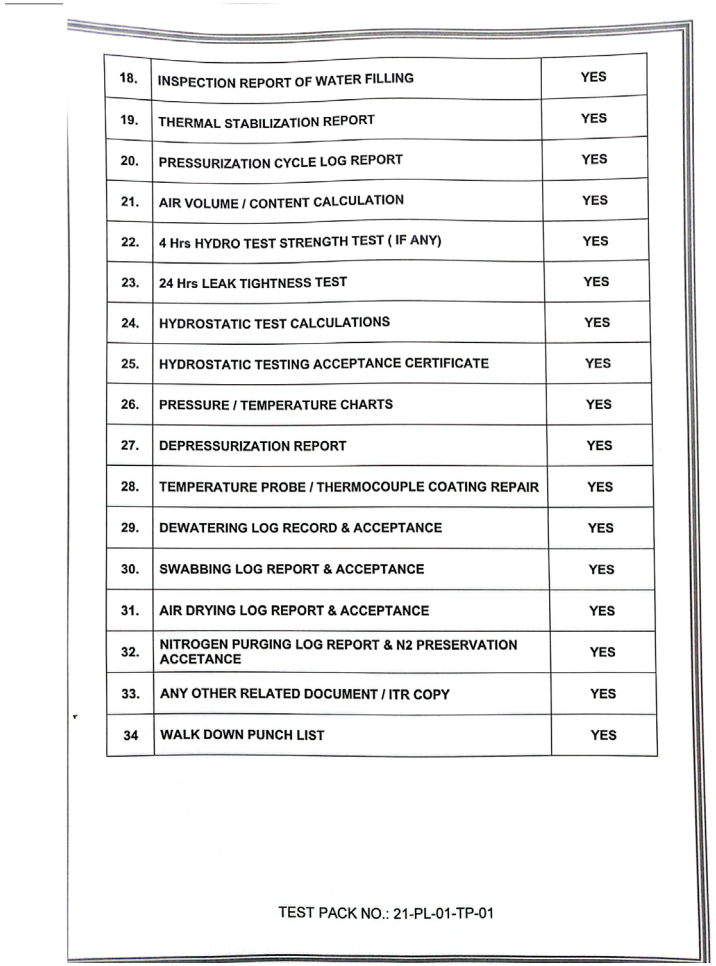


Petroleum Development Oman LLC

L&T Hydrocarbon Engineering

TEST PACK INDEX

S.NO	DESCRIPTION	YES / NO
1.	TEST PLAN / DETAILS FOR HYDRO TEST	YES
2.	HYDRO TEST DIAGRAM / ELEVATION PROFILE CHART	YES
3.	THERMOCOUPLE POSITIONING CHART	YES
4.	PLOT PLAN / KEY PLAN	YES
5.	PEFS MARKED-UP DRAWINGS & GOLDEN TIE-IN SCHEMATIC	YES
6.	PIPE BOOK	YES
7.	PRE-PADDING REPORT	YES
8.	LOWERING REPORT	YES
9.	POST PADDING REPORT	YES
10.	WATER ANALYSES REPORT, WATER VOLUME, CORROSION INHIBITOR VOLUME ALONGWITH DOSAGE RECOMMENDATION COPY & TD APPROVED COPY for USE OF RO WATER	YES
11.	MECHANICAL CLEARANCE CERTIFICFATE for HYDROSTATIC TEST	YES
12.	SAFETY CHECK LIST	YES
13.	LIST OF INSTRUMENT & CALIBRATION CERTIFICATES	YES
14.	LIST OF EQUIPMENT	YES
15.	CLEARANCE CERTIFICFATE FOR CLEANING & GAUGE PIGGING	YES
16.	AIR CLEANING INSPECTION LOG REPORT & ACCEPTANCE	YES
17.	GAUGING LOG INSPECTION REPORT & ACCEPTANCE	YES



18.	INSPECTION REPORT OF WATER FILLING	YES
19.	THERMAL STABILIZATION REPORT	YES
20.	PRESSURIZATION CYCLE LOG REPORT	YES
21.	AIR VOLUME / CONTENT CALCULATION	YES
22.	4 Hrs HYDRO TEST STRENGTH TEST (IF ANY)	YES
23.	24 Hrs LEAK TIGHTNESS TEST	YES
24.	HYDROSTATIC TEST CALCULATIONS	YES
25.	HYDROSTATIC TESTING ACCEPTANCE CERTIFICATE	YES
26.	PRESSURE / TEMPERATURE CHARTS	YES
27.	DEPRESSURIZATION REPORT	YES
28.	TEMPERATURE PROBE / THERMOCOUPLE COATING REPAIR	YES
29.	DEWATERING LOG RECORD & ACCEPTANCE	YES
30.	SWABBING LOG REPORT & ACCEPTANCE	YES
31.	AIR DRYING LOG REPORT & ACCEPTANCE	YES
32.	NITROGEN PURGING LOG REPORT & N2 PRESERVATION ACCETANCE	YES
33.	ANY OTHER RELATED DOCUMENT / ITR COPY	YES
34	WALK DOWN PUNCH LIST	YES

TEST PACK NO.: 21-PL-01-TP-01

Cleaning and Gauging

According to SP-1212 Sec. 6.1 :

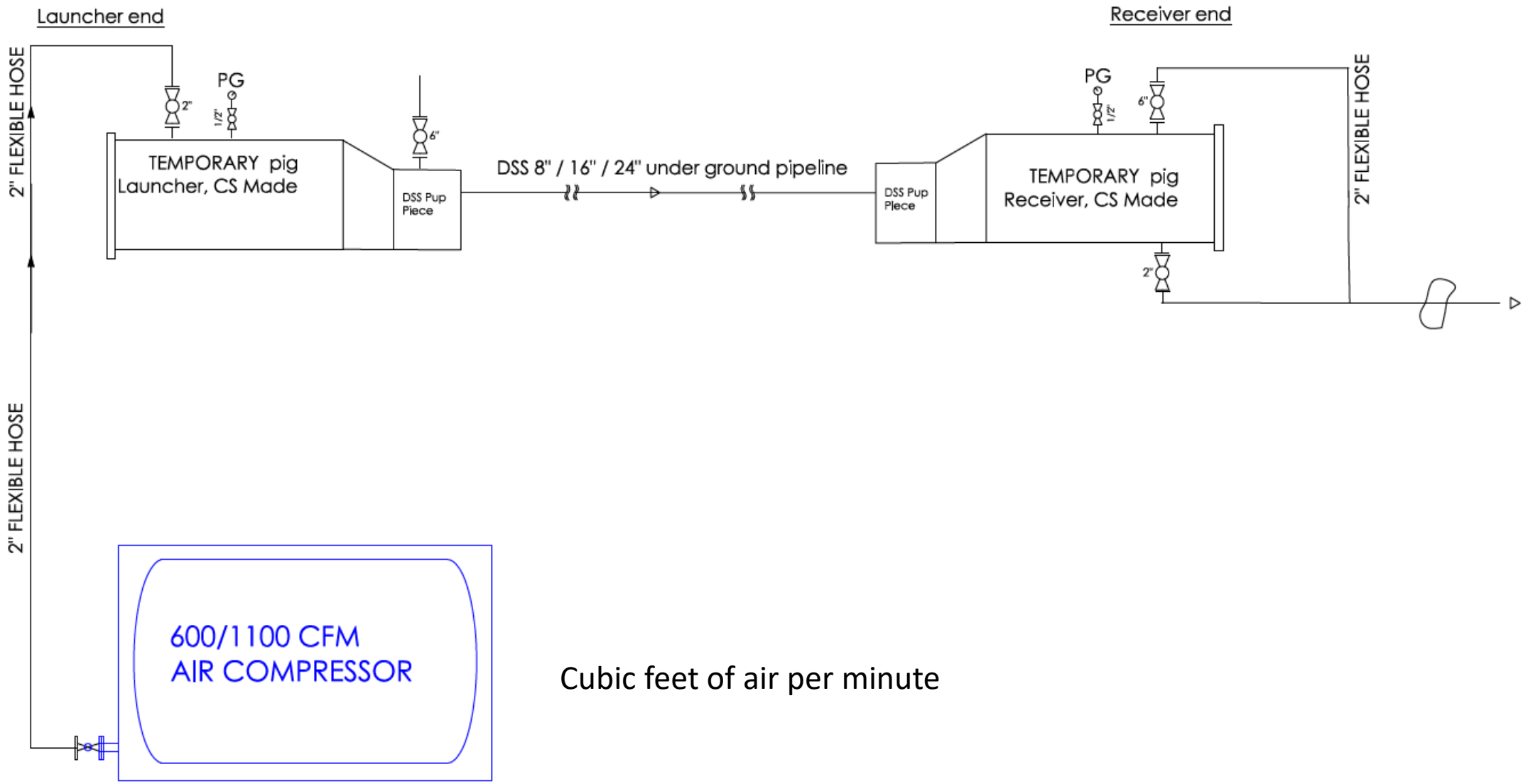
Temporary pig launchers and receivers **shall be approved** by the Company prior to use and shall be welded to the test section or flanged if a permanent flange is available.

If compressed air is to be used as the driving medium, the air should be water-free and the inlet line of the driving medium should be fitted with a **pressure relief valve set at 7 bar (g)**.

In pipelines **longer than 5 km**, single pigs or the last pig of a pig train should be **fitted with a pig location device**.

All pigging operations shall be documented in a pig register.

If a pig becomes stuck in the pipeline and the driving medium is air, the Contractor shall not employ a differential pressure greater than 7 bar to dislodge the pig $\Delta \boldsymbol{P}[\boldsymbol{bar}] \leq \mathbf{7}$.



Cubic feet of air per minute

Cont. Cleaning

According to SP-1212 Sec. 6.2 :

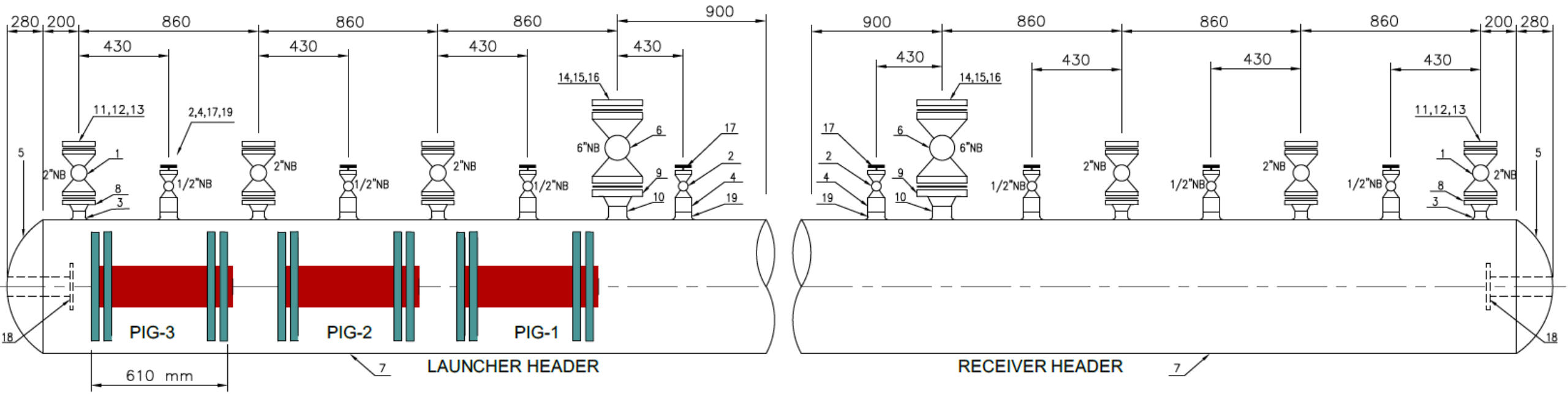
The speed of the cleaning pigs should be $0.5 \leq \dot{d}[\frac{m}{s}] \leq 2.5$.

The first pig driven through the cleaning section should be of bi-directional type.

A series of steel or metallic wire brush cleaning pigs in combination with a bi-directional pig should follow until the required cleanliness of the cleaning section has been established.

Pigging shall continue until the volume of the received material is less than 5 liters.

Title: MAIN LINE TEST HEADER SCHEMATIC DIAGRAM FOR Ø 16"



Cont. Gauging

According to SP-1212 Sec. 6.3 :

After cleaning and back-filling the trench, the complete test section shall be **gauged** by means of either a gauge plate pig or an instrumented caliper pig.

A **bi-directional pig** with **2 sets of separate guiding and sealing discs** shall be fitted with one or two **aluminum gauging plates**.

The gauging plates shall be examined for any signs of damage or irregularities such as **dents** and **buckles**.

The gauging plate diameter shall be determined from the formula:

d = ID - 0.01 D - 2b or d = 0.95 x ID, whichever is smaller,

where:	d	=	gauging plate diameter	mm
	D	=	nominal outside diameter	mm
	ID	=	minimum internal diameter taking due account of any thick wall pipe section and internal diameter of fittings	mm
	b	=	clearance of 5	mm

$D := 16\ \text{in} = 406.4\ \text{mm}$ $t := 10.5\ \text{mm}$

$ID := D - 2 \cdot t = 385.4\ \text{mm}$ $b := 5\ \text{mm}$

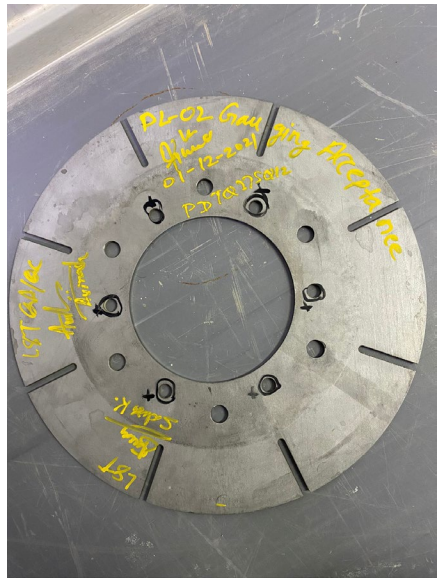
$d_1 := ID - 0.01 \cdot D - 2 \cdot b = 371.336\ \text{mm}$

$d_2 := 0.95 \cdot ID = 366.13\ \text{mm}$

$d_1 > d_2 = 1$ Therefore, d_2 shall be used.

DETAILS OF S S GAUGE PLATE

DESCRIPTION	SYMBOL	16"
GAUGE PLATE THK.	T	5 mm
INCISION LENGHT	I	25 mm
PITCH CIRCLE DIA	PCD	204 mm
No. Of Holes	N	6
Hole Dia	D	10 mm
No. Of INCISION AT 45 Deg		8
INNER CIRCLE DIA(Inner Cut)	ICD	152 mm



Water filling

For Duplex stainless steel pipelines & flow lines, the water quality analysis shall meet below requirements:

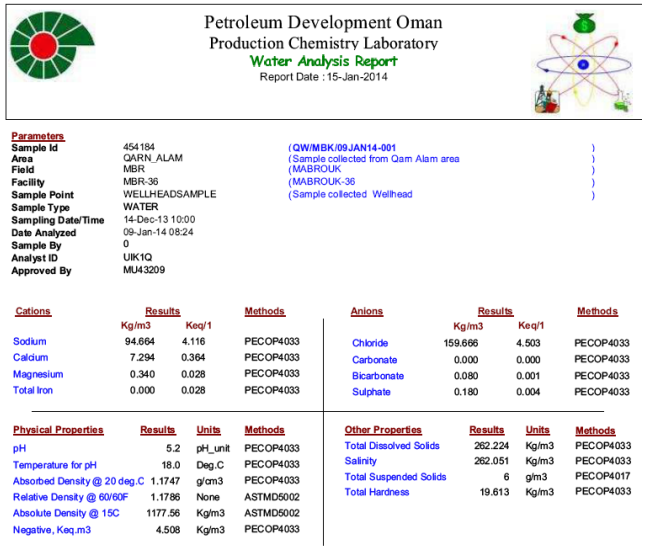
Substance	Concetration
Chlorides	<10.000ppm
Dissolved O_2	< 20ppb
Sulphate	<40ppm
Ammonium	<1 ppm
Phosphorus	<1 ppm

Cont.

The water shall be filtered through **50 micron filters** immediately prior to entering the pipeline.

For use in Water **Injection lines the filter size shall be 10 microns**.

Air should be prevented from entering the pipeline, by leaving the system full of water and **continuously pressurized at 1.5 bar**.



Petroleum Development Oman
Production Chemistry Laboratory
Water Analysis Report
Report Date : 15-Jan-2014

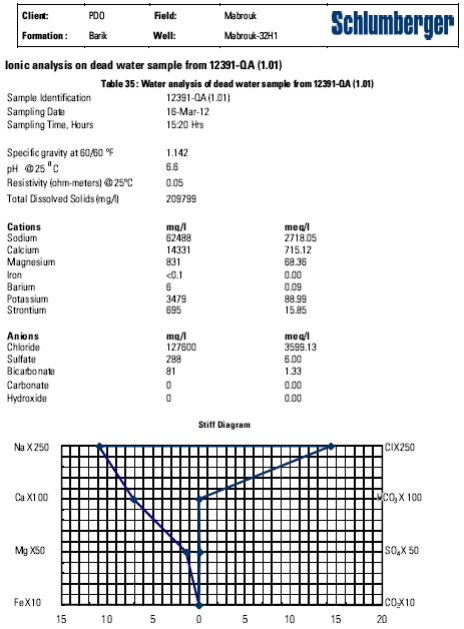
Parameters		
Sample Id	454184	(QW/MBK/09JAN14-001)
Area	QARN_ALAM	(Sample collected from Qam Alam area)
Field	MBR	(MABROUK)
Facility	MBR-36	(MABROUK-36)
Sample Point	WELLHEADSAMPLE	(Sample collected Wellhead)
Sample Type	WATER	
Sampling Date/Time	14-Dec-13 10:00	
Date Analyzed	09-Jan-14 08:24	
Sample By	0	
Analyst ID	UIK1Q	
Approved By	MU43209	

Cations	Results Kg/m3	Results Keq/l	Methods
Sodium	94.664	4.116	PECOP4033
Calcium	7.294	0.364	PECOP4033
Magnesium	0.340	0.028	PECOP4033
Total Iron	0.000	0.028	PECOP4033

Anions	Results Kg/m3	Results Keq/l	Methods
Chloride	159.666	4.503	PECOP4033
Carbonate	0.000	0.000	PECOP4033
Bicarbonate	0.080	0.001	PECOP4033
Sulphate	0.180	0.004	PECOP4033

Physical Properties	Results	Units	Methods
pH	5.2	pH_unit	PECOP4033
Temperature for pH	18.0	Deg.C	PECOP4033
Absorbed Density @ 20 deg.C	1.1747	g/cm3	PECOP4033
Relative Density @ 60/60F	1.1786	None	ASTMD5002
Absolute Density @ 15C	1177.56	Kg/m3	ASTMD5002
Negative, Keq.m3	4.508	Kg/m3	PECOP4033

Other Properties	Results	Units	Methods
Total Dissolved Solids	262.224	Kg/m3	PECOP4033
Salinity	262.051	Kg/m3	PECOP4033
Total Suspended Solids	6	g/m3	PECOP4017
Total Hardness	19.613	Kg/m3	PECOP4033



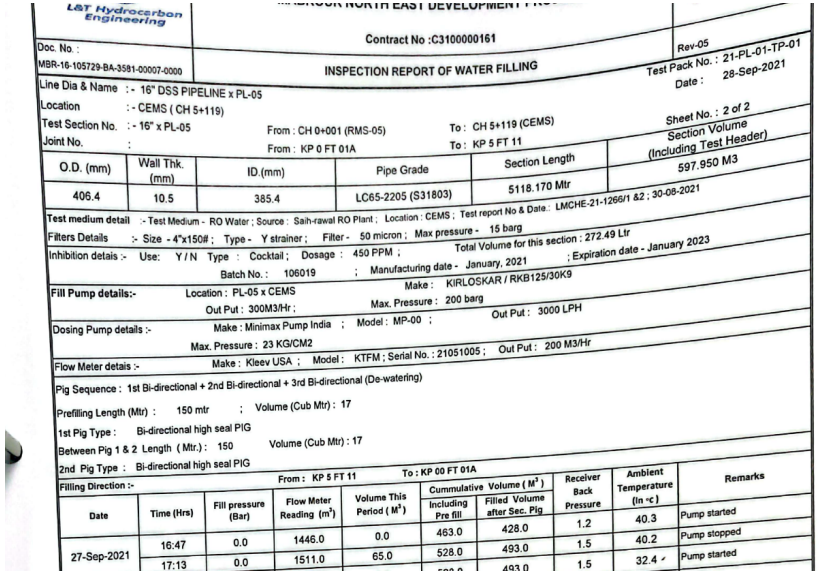
Client: PDO Field: Mabrouk
Formation : Barik Well: Mabrouk-32H1
Schlumberger

Ionic analysis on dead water sample from 12391-QA (1.01)

Table 35: Water analysis of dead water sample from 12391-QA (1.01)

Sample Identification	12391-QA (1.01)	
Sampling Date	16-Mar-12	
Sampling Time, Hours	15:20 Hrs	
Specific gravity at 60/60 °F	1.142	
pH @25 °C	6.6	
Resistivity (ohm-meters) @25°C	0.05	
Total Dissolved Solids (mg/l)	209799	
Cations	**mg/l**	**meq/l**
Sodium	62488	2718.05
Calcium	14331	715.12
Magnesium	831	68.36
Iron	<0.1	0.00
Barium	6	0.09
Potassium	3479	88.99
Strontium	695	15.85
Anions	**mg/l**	**meq/l**
Chloride	127600	3599.13
Sulfate	288	6.00
Bicarbonate	81	1.33
Carbonate	0	0.00
Hydroxide	0	0.00

Stiff Diagram



L&T Hydrocarbon Engineering

Contract No :C3100000161

Doc. No. : MBR-16-105729-BA-3581-00007-0000

Rev-05

INSPECTION REPORT OF WATER FILLING

Test Pack No. : 21-PL-01-TP-01
Date : 28-Sep-2021

Line Dia & Name : - 16" DSS PIPELINE x PL-05
Location : - CEMS (CH 5+119)
Test Section No. : - 16" x PL-05 From : CH 0+001 (RMS-05) To : CH 5+119 (CEMS)
Joint No. : From : KP 0 FT 01A To : KP 5 FT 11

Sheet No. : 2 of 2

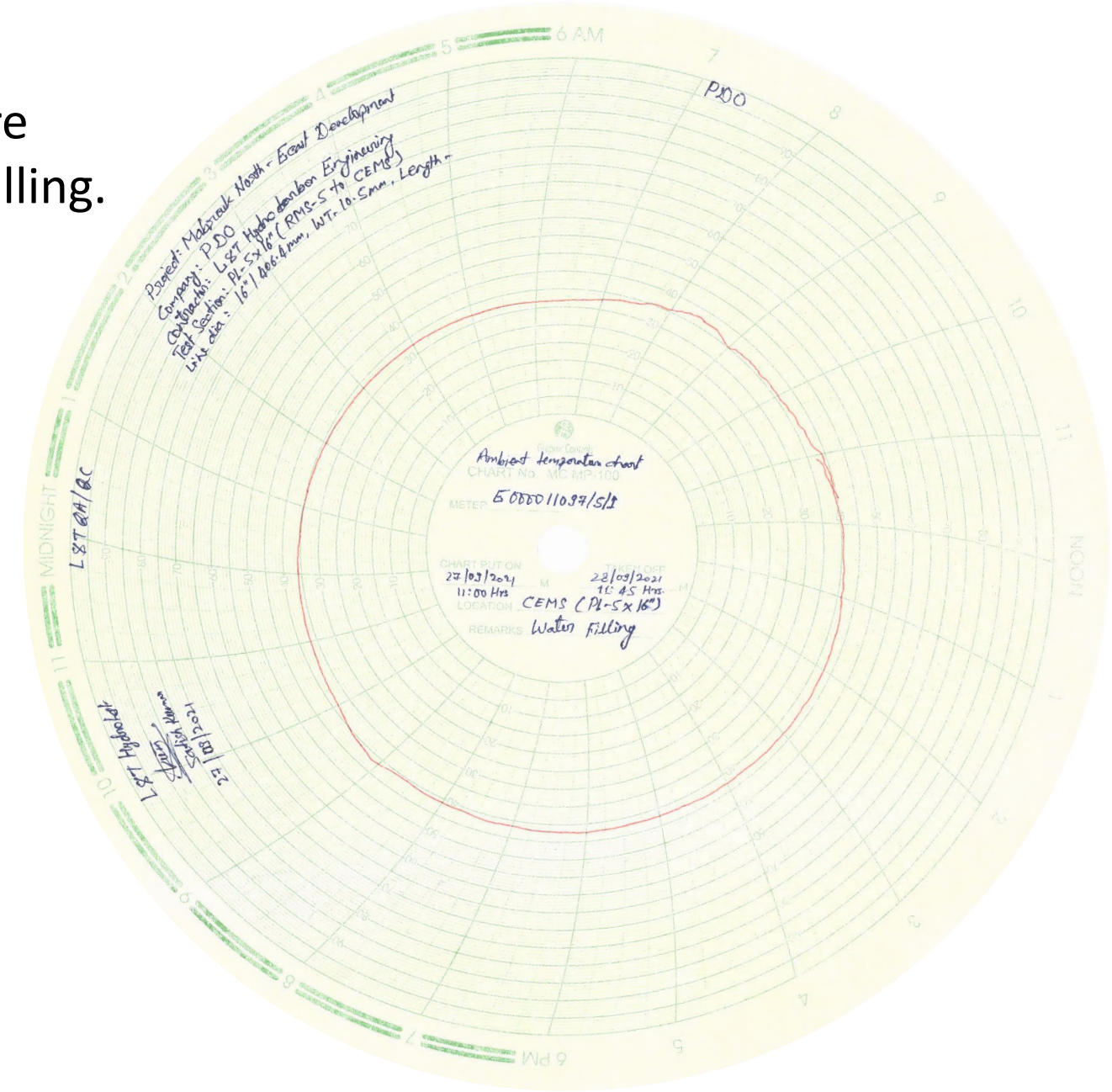
O.D. (mm)	Wall Thk. (mm)	ID.(mm)	Pipe Grade	Section Length	Section Volume (Including Test Header)
406.4	10.5	385.4	LC65-2205 (S31803)	5118.170 Mtr	597.950 M3

Test medium detail :- Test Medium - RO Water ; Source : Saih-rawal RO Plant ; Location : CEMS ; Test report No & Date.: LMCHE-21-1266/1 &2 ; 30-08-2021
Filters Details :- Size - 4"x150# ; Type - Y strainer ; Filter - 50 micron ; Max pressure - 15 barg
Total Volume for this section : 272.49 Ltr
Inhibition details :- Use: Y / N Type : Cocktail ; Dosage : 450 PPM ; Batch No. : 106019 ; Manufacturing date - January, 2021 ; Expiration date - January 2023
Fill Pump details:- Location : PL-05 x CEMS Make : KIRLOSKAR / RKB125/30K9
Out Put : 300M3/Hr ; Max. Pressure : 200 barg
Dosing Pump details :- Make : Minimax Pump India ; Model : MP-00 ; Out Put : 3000 LPH
Max. Pressure : 23 KG/CM2
Flow Meter details :- Make : Kleev USA ; Model : KTFM ; Serial No. : 21051005 ; Out Put : 200 M3/Hr
Pig Sequence : 1st Bi-directional + 2nd Bi-directional + 3rd Bi-directional (De-watering)
Prefilling Length (Mtr) : 150 mtr ; Volume (Cub Mtr) : 17
1st Pig Type : Bi-directional high seal PIG
Between Pig 1 & 2 Length (Mtr.) : 150 Volume (Cub Mtr) : 17
2nd Pig Type : Bi-directional high seal PIG
Filling Direction :- From : KP 5 FT 11 To : KP 00 FT 01A

Date	Time (Hrs)	Fill pressure (Bar)	Flow Meter Reading (M^3)	Volume This Period (M^3)	Cummulative Volume (M^3) Including Pre fill	Cummulative Volume (M^3) Filled Volume after Sec. Pig	Receiver Back Pressure	Ambient Temperature (in °c)	Remarks
27-Sep-2021	16:47	0.0	1446.0	0.0	463.0	428.0	1.2	40.3	Pump started
	17:13	0.0	1511.0	65.0	528.0	493.0	1.5	40.2	Pump stopped
						493.0	1.5	32.4	Pump started

Corrosion inhibitor injection

Ambient temperature chart during water-filling.



Stabilization

According to SP-1212 Sec. 7.2 :

Before the hydrostatic test is commenced, the water temperature should be **within 1.0 °C** of ground or seabed temperature.

The calculation of the temperature stabilization period based on the **expected line-fill water temperature** and **ambient temperature** shall be detailed in the test procedure.

Pressure and temperatures, including ambient, shall be recorded every hour during the stabilization period.

The test section temperature and the ambient temperature (ground/air/water) shall be plotted against time during the temperature stabilization period.

L&T Hydrocarbon Engineering

MABROUK NORTH EAST DEVELOPMENT PROJECT

Contract No :C3100000161

شركة تنمية نفط عمان Petroleum Development Oman

Doc. No. : MBR-16-105729-BA-3581-00007-0000	Temperature Thermocouple/Probe Location Chart (PL-05 x 16")	Rev-05

Line Dia & Name : 16" DSS PIPELINE

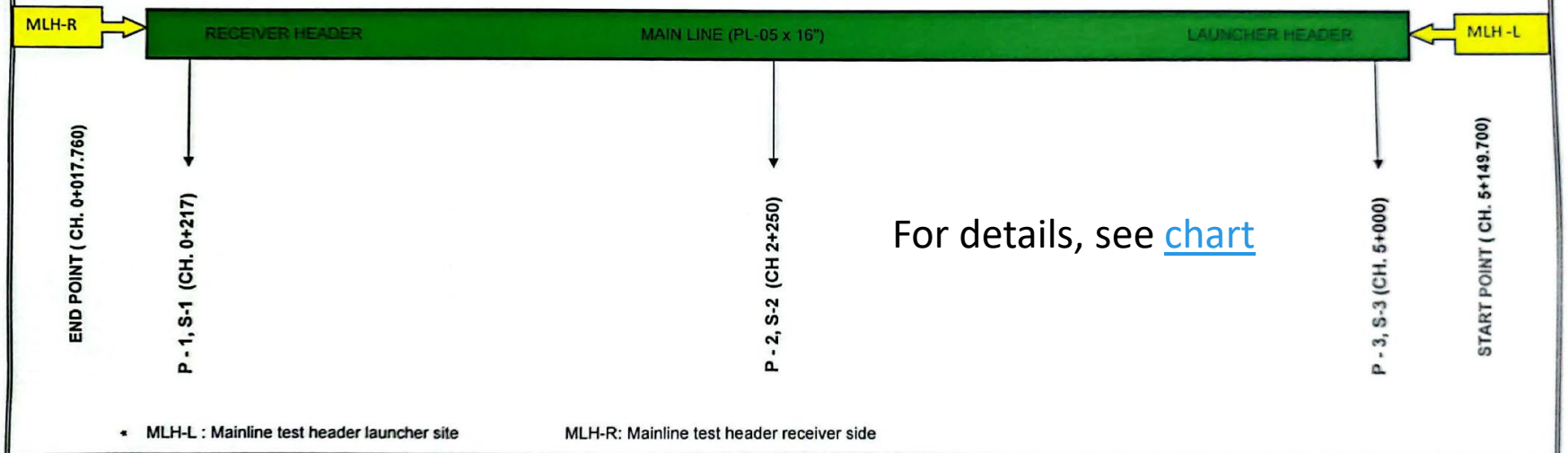
Test Location : CEMS (CH 5+116)

Test Pack No. : 21-PL-01-TP-01

Date : 10-Aug-2021

Test Section no. (TS) :PL-05 x 16" From : CH 0+000 (RMS-05) To : CH 5+116 (CEMS)

Joint No. : From : KP 0 FJ 01B To : KP 5 FJH 10

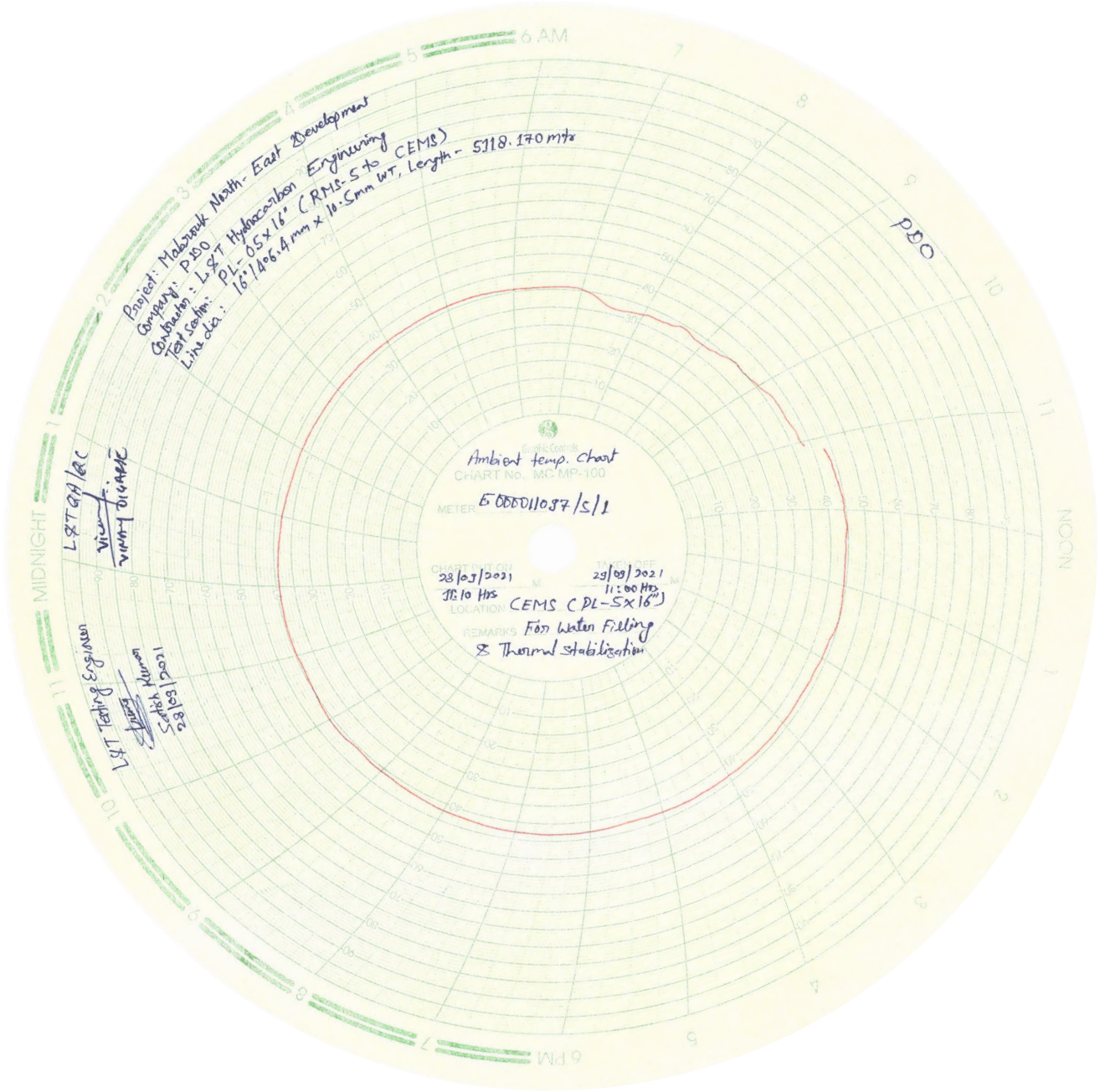


For details, see chart

* MLH-L : Mainline test header launcher site MLH-R: Mainline test header receiver side

Remarks (if any) :

For L&T TEST ENGINEER	For L&T QA/QC	For PDO / OWNER
Sign :	Sign :	Sign :
Name : Satish K.	Name : VINAY DIGHASE	Name : AKHILESH.V.N/PDTG27
Date : 28/09/2021	Date : 28.09.21	Date : 29/Sept/2021


Project: Mabrouk North-East Development
Company: PDO
Contractor: L&T Hydrocarbon Engineering
Test section: PL-05x16" (RMS-5 to CEMS)
Line dia.: 16"/406.4mm x 10.5mm WT, Length - 5118.170mtr
Ambient temp. Chart
CHART No. MC MP-100
5000011037/5/1
28/03/2021
18:10 Hrs
29/03/2021
11:00 Hrs
CEMS (PL-5x16")
For Water Filling
& Thermal stabilization
L&T QA/QC
L&T Testing Engineer
Satish Kumar
28/03/2021
PDO
MIDNIGHT
NOON
6 AM
6 PM

Pressurization

During the hydrostatic pressure test the**combined stress shall not exceed 100% SMYS** of line pipe material based **on minimum wall thickness**. The combined stress shall be calculated in accordance with SP-1211 section 4.3.5. **In no case the test pressure at the lowest point in the system, shall be more than 95 % SMYS**.

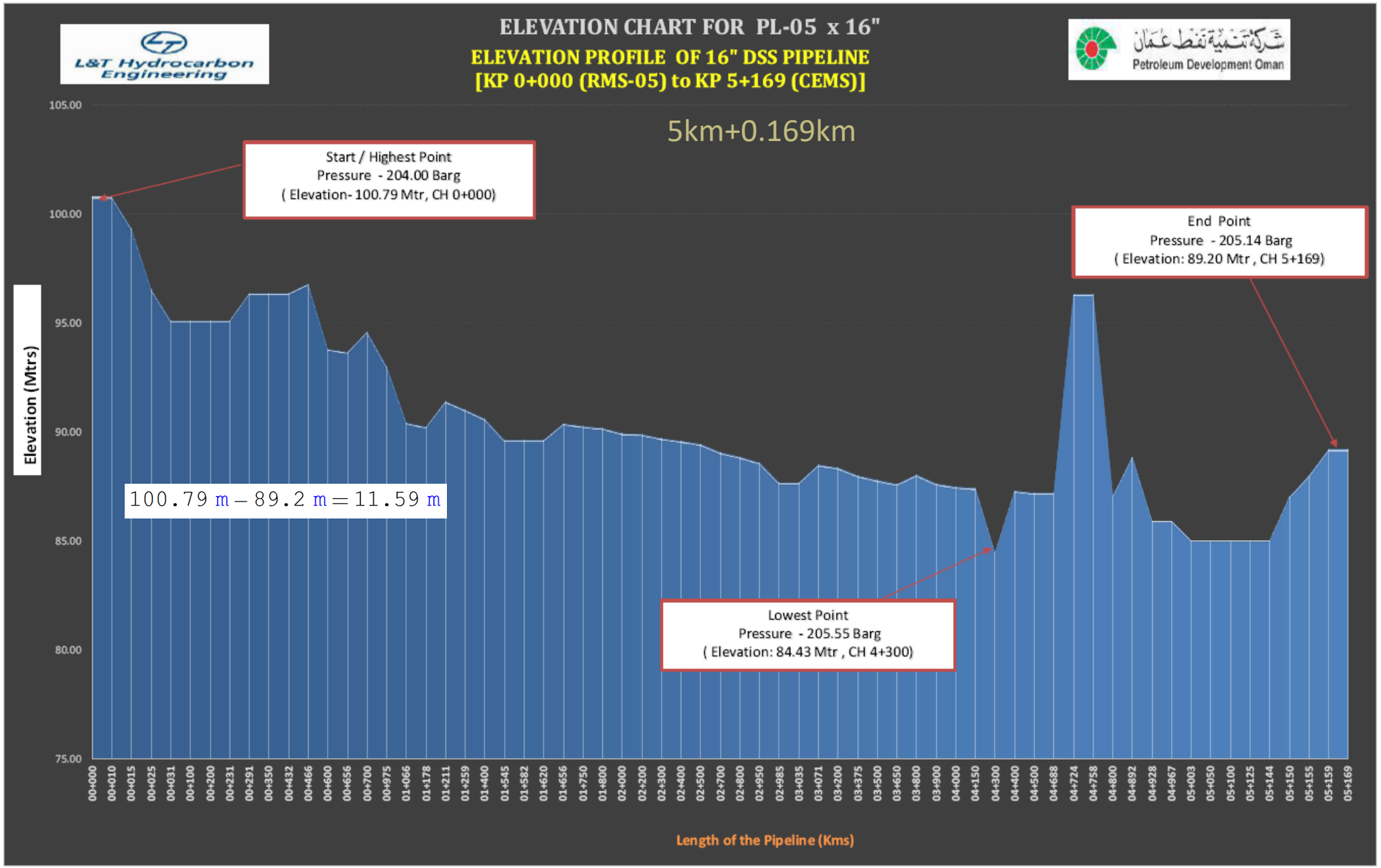
The elevation profile shall be plotted to assist in checking that the test pressures at the low and high points and shall not result in pressures OR combined stresses outside the limits specified above.

According to SP-1212 Sec. 7.3 :

The test engineer shall draw a plot of pressure/added volume (P/V plot, seeappendix 2), taking the volume added as measured either by **pump strokes** or **flow meter** and the pressure as measured by **deadweight tester** or **pressure data logger**.

Pressurization sequence

1. Test pressure at the Dead weight tester shall be decided that lowest elevation does not exceed the maximum test pressure.
2. All the temporary valves, fittings and high pressure hoses shall be rated up to minimum **6000PSI**.
3. As soon as thermal stabilization is achieved, pressurizing can be started. Pressure and temperature chart shall be **signed** by all parties prior to start the pressurization.
4. The rate of pressurization **shall not exceed 1 bar per minute** and shall continue **up to 35 Bar**.
5. During this period volume and pressure reading shall be recorded at **1bar increment intervals**. A plot of pressure/volume shall be made and the linear section of the curve extrapolated to the volume axis, which shall correspond to **static head pressure**.
6. Pressurization shall be stopped on reaching 35 bar of the test pressure and hold for 30 minutes for Air Volume calculation [∴]


ELEVATION CHART FOR PL-05 x 16"
ELEVATION PROFILE OF 16" DSS PIPELINE
[KP 0+000 (RMS-05) to KP 5+169 (CEMS)]
L&T Hydrocarbon Engineering
Petroleum Development Oman
5km+0.169km
Start / Highest Point
Pressure - 204.00 Barg
(Elevation- 100.79 Mtr, CH 0+000)
End Point
Pressure - 205.14 Barg
(Elevation: 89.20 Mtr , CH 5+169)
Lowest Point
Pressure - 205.55 Barg
(Elevation: 84.43 Mtr , CH 4+300)
100.79 m − 89.2 m = 11.59 m
Elevation (Mtrs)
105.00
100.00
95.00
90.00
85.00
80.00
75.00
Length of the Pipeline (Kms)

Cont. TP Calculations

a) Hydrostatic Test Pressure Calculation

If the test pressure is required to give a hoop stress of 90 % OR 95 % of SMYS based on minimum wall thickness, it should be calculated as follows:

$$TP = \frac{2 \times (t_{min}) \times S \times F \times E \times T}{D_o}$$

Where,

TP	=	Hydrostatic strength test pressure	MPa (g)
tmin	=	specific minimum wall thickness of pipe (i.e. nominal wall thickness less maximum negative tolerance)	m
Do	=	nominal outside diameter of pipe	m
S	=	Specified Minimum Yield Strength (SMYS)	Mpa
F	=	Design factor (for hydrostatic strength test, i.e. 90% stress level, F = 0.90)	
E	=	Longitudinal joint factor (for linepipe in accordance with DEP 31.40.20.37-Gen., E = 1.0)	
T	=	Temperature derating factor (for hydrostatic strength test, T = 1.0)	

$t_{wall} := 10.5\ mm$

$t_{Max.minus} := 0.21\ mm$

$D_{Nominal.out} := 16\ in = 406.4\ mm$

$S := 448\ MPa$

$F := 0.90$

$E := 1.0$

$T := 1.0$

$$TP := \frac{2 \cdot \left(t_{wall} - t_{Max.minus} \right) \cdot S \cdot F \cdot E \cdot T}{D_{Nominal.out}} = 204.1795\ bar$$

Cont. PV Calculations

a) Pipeline Volume (PV)

$$PV = \frac{\pi \times (I.D.)^2 \times L}{4}$$

Where

PV	:	Pipeline volume in cubic meters (m^3)
π	:	3.14159 or 22/7
ID	:	Pipeline Inside diameter (m)
L	:	Pipeline length (m)

Approx. Value

$L_{DataSum} := 5.169\ km = 5169\ m$

Exact Value

$L_{TestPack} := 5118.170\ m$

$ID := 385.4\ mm$

$$PV_1 := \frac{\pi \cdot ID^2 \cdot \left(L_{DataSum}\right)}{4} = 603.0035\ m^3$$

$$PV_2 := \frac{\pi \cdot ID^2 \cdot \left(L_{TestPack}\right)}{4} = 597.0738\ m^3$$

Error Percentage

$$\frac{PV_1 - PV_2}{PV_2} \cdot 100 = 0.9931$$

The error % is less than 1%; therefore negligible

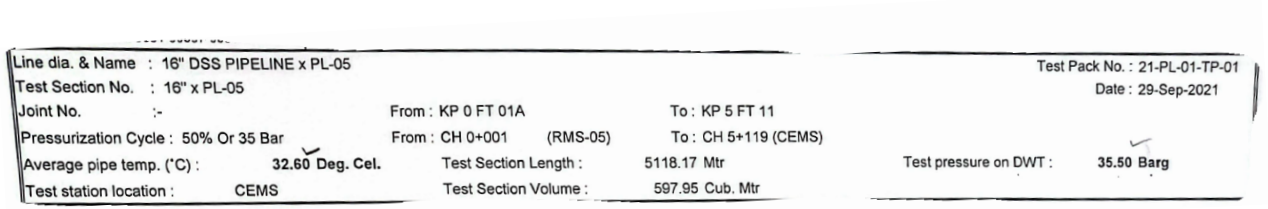
Cont. Air Volume Calculations

The followings formula can be used to calculate the theoretical volume of water required to raise the pressure in the pipeline:

$$\frac{\Delta V}{\Delta P} = PV \times \left[\frac{D \times (1 - u^2)}{Et} + \frac{1}{B} \right]$$

Where

ΔV	= incremental volume	(in m3)
Δp	= incremental pressure	(in bar)
PV	= Pipeline volume	(in m3)
D	= Pipeline outside diameter	(in m)
T	= Pipeline wall thickness	(in m)
E	= Young's elastic modulus of steel	= 2.07 x 106 bar
u	= Poisson's ratio	= 0.3 bar (For CS Pipes)
B	= Bulk modulus of water in bar based on temperate	(in Ċ)



Line dia. & Name	: 16" DSS PIPELINE x PL-05				Test Pack No. : 21-PL-01-TP-01
Test Section No.	: 16" x PL-05				Date : 29-Sep-2021
Joint No.	:-	From : KP 0 FT 01A		To : KP 5 FT 11	
Pressurization Cycle :	50% Or 35 Bar	From : CH 0+001	(RMS-05)	To : CH 5+119 (CEMS)	
Average pipe temp. (°C) :	32.60 Deg. Cel.	Test Section Length :	5118.17 Mtr	Test pressure on DWT :	35.50 Barg
Test station location :	CEMS	Test Section Volume :	597.95 Cub. Mtr		

$PV := 597.0738\ m^3$

$E := 2.00 \cdot 10^6\ bar$

$B := 22656.25\ bar$

Poisson's ratio for DSS

$\nu := 0.3$

$T := 10.5\ mm = 0.0105\ m$

$D := 16\ in = 0.4064\ m$

Test Pressure on DWT (initial)

$P_1 := 5\ bar$

Test Pressure on DWT (final) (deadweight tester)

$P_2 := 35.50\ bar$; Appendix_2

Incremental Pressure

$\Delta P := P_2 - P_1 = 30.5\ bar$

Incremental Volume

$$\Delta V := \left[PV \cdot \left[\frac{D \cdot \left[1 - \nu^2 \right]}{E \cdot T} + \frac{1}{B} \right] \right] \cdot \Delta P = 1.1245\ m^3$$

Cont. Air Volume Calculations

Air Volume Calculations for underground sections / Pressurization Calculations

$$V = \frac{(V\ act - V\ th) \times 100}{PV}$$

Where

V : Air content (%)

V act : Actual volume pumped (based on stroke counter reading)

V th : Theoretical volume to pressurize pipeline to required pressure

PV : Pipeline total fill volume

For the value of actual volume pumped, see Appendix 2

$$V_{Theoretical} := \Delta V = 1.1245\ m^3$$

$$V_{Actual} := 1210.0\ L = 1.21\ m^3$$

Percentage of air content

$$V_{Air\%} := \frac{\left(V_{Actual} - V_{Theoretical}\right)}{PV} \cdot 100 = 0.0143$$

Since **0.0143% is less than 0.2%** (total fill volume), then it satisfies the acceptance of Air Volume criteria.

Pressure – Temperature Effect Calculations

e) Pressure – Temperature Effect Calculation:

To determine whether any pressure variation is due to temperature changes or whether a leak is present, the pressure/temperature changes shall be calculated from the pressure/ temperature equation Formula 1 (1a for restrained test section or 1b for unrestrained test section).

Formula 1. Pressure/temperature equation for restrained test sections

$$\frac{\Delta P}{\Delta T} = \frac{y - 2(1+u) \times \alpha}{D \times \frac{(1-u2)}{Et} + \frac{1}{B}}$$

Formula 2. Pressure/temperature equation for un-restrained test sections

$$\frac{\Delta P}{\Delta T} = \frac{y - 3(1+u) \times \alpha}{D \times \frac{(1-u2)}{Et} + \frac{1}{B}}$$

Model : CST100 S. No. : E000011097/5 Calibration TC no. & Date : 0321/3950/250

Description	Highest Point	Lowest Point	Start Point	End Point
Elevation (In Meters)	100.82	84.71	89.41	100.82
Pressure (In Bar)	135.23	136.81	136.35	135.23

	Date	Time (Hrs)	DWT Pressure Reading (Bar)	Average Pipe Temp. (°C)
Start of test	30-Sep-2021	5:00	135.70	33.70
End of test	1-Oct-2021	5:00	136.35	34.25
Algebric difference (Start-End)			0.65 Bar (+/- ve Increase)	0.56 °C (+/- ve Increase)

To determine whether any pressure variation is due to temperature

$\Delta T := 0.56\ °C$

Volumetric expansion coefficient of water

$y := 340.909 \cdot 10^{-6}\ °C^{-1}$

See Appendix 2

Coefficient linear expansion of DSS

$\alpha := 13.5 \cdot 10^{-6}\ °C^{-1}$

$D := 16\ in = 0.4064\ m$

$t := 10.5\ mm = 0.0105\ m$

Young's elastic modulus of DSS

$E := 2 \cdot 10^{6}\ bar$

Poisson's ratio

$\nu := 0.3$

Bulk modulus of water

$B := 23187.5\ bar$

Cont.

Ratio ΔP/ΔT

$$n := \frac{y - 2 \cdot (1 + \nu) \cdot \alpha}{\frac{D \cdot \left[1 - \nu^{2}\right]}{E \cdot t} + \frac{1}{B}} = 5.0349 \cdot 10^{5} \ \frac{\text{Pa}}{°\text{C}}$$

$$5.0349 \cdot 10^{5} \ \text{Pa} \cdot (0.56) = 2.8195 \cdot 10^{5} \ \text{Pa}$$

relative pressure change for 0.56 C

$$\Delta P_{\alpha} := 2.8195 \cdot 10^{5} \ \text{Pa} = 2.8195 \ \text{bar}$$

$$P_1 := 135.70 \ \text{bar}$$

$$P_2 := 136.35 \ \text{bar}$$

Pressure measured

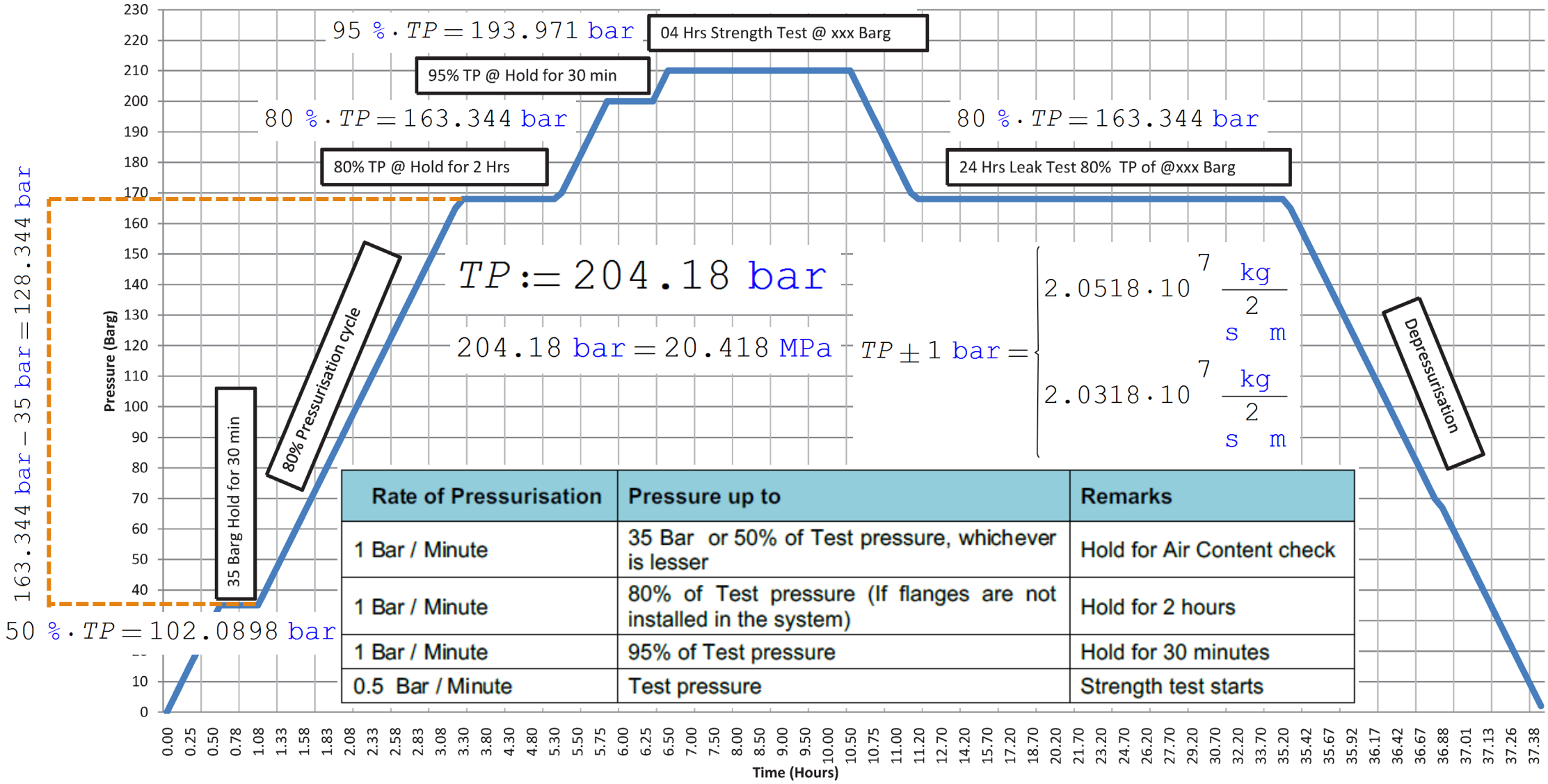
$$\Delta P_{\beta} := P_2 - P_1 = 0.65 \ \text{bar}$$

$$\Delta P_{\beta} \leq \Delta P_{\alpha} = 1$$

Therefore; the change is due to weather change not leakage.

Pressure Vs. Time Graph Chart for 8"/16"24"(KP __ to KP__)

$TP := 204.18\ bar$



$TP := 204.18\ bar$

$204.18\ bar = 20.418\ MPa$

$TP \pm 1\ bar = \begin{cases} 2.0518 \cdot 10^{7}\ \frac{kg}{s^2 m} \\ 2.0318 \cdot 10^{7}\ \frac{kg}{s^2 m} \end{cases}$

Rate of Pressurisation	Pressure up to	Remarks
1 Bar / Minute	35 Bar or 50% of Test pressure, whichever is lesser	Hold for Air Content check
1 Bar / Minute	80% of Test pressure (If flanges are not installed in the system)	Hold for 2 hours
1 Bar / Minute	95% of Test pressure	Hold for 30 minutes
0.5 Bar / Minute	Test pressure	Strength test starts

Strength test (4 hours test)

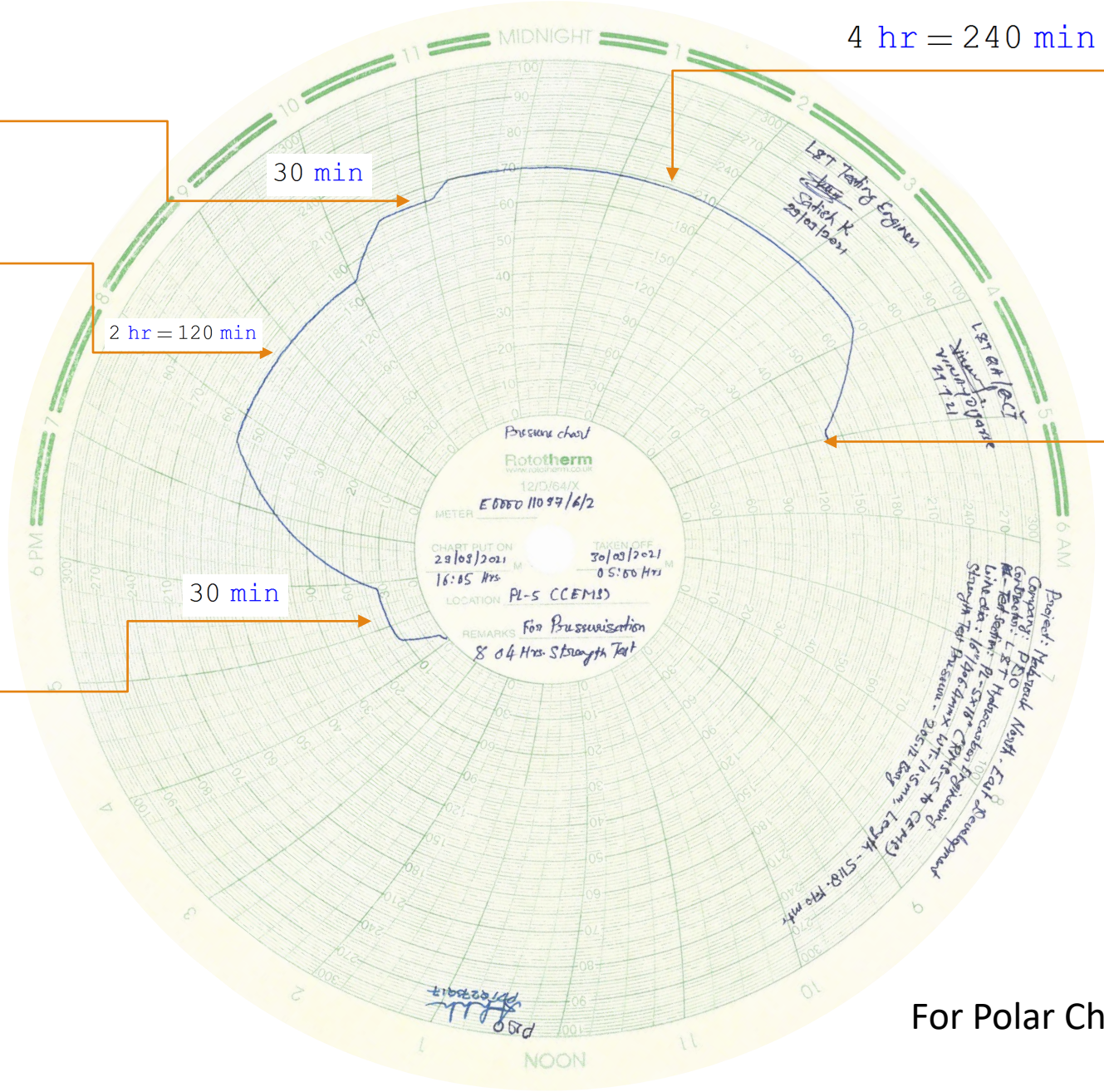
According to SP-1212 Sec. 8.2 :

The pressure shall be maintained during the strength test at strength test pressure **± 1 bar** by bleeding or adding water as required.

During the test, the test pressure shall be recorded continuously, and the deadweight tester readings or pressure data logger readings shall be recorded at least every 30 minutes. The **pipe soil and air** temperature shall be recorded **every 1.5 hours**.

When leak is suspected, then according to SP-1212 Sec. 10.1 :

1. Contractor shall reduce the pressure to DP and hold line at DP until leak is detected, by carrying out a visual examination.
2. If it is not possible to locate the suspected leak by visual examination, the Contractor shall use a method which enables the locating of leaks at test pressure without endangering the personnel carrying out the work.
3. When the leak has been found, the Contractor shall repair the test section in accordance with (SP-1212 Sec. 10.2 and Sec. 10.3).



$4\ \text{hr} = 240\ \text{min}$

$TP := 204.18\ \text{bar}$

$95\ \% \cdot TP = 193.971\ \text{bar}$

30 min

$80\ \% \cdot TP = 163.344\ \text{bar}$

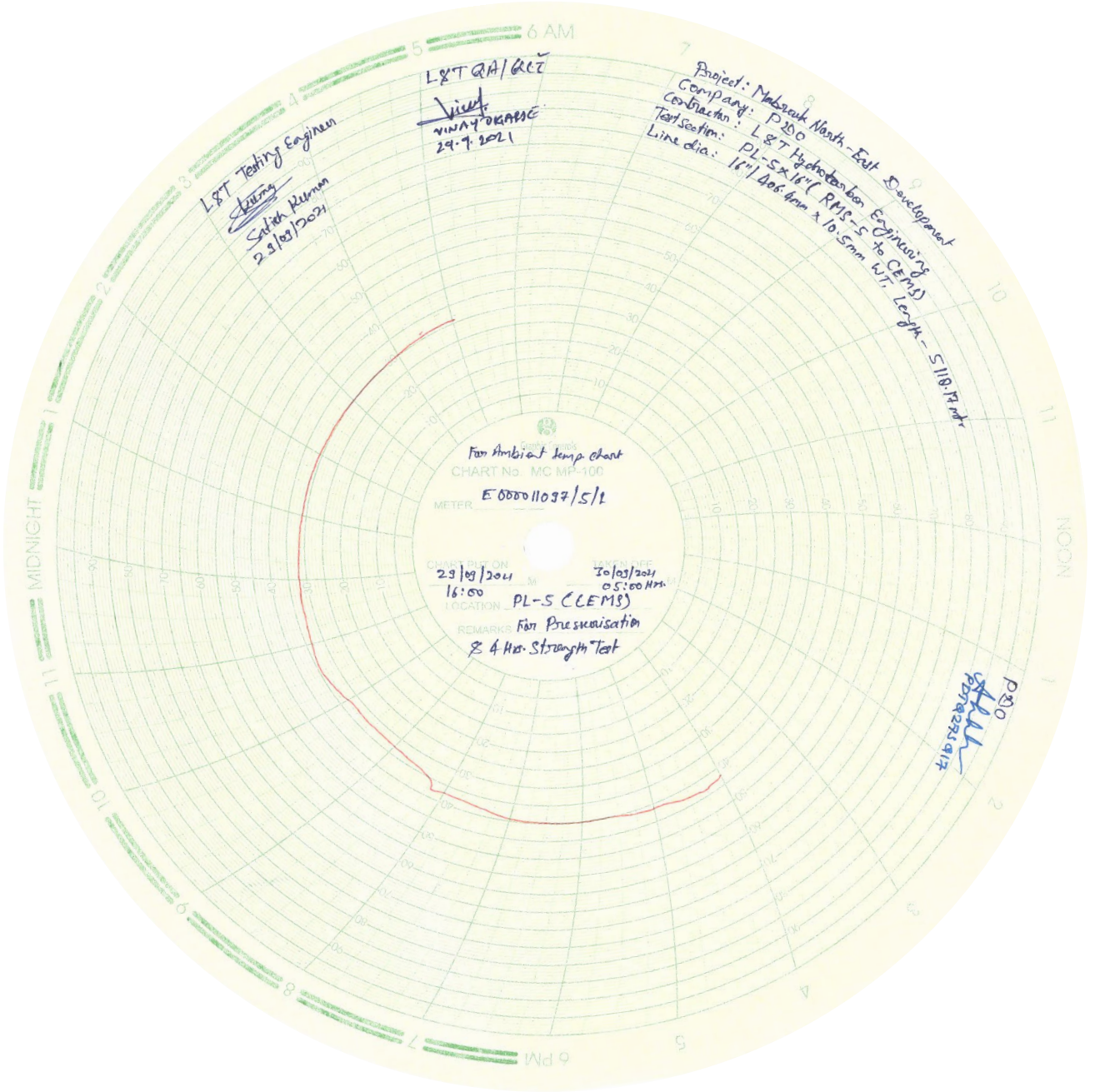
$2\ \text{hr} = 120\ \text{min}$

$80\ \% \cdot TP = 163.344\ \text{bar}$

30 min

35 bar

For Polar Chart Legends, see Appendix 2


L&T QA/QC
L&T Testing Engineer
Satish Kumar
29/09/2021
Project: Mabrouk North-East Development
Company: PDO
Contractor: L&T Hydrocarbon Engineering
Test section: PL-5 x 16" (RMS-5 to CEMS)
Line dia: 16" / 406.4mm x 10.5mm WT, Length - 5118.17 Mtr.
For Ambient temp. chart
CHART No. MC MP-100
E 0000110397/5/L
29/09/2021
16:00
10/03/2021
05:00 Hrs.
PL-5 (CEMS)
For Pressurisation
& 4 Hrs. Strength Test
PDO
MIDNIGHT
NOON
6 AM
6 PM

Leak test (or leak tightness test)

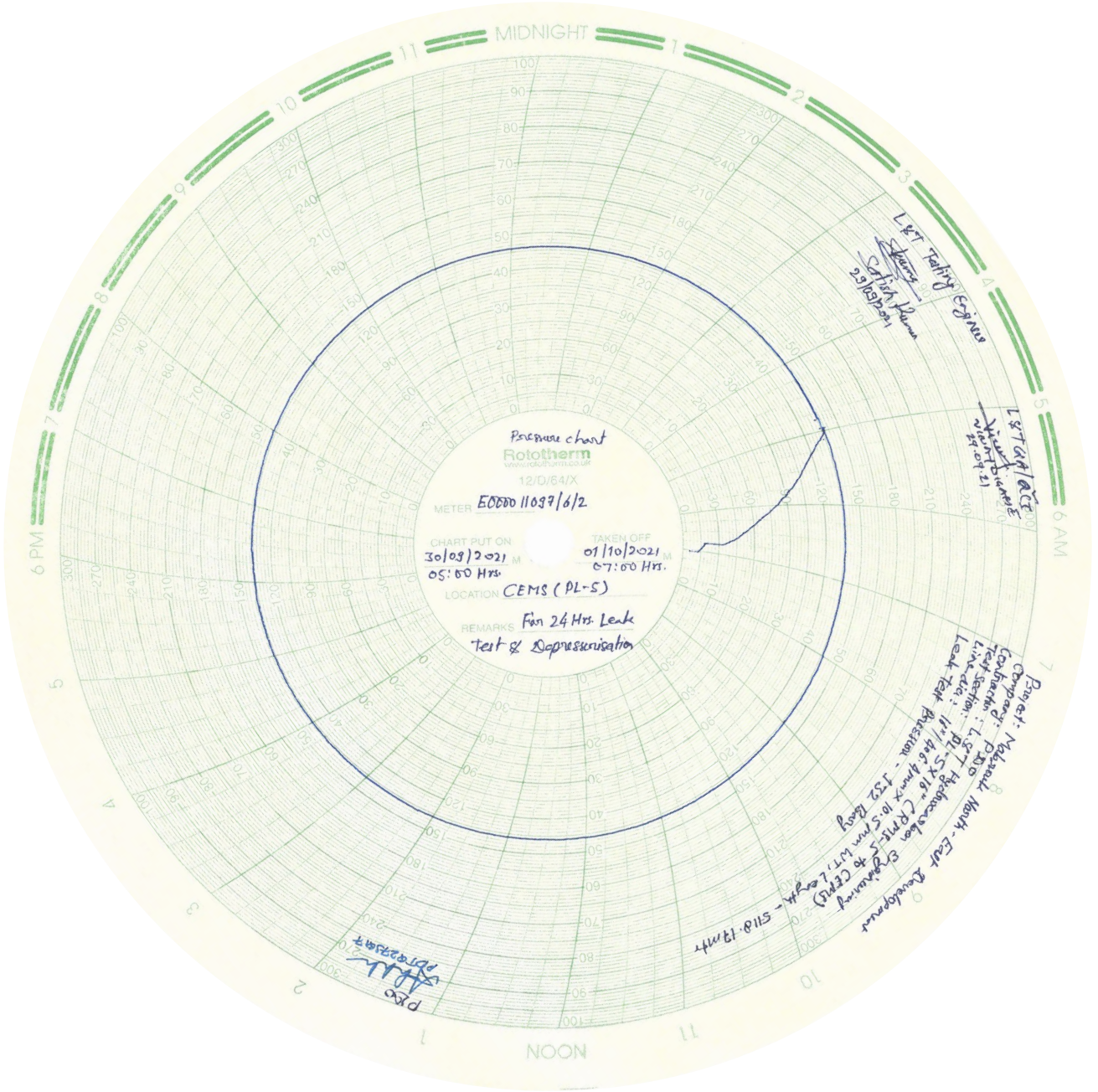
According to SP-1212 Sec. 8.3 :

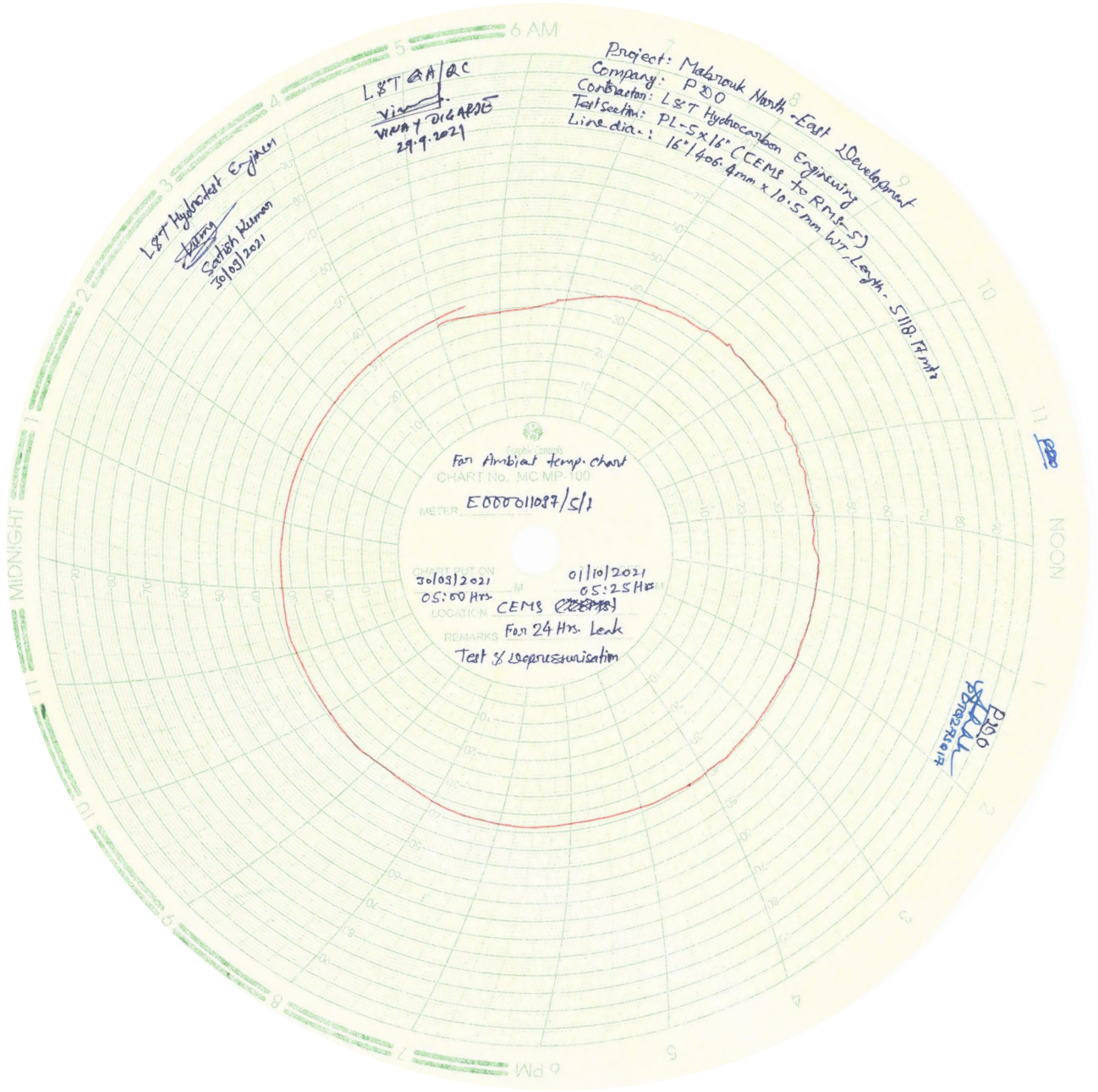
No water shall be added or removed during the tightness test.

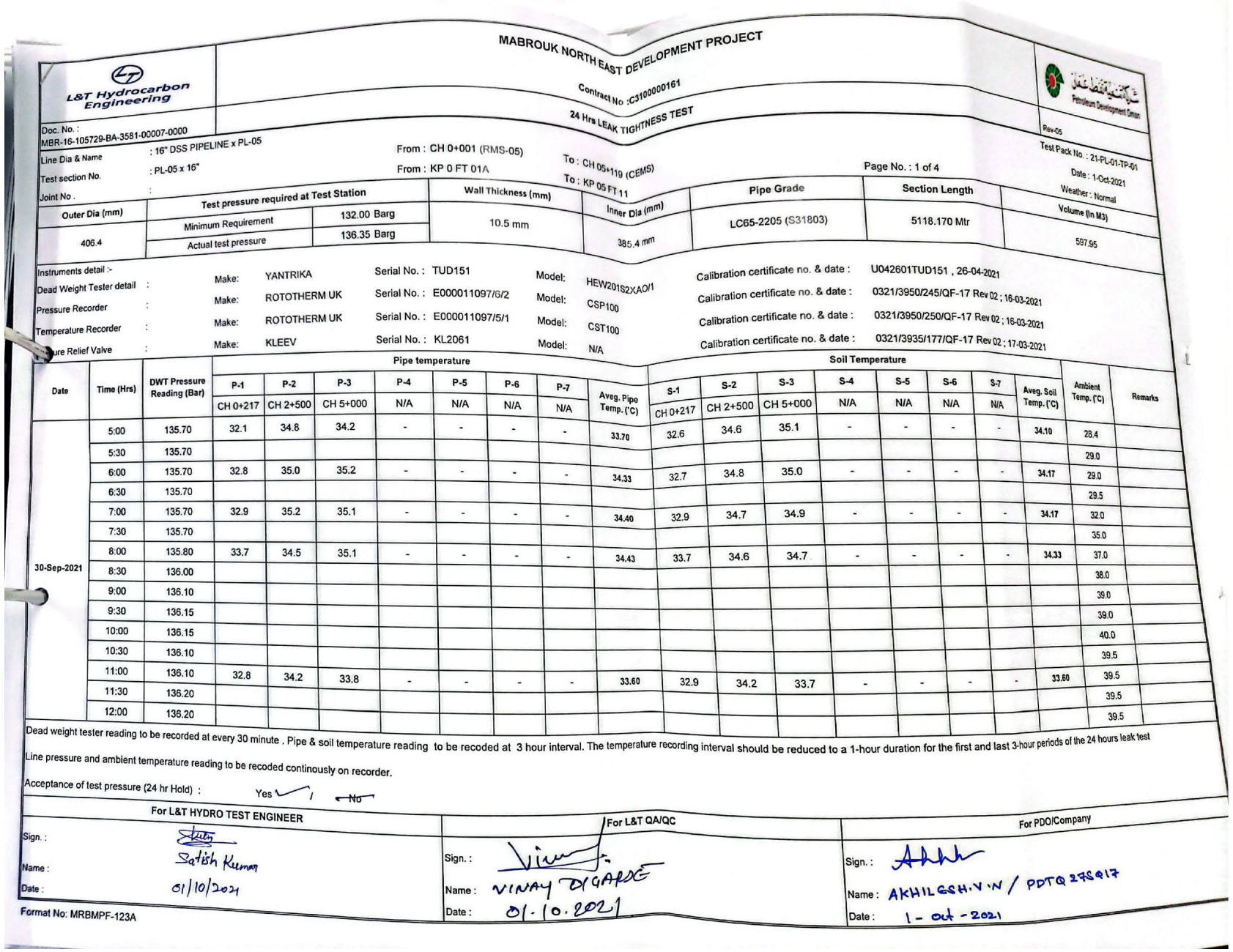
To allow for pressure variations caused by temperature fluctuations during the test duration, the test pressure should be set to a level of **1.1 times DP**.

During the test, the pressure shall be recorded continuously, and the deadweight tester readings shall be recorded every 30 minutes.

If a leak is suspected, actions shall be taken in accordance with (SP-1212 Sec.10.1).


MIDNIGHT
NOON
6 AM
6 PM
Pressure chart
Rototherm
12/D/64/X
METER E0000 11097/6/2
CHART PUT ON
30/09/2021
05:00 Hrs.
TAKEN OFF
01/10/2021
07:00 Hrs.
LOCATION CEMS (PL-5)
REMARKS Fin 24 Hrs. Leak Test & Depressurisation
Left Facility Engineer
Left GAIL/ACT
PDO


Project: Mabrouk North -East Development
Company: PDO
Contractor: L&T Hydrocarbon Engineering
Test section: PL-5 x 16" CEMS to RMS-5)
Line dia.: 16"/406.4mm x 10.5mm WT, Length - 5118 Rmts
L&T QA/QC
VINAY DIGAPOE
29.9.2021
L&T Hydrocarbon Engineer
Satish Kumar
30/09/2021
For Ambient temp. chart
E0000110087/S/1
30/03/2021
05:00 Hrs.
01/10/2021
05:25 Hrs
CEMS
For 24 Hrs. Leak
Test & Depressurisation
PDO



L&T Hydrocarbon Engineering

MABROUK NORTH EAST DEVELOPMENT PROJECT

Contract No :C3100000161

24 Hrs LEAK TIGHTNESS TEST

Petroleum Development Oman

Doc. No. : MBR-16-105729-BA-3581-00007-0000

Rev-05

Line Dia & Name : 16" DSS PIPELINE x PL-05

Test section No. : PL-05 x 16"

Joint No . :

From : CH 0+001 (RMS-05)

From : KP 0 FT 01A

To : CH 05+119 (CEMS)

To : KP 05 FT 11

Page No. : 1 of 4

Test Pack No. : 21-PL-01-TP-01

Date : 1-Oct-2021

Weather : Normal

Outer Dia (mm)	Test pressure required at Test Station		Wall Thickness (mm)	Inner Dia (mm)	Pipe Grade	Section Length	Volume (In M3)
406.4	Minimum Requirement	132.00 Barg	10.5 mm	385.4 mm	LC65-2205 (S31803)	5118.170 Mtr	597.95
	Actual test pressure	136.35 Barg					

Instruments detail :-

Dead Weight Tester detail :	Make: YANTRIKA	Serial No. : TUD151	Model: HEW201S2XAO/1	Calibration certificate no. & date :	U042601TUD151 , 26-04-2021	
Pressure Recorder :	Make: ROTOTHERM UK	Serial No. : E000011097/6/2	Model: CSP100	Calibration certificate no. & date :	0321/3950/245/QF-17 Rev 02 ; 16-03-2021	
Temperature Recorder :	Make: ROTOTHERM UK	Serial No. : E000011097/5/1	Model: CST100	Calibration certificate no. & date :	0321/3950/250/QF-17 Rev 02 ; 16-03-2021	
ure Relief Valve :	Make: KLEEV	Serial No. : KL2061	Model: N/A	Calibration certificate no. & date :	0321/3935/177/QF-17 Rev 02 ; 17-03-2021	

Date	Time (Hrs)	DWT Pressure Reading (Bar)	Pipe temperature								Soil Temperature								Ambient Temp. (°C)	Remarks
			P-1 CH 0+217	P-2 CH 2+500	P-3 CH 5+000	P-4 N/A	P-5 N/A	P-6 N/A	P-7 N/A	Aveg. Pipe Temp. (°C)	S-1 CH 0+217	S-2 CH 2+500	S-3 CH 5+000	S-4 N/A	S-5 N/A	S-6 N/A	S-7 N/A	Aveg. Soil Temp. (°C)		
30-Sep-2021	5:00	135.70	32.1	34.8	34.2	-	-	-	-	33.70	32.6	34.6	35.1	-	-	-	-	34.10	28.4	
	5:30	135.70																	29.0	
	6:00	135.70	32.8	35.0	35.2	-	-	-	-	34.33	32.7	34.8	35.0	-	-	-	-	34.17	29.0	
	6:30	135.70																	29.5	
	7:00	135.70	32.9	35.2	35.1	-	-	-	-	34.40	32.9	34.7	34.9	-	-	-	-	34.17	32.0	
	7:30	135.70																	35.0	
	8:00	135.80	33.7	34.5	35.1	-	-	-	-	34.43	33.7	34.6	34.7	-	-	-	-	34.33	37.0	
	8:30	136.00																	38.0	
	9:00	136.10																	39.0	
	9:30	136.15																	39.0	
	10:00	136.15																	40.0	
	10:30	136.10																	39.5	
	11:00	136.10	32.8	34.2	33.8	-	-	-	-	33.60	32.9	34.2	33.7	-	-	-	-	33.60	39.5	
	11:30	136.20																	39.5	
	12:00	136.20																	39.5	

Dead weight tester reading to be recorded at every 30 minute . Pipe & soil temperature reading to be recoded at 3 hour interval. The temperature recording interval should be reduced to a 1-hour duration for the first and last 3-hour periods of the 24 hours leak test

Line pressure and ambient temperature reading to be recoded continously on recorder.

Acceptance of test pressure (24 hr Hold) : Yes ✓ / ~~No~~

For L&T HYDRO TEST ENGINEER	For L&T QA/QC	For PDO/Company
Sign. :	Sign. :	Sign. :
Name : Satish Kumar	Name : VINAY DIGARSE	Name : AKHILESH.V.N / PDTQ 275917
Date : 01/10/2021	Date : 01.10.2021	Date : 1-Oct-2021

Format No: MRBMPF-123A

Dewatering

Pre-dewatering:

- Depressurization (SP-1212 Sec. 9.1):
- The test section shall be depressurized to **static head plus 1.5 bar at highest point**, so that air does not enter into the test section.
- The depressurization rate **shall not exceed 1 bar per minute** until the pressure has **been reduced to 40 % of the test pressure**.
- Then depressurization shall continue at a rate of **less than 2 bar per minute**.

Dewatering (SP-1212 Sec. 9.3):

Method statements for these activities shall be submitted by CONTRACTOR to COMPANY Pipeline **TA3** for approval.

Drying

According to Method Statement For Dewatering, Swabbing, Drying & N2

Preservation Of Pipeline Sec. 6.6 :

The pipeline will be dried by the introduction of dry air with a dew point below**- 40 degree Celsius**.

During the injection of the dry air, foam pigs will be propelled through the pipeline to further absorb any water pockets left in the line from the final swabbing operation.

The air-drying operation will be accepted upon maintaining the required dew-point below of 5 degree Celsius or better at both ends of the pipelines.

Nitrogen preservation

The pipeline should be preserved with nitrogen until the system is ready for gas-in or commissioning.

The **pipeline to be preserved** under nitrogen pressure of **minimum 1 barg** or as instructed by owner in reference to overall pre-commissioning circumstances at that time.

Upon the completion of drying, the pipeline shall be preserved at pressure of 0.5 barg with nitrogen above the ambient pressure at any point along the pipeline.

Nitrogen used for purging and preservation shall have a minimum dew point of **-50 degree Celsius** at atmospheric pressure.

The **oxygen** content shall be checked and the same shall be **less than 2%** at the end of purging.

Temporary pressure gauge to be installed for verifying the positive nitrogen pressure in the pipeline and record it in a register, and to be **monitored monthly**.

L&T Hydrocarbon Engineering

MABROUK NORTH EAST DEVELOPMENT PROJECT

Contract No :C3100000161

Petroleum Development Oman

Doc. No. : MBR-16-105729-BA-3581-00008-0000

Nitrogen Purging Log Report

Rev.03

Test Pack No. : 21-PL-01-TP-01

Line Dia Ø : : PL-05 x 16" DSS Pipeline

Date : 28-Nov-2021

Test section no : PL-05 From : CH 0+000 (RMS-05) To : CH 5+118 (CEMS)

Joint No . : From : KP 00 GT 01 To : KP 05 GT 12

Outer Dia (mm)	Wall Thickness (mm)	Inner Dia (mm)	Pipe Grade	Section Length	Volume (m³)
406.4	10.5 mm	385.4	LC65-2205 (S31803)	5118.170 Mtr	597.950 Cub. Mtr
Date	Time (Hrs)	Pipeline Pessure (Bar)	Receiver end Oxygen (%)	Ambient Temp (°C)	Remarks
28-Nov-2021	15:45	0.0	19.5	38.2	N2 Purging start
	15:55	0.2	14.2	38.9	
	16:05	0.4	10.3	38.1	
	16:15	0.6	8.2	37.2	
	16:25	0.8	7.2	36.1	N2 Purging started. Blow down process is continue at the receiver side until O2 content measurement will not achiev less than or equal to 2 %
	16:35	0.8	5.1	35.0	
	16:45	0.9	1.2	35.0	
	16:55	1.2	0.0	33.0	
	17:05	1.5	0.0	33.0	
	17:15	1.9	0.0	31.2	
	17:25	2.1	0.0	28.4	
	17:35	2.2	0.0	27.3	02 content found with acceptable limit. Line has packed at 2.2 barg N2 pressure.
					* Dew point found at CEMS side is -51.8
					* Dew point found at RMS-05 side is -52.3

Remarks :

For L&T Testing Engineer	For L&T QA/QC	For PDO / Company
Sign. :	Sign. :	Sign. :
Name : Satish Kumar	Name : VINAY DIGARSE	Name : Fimas / PDTQ275012
Date : 28/11/2021	Date : 28-NOV-2021	Date : 30-11-2021

Format No: MRB-MPF-152

L&T Hydrocarbon Engineering

MABROUK NORTH EAST DEVELOPMENT PROJECT

Contract No :C3100000161

Petroleum Development Oman

Doc. No. : MBR-16-105729-BA-3581-00008-0000

Nitrogen Acceptance Report

Format No: MRB-MPF-153

Rev.03

Test Pack No. : 21-PL-01-TP-01

Line Dia Ø : : PL-05 x 16" DSS Pipeline

Date : 28-Nov-2021

Test section no : PL-05 From : CH 0+000 (RMS-05) To : CH 5+118 (CEMS)

Joint No . : From : KP 00 GT 01 To : KP 05 GT 12

Outer Dia (mm)	Wall Thickness (mm)	Inner Dia (mm)	Pipe Grade	Section Length	Volume (m³)
406.4	10.5 mm	385.4	LC65-2205 (S31803)	5118.170 Mtr	597.950 Cub. Mtr

Instrument Details :		Serial No :	Manufacture :	Calibration Date
	Oxygen Detector :	OY4070430	Riken Keiki	8-Aug-2021
	Pressure Gauge :	21DA - 0047	KLEEV USA	13-Apr-2021
	Temperature Recorder :	E000011097/5/1	Rototherm UK	16-Mar-2021

Accepted Oxygen % :	Oxygen %	Time (Hrs)	Date
	0.0	16:45	28-Nov-2021

Nitrogen injection Point: CH 05+118 (PL-05 x CEMS)

Acceptance Criteria : The acceptance criteria of nitrogen purging activity for air displacement, is when O2 percentage reaches at the receiver end below 2%

Remarks if any :

* Dew point found during N2 purging :

1) At PL-05 RMS-05 : -52.3

2) At PL-05 CEMS : -51.3

* PL-05 Pipeline has packed at 2.2 barg N2 pressure.

For L&T Testing Engineer	For L&T QA/QC	For PDO / Company
Sign. :	Sign. :	Sign. :
Name : Satish Kumar	Name : VINAY DIGARSE	Name : Fimas / PDTQ275012
Date : 28/11/2021	Date : 28/NOV/2021	Date : 30/NOV/2024

Format No: MRB-MPF-153

Usage of N_2

Facilities	Purging	Sensitive Leak Test	Pressure Test
Underground Pipeline	✓	X	X
Aboveground Piping	✓	✓ (Note-1)	✓

Appendix_1

– The maximum elapsed time between completion of blast-cleaning and preheating depends upon relative humidity but shall in any event not exceed 4 hours. If the elapsed time is exceeded, the field joint must be re-blasted.

Relative humidity (%)	Elapsed time (hours)
85	0.5
80	1
70	1.5
60	1.75
50	2

- The acceptable peel strength value as mentioned below.

20 °C (68°F)	> 4.0 N/mm (22.8 lbf/in)
25 °C to 60 °C (77 to 140°F)	> 2.0 N/mm (11.4 lbf/in)
> 60 °C (140°F)	> 2.0 N/mm (11.4 lbf/in)

Figure 1 - The saturated filter paper extraction method

Fill the syringe with 1.6 ml of high purity water.

Note: Non-pure water (up to 2µg/cm²) can be automatically offset with the gauge.

Eject the 1.6ml on to a clean unused sample paper, taking care to retain all the water on the paper.

Place wetted paper on to the area under test, pressing firmly into contours and irregularities to remove any entrapped air.

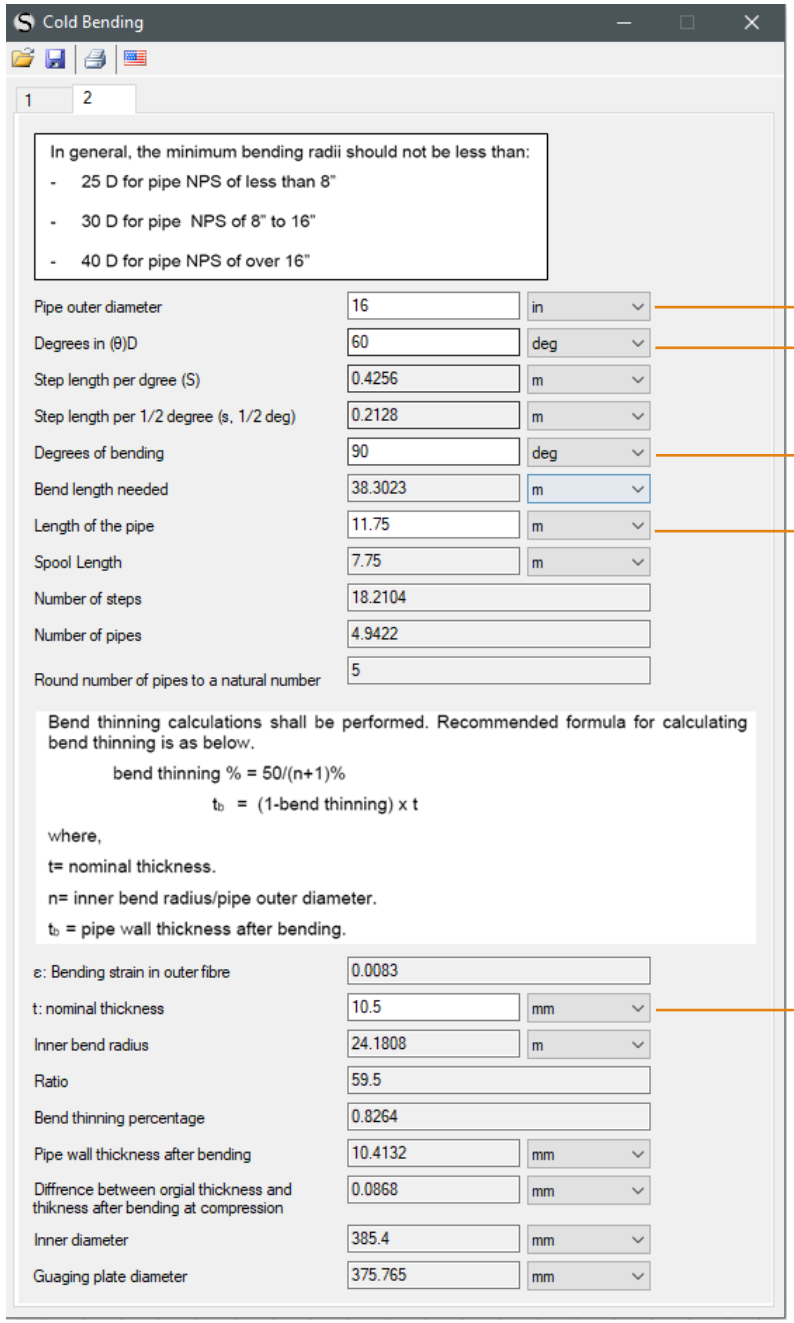
Start the timer on the gauge. Whilst waiting for the sample time to elapse, additional tests can be prepared.

After 2 minutes, remove the paper from the surface and place it on to the gold-plated electrodes.

Close the lid, ensuring that the magnetic catch is fully engaged.

The reading will automatically be displayed and stored into memory together with paper size, temperature, date and time.

The reading will be displayed.



Inputs with options to choose compatible units

→ Appendix_2

Doc. No. : MBR-16-105729-BA-3581-00007-0000

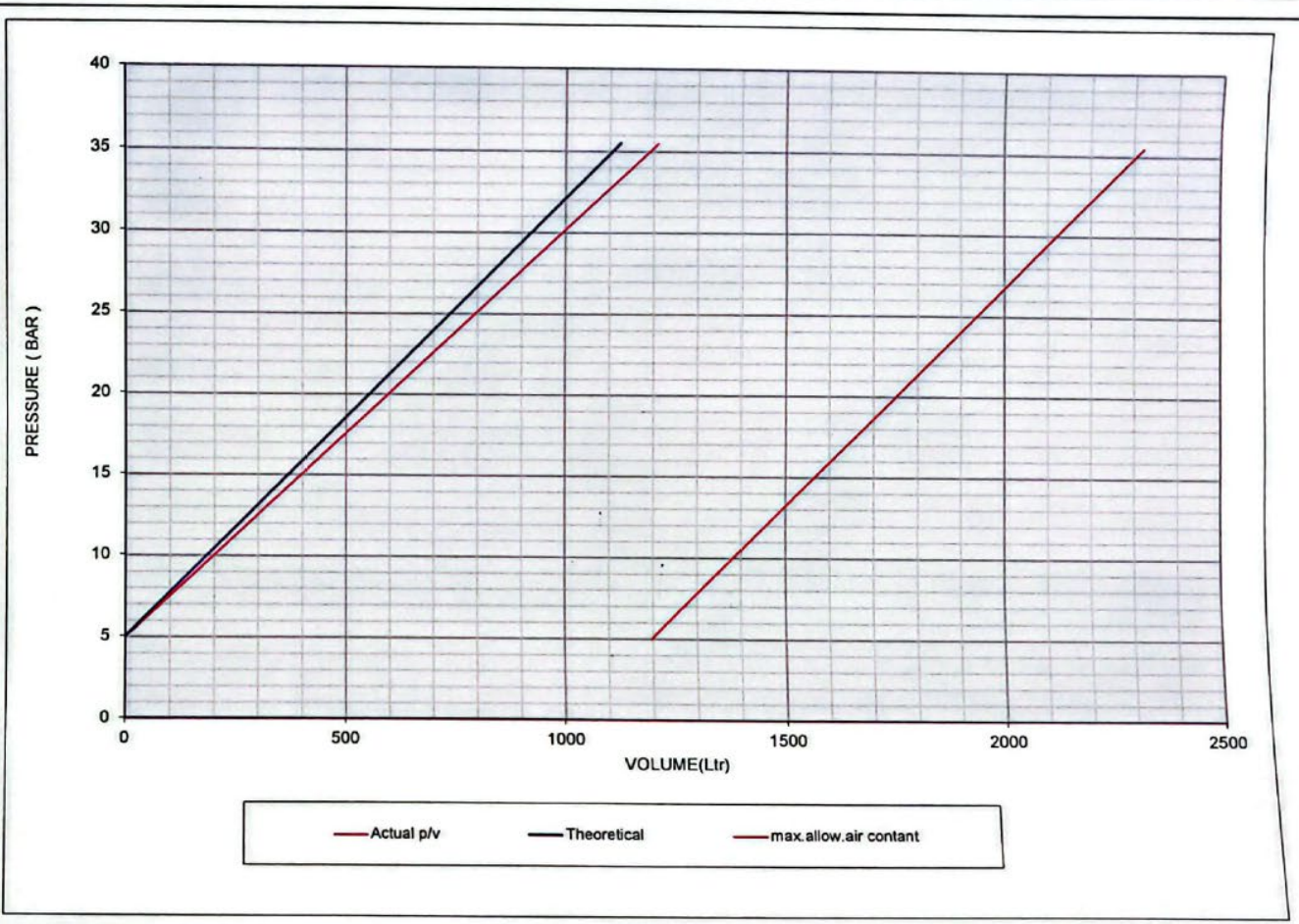
PV CHART for 35 Bar Air Content

Line Dia & Name : 16" DSS Pipeline
Test section No : PL-05 x 16"
Joint No . :

From : CH 0+001 (RMS-05)
From : KP 0 FT 01A
To : CH 5+119 (CEMS)
To : KP 5 FT 11

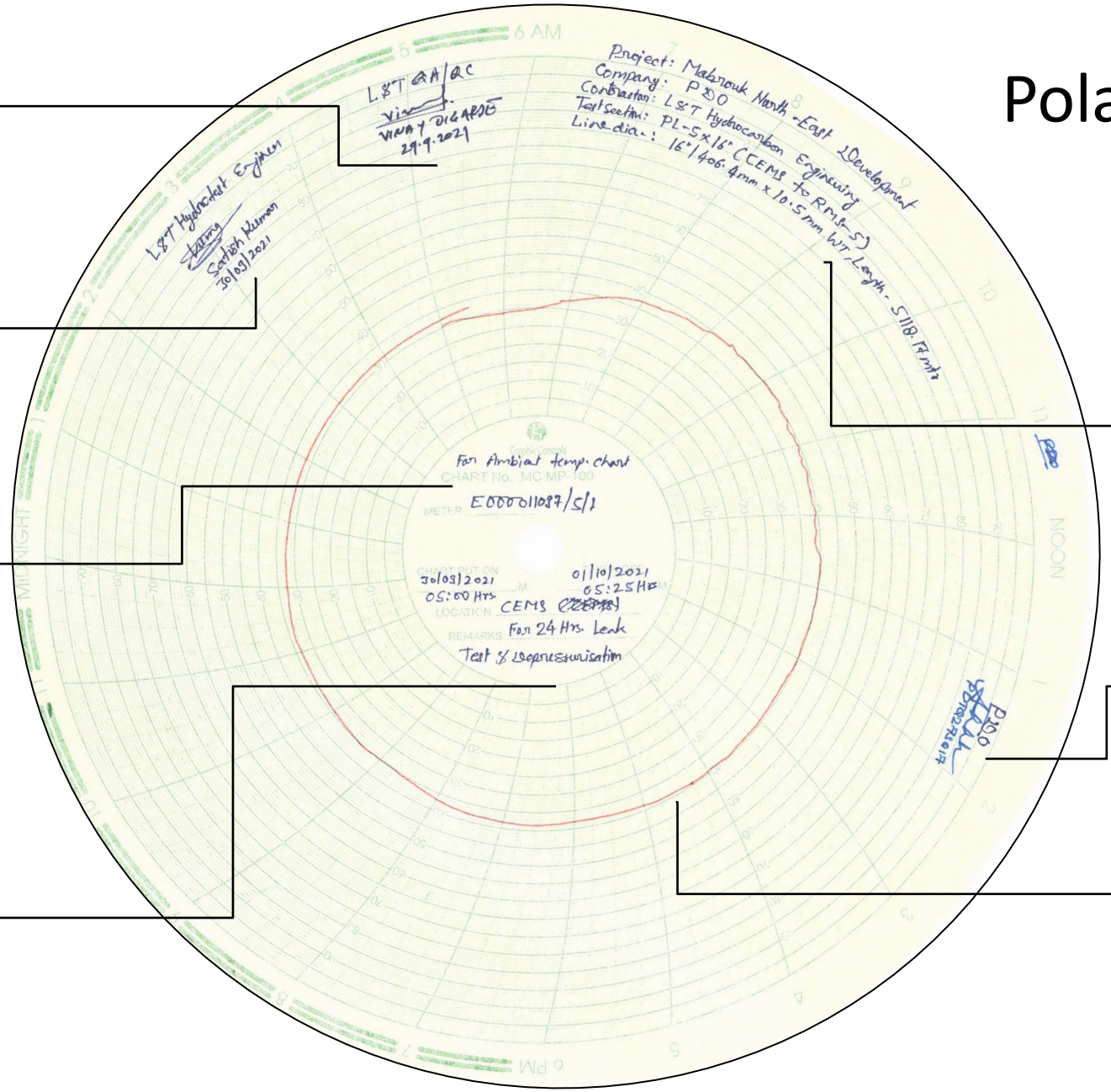
Test Pack No. : 21-PL-01-TP-01
Date : 29-Sep-2021
Weather : Normal

Pressure (Barg)	Theoretical Volume (Ltr)	Pressure (Barg)	Actual Volume (Ltr)	Pressure (Barg)	0.2% Allowance Volume (Ltr)
5.00	0.000	5.00	0.00	5.00	1195.9
6.00	36.922	6.00	39.672	6.00	1232.82
7.00	73.844	7.00	79.344	7.00	1269.74
8.00	110.766	8.00	119.016	8.00	1306.67
9.00	147.688	9.00	158.688	9.00	1343.59
10.00	184.610	10.00	198.360	10.00	1380.51
11.00	221.532	11.00	238.032	11.00	1417.43
12.00	258.454	12.00	277.704	12.00	1454.35
13.00	295.376	13.00	317.376	13.00	1491.28
14.00	332.298	14.00	357.048	14.00	1528.20
15.00	369.220	15.00	396.720	15.00	1565.12
16.00	406.142	16.00	436.392	16.00	1602.04
17.00	443.064	17.00	476.064	17.00	1638.96
18.00	479.986	18.00	515.736	18.00	1675.89
19.00	516.908	19.00	555.408	19.00	1712.81
20.00	553.830	20.00	595.080	20.00	1749.73
21.00	590.752	21.00	634.752	21.00	1786.65
22.00	627.674	22.00	674.424	22.00	1823.57
23.00	664.596	23.00	714.096	23.00	1860.50
24.00	701.518	24.00	753.768	24.00	1897.42
25.00	738.440	25.00	793.440	25.00	1934.34
26.00	775.362	26.00	833.112	26.00	1971.26
27.00	812.284	27.00	872.784	27.00	2008.18
28.00	849.206	28.00	912.456	28.00	2045.11
29.00	886.128	29.00	952.128	29.00	2082.03
30.00	923.050	30.00	991.800	30.00	2118.95
31.00	959.972	31.00	1031.472	31.00	2155.87
32.00	996.894	32.00	1071.144	32.00	2192.79
33.00	1033.816	33.00	1110.816	33.00	2229.72
34.00	1070.738	34.00	1150.488	34.00	2266.64
35.50	1126.121	35.50	1210.0	35.50	2322.02



For L&T HYDRO TEST ENGINEER	For L&T QA/QC	For PDO / COMPANY
Sign. :	Sign. :	Sign. :
Name : Satish Kumar	Name : VINAY DIGAPJE	Name : AKHILESH.V.N/POTQ275017
Date : 29/09/2021	Date : 29-Sep-21	Date : 29-Sept-2021

Polar Chart Legends



QA/QC approval date and signature (Contractor)

Certified hydrotest engineer signature

The chart type e.g. ambient temp chart

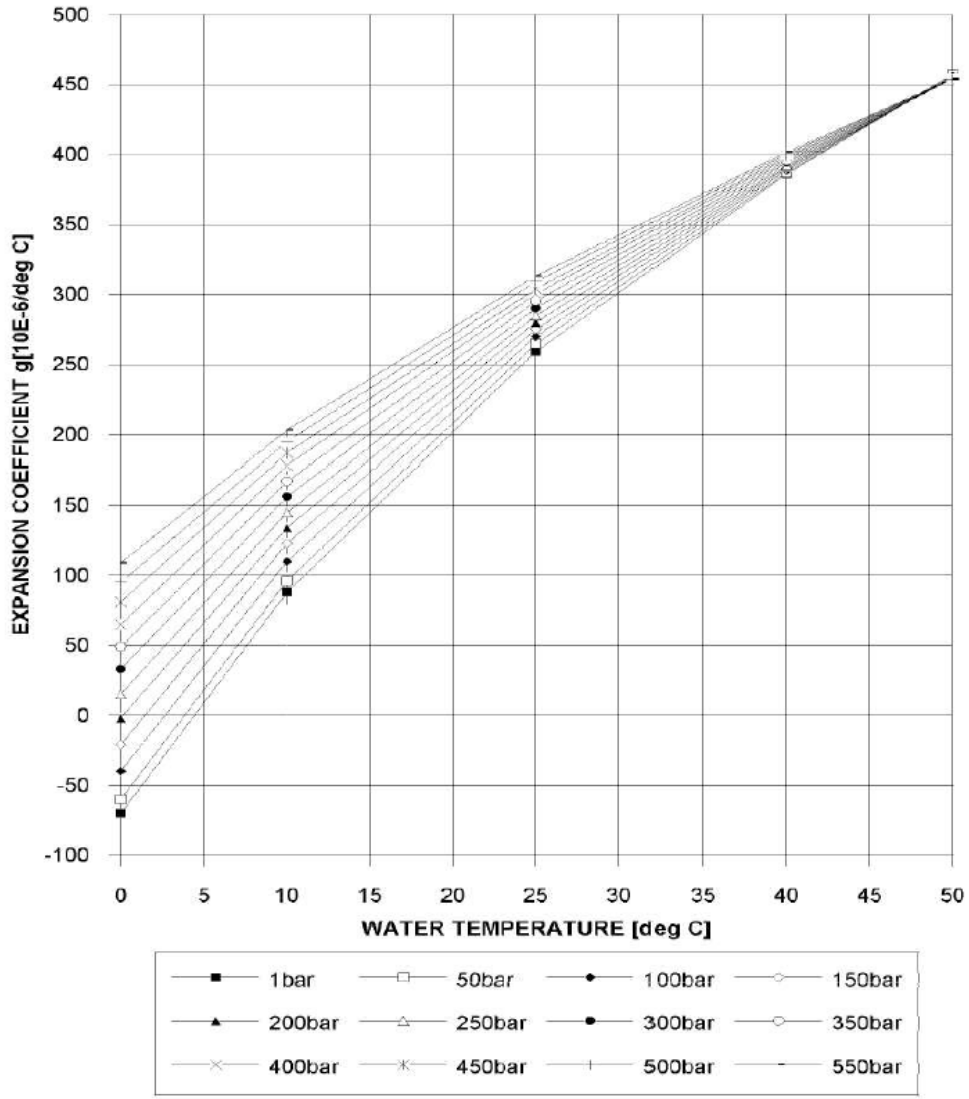
Location: CEMS
Date
Duration: 24hrs.
Purpose: leak test and pressurization

Project
Company
Contractor
Test section
Line diameter

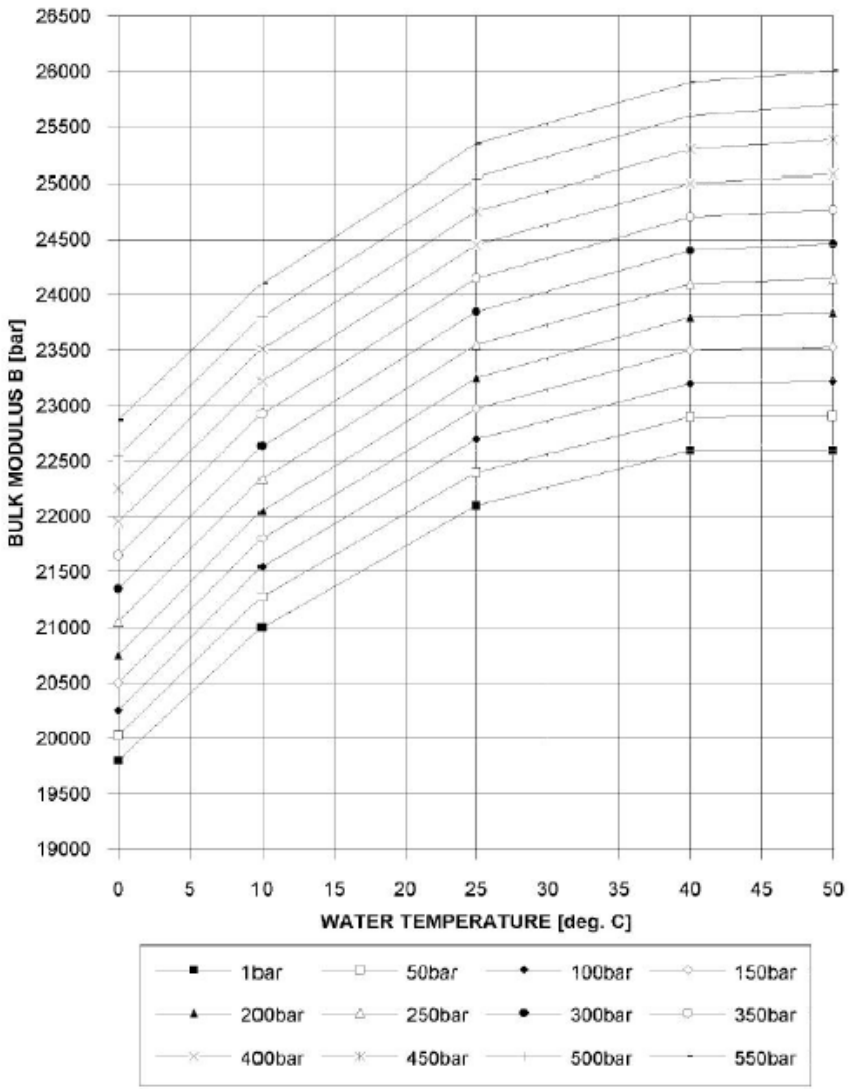
Approval signature (Company)

Red ➔ temperature
Blue ➔ pressure

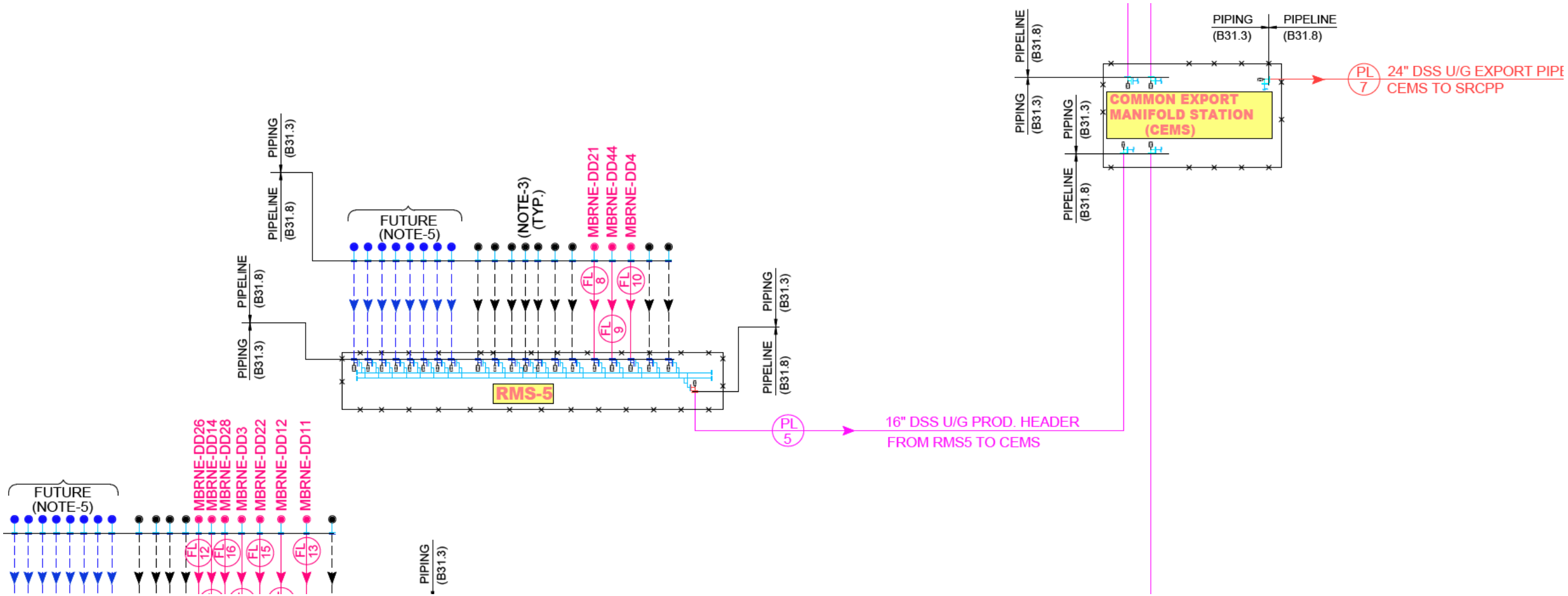
VOLUMETRIC EXPANSION COEFFICIENT OF FRESH WATER



BULK MODULUS OF FRESH WATER



Backup Slides


PIPING (B31.3)
PIPELINE (B31.8)
FUTURE (NOTE-5)
(NOTE-3) (TYP.)
MBRNE-DD21
MBRNE-DD44
MBRNE-DD4
FL 8
FL 10
FL 9
PIPELINE (B31.8)
PIPING (B31.3)
RMS-5
PIPING (B31.3)
PIPELINE (B31.8)
PL 5
16" DSS U/G PROD. HEADER FROM RMS5 TO CEMS
PIPELINE (B31.8)
PIPING (B31.3)
PIPING (B31.3)
PIPELINE (B31.8)
COMMON EXPORT MANIFOLD STATION (CEMS)
PIPING (B31.3)
PIPELINE (B31.8)
PL 7
24" DSS U/G EXPORT PIPE CEMS TO SRCPP
FUTURE (NOTE-5)
MBRNE-DD26
MBRNE-DD14
MBRNE-DD28
MBRNE-DD3
MBRNE-DD22
MBRNE-DD12
MBRNE-DD11
FL 12
FL 16
FL 15
FL 13
PIPING (B31.3)