Basic Engineering Study for
Aung Sinkha Development Project Phase 1A

PIPELINE APL03 CALCULATION PACKAGE

(WALL THICKNESS, ROAD CROSSING, AND BUOYANCY)

PTT Exploration and Production Public Company Limited
Aung Sinkha Development Project Phase 1A
Basic Engineering

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Basic Engineering Study for Aung Sinkha Development Project Phase 1A

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1. INTRODUCTION

1.1 Project Overview

PTTEP International Limited (PTTEPI) intends to develop and produce hydrocarbon from the offshore Block M3 named Aung Sinkha (ASK) field. The project is under Production Sharing Contract (PSC) with Myanmar Oil & Gas Enterprise (MOGE) signed on 7th August 2004 while the PSC effective date was on 1st November 2004.

PTTEPI as an Operator had performed 2,842 line - km of 2D seismic, 619 km2 of 3D seismic, and drilled 11 Exploration and Appraisal wells. After successful exploration and appraisal drilling campaigns in 2015, PTTEPI completed the ASK Field Development Plan and received MOGE approval for ASK Field Development Plan in April 2021.

The ASK field is located at offshore in the Gulf of Moattama, Myanmar, as illustrated in Figure 1.0. The field is located approximately 70 km from Land Fall Point (LFP) at Daw Nyein village and 200 km south - west of Yangon with water dept range 15 - 25 meters.

The feed gas will be transported from two (2) offshore wellhead platforms through an offshore export pipeline to ASK Onshore Processing Facilities (APF) located in Daw Nyein village for processing. The sales gas after processing will be exported to ASK Metering Station (AMS) which is located nearby the MOGE Pipeline Center Station at Daw Nyein Village, via gas export pipeline 2.5 km from APF and tied-in to the existing MOGE gas pipeline network. The condensate will be stabilized and stored at APF before being transported via pipeline to ASK Condensate Offloading and Personnel Transfer Facilities (ACP) at Kyon Kaw river and offloaded to customers via tankers barge.

The design of the surface facilities will be based on a Contractual Daily Capacity (CDC) of 60 MMscfd with provision for future expansion to 100 MMscfd.

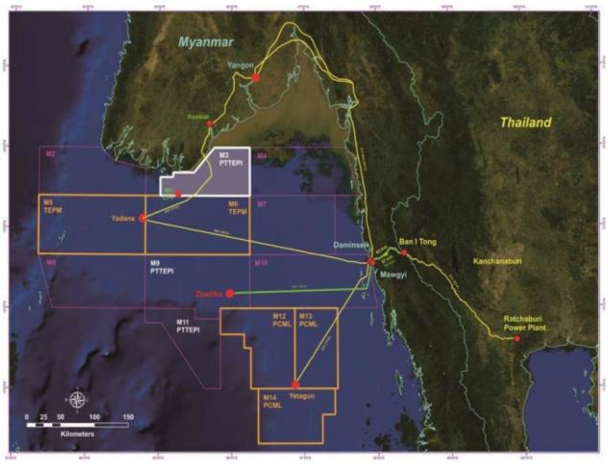

Figure 1-1: Block M3 – Aung Sinkha Field, Offshore Myanmar

The development of Phase 1A consists of the following facilities, as illustrated in Figure 1-2.

- Two (2) - Wellhead Platforms (WPA01 and WPA02) with jacket weight of 1,200 MT approx. and topside weight of 1,000 - 1,400 MT approx.
- One (1) - 12” x 6 km approx. Intra-field Pipeline which links between WPA01 and WPA02
- One (1) – 20” x 90 km approx. Multiphase Offshore Export Pipeline to transport combined fluid of WPA01 and WPA02 to Daw Nyein Land Fall Point
- APL01 One (1) – 20” x 2.5 km approx. Multiphase Onshore Export Pipeline to transport combined fluid from Daw Nyein Land Fall Point to ASK Onshore Processing Facilities (APF)
- ASK Onshore Block Valve Station No.1 (ABV01)
- ASK Onshore Processing Facilities (APF)
- APL02 One (1) – 8” x 18 km approx. Onshore Condensate Export Pipeline from APF to ACP
- APL03 One (1) – 12” x 1.58 km approx. Onshore Export Pipeline from APF to MOGE PLC at Daw Nyein Village
- ASK Metering Station No.1 (AMS01)
- ASK Condensate Offloading and Personnel Transfer Facilities (ACP) i.e., Condensate Offtake Facilities, Accommodation, Personnel and Material Transfer Facilities, Telecommunication System, road, etc.

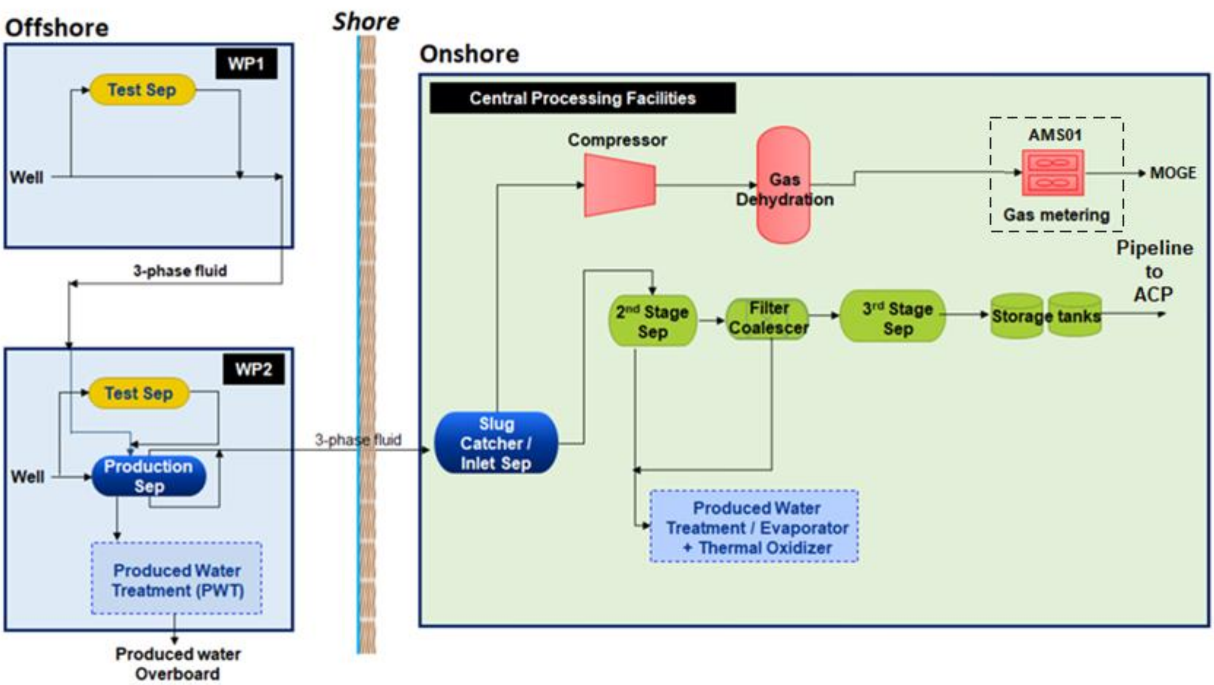

Figure 1-2: Field Block Flow Diagram

1.2 Purpose of Document

The purpose of this document is to calculate pipeline wall thicknesses based on the selected material grade for underground restrained and unrestrained sections, road crossing wall thickness validation, and buoyancy calculation utilizing screw anchors for the 12” Onshore Gas APL03 Pipeline from APF to AMS01 in Daw Nyein in the Provision of Basic Engineering for Pipelines and Onshore Facilities for Aung Sinkha Development Project Phase 1A.

1.3 Definitions

The following definitions shall apply to this document:

COMPANY	PTTEP International Limited
PROJECT	Basic Engineering Study for Aung Sinkha Development Project Phase 1A

1.4 Abbreviation

3LPE	Three Layer Polyethylene
AMS	ASK Onshore Metering Station
APF	ASK Onshore Processing Facilities
API	American Petroleum Institute
ASK	Aung Sinkha Development Project
ASME	American Society of Mechanical Engineers
DOH	Department of Highways
DP	Design Pressure
FEED	Front End Engineering Design
HDD	Horizontal Directional Drilling
HFW	High Frequency Welding Pipe
LFP	Land Fall Point
LSAW	Longitudinally Submerged Arc Weld
MOGE	Myanmar Oil & Gas Enterprise
OD	Outside Diameter
OT	Operating Temperature
SMTS	Specified Minimum Tensile Strength

SMYS	Specified Minimum Yield Strength
WPA	Wellhead Platform
WT	Wall Thickness

2. SUMMARY AND CONCLUSIONS

2.1 Summary

The APL03 pipeline design has considered available Project material to optimize procurement project, since 12” AIP01 offshore pipeline length is about 6 km, material grade is API 5L X65, wall thickness of 15.9 mm and the length is longer than onshore pipeline significantly, reducing number of wall thickness line pipe to be manufactured, the nominal 12-inch API 5L X65, wall thickness of 15.9 mm line pipe should be applied for the APL03 onshore pipeline.

Pipeline wall thickness verification and road crossing analyses were performed for constant OD philosophy in accordance with design data in Section 3. and methodology in Section 4. Obtained results are in Section 5.

Road crossing analyses per API RP1102 was performed for open cut sections with flexible pavement and worse soil condition criteria was available in the code, conservatively. For open cut for road crossing, minimum cover depth of 3.0 m was considered.

The road crossing wall thickness verification results was based on 12.90 mm wall thickness, by means of the excluding 3mm corrosion allowance of the selected wall thickness of 15.90 mm, it is found the selected wall thickness of the line pipe is suitable for installation.

This report has also identified the requirements for buoyancy control of the APL03 pipeline utilizing pipeline screw anchors to prevent the pipeline from uplift in the case soil is liquefied due to the high water table of Daw Nyein area and the area is also subject to water logging during monsoon seasons. It is concluded that screw anchors shall be installed at a spacing;

- APL03; 38.5 meters

By using screw anchor pair with minimum hold down capacity of 40,000 lbf (177.9 kN), longitudinal and combined stresses in the pipeline are within the allowable limits of ASME B31.8 requirements. Safety factor of ratio of total downward force to upward force is more than 1.2.

3. DESIGN DATA AND ASSUMPTIONS

3.1 Pipeline Design Data

Pipeline design data are presented in Table 3-1[1].

Table 3-1: Pipeline Design Data [1]

Description	Unit	Value
Service	-	Onshore Gas Pipeline (Sweet Service)
Originating from	-	APF
Terminating at	-	AMS01
Pipeline Size	mm (Inch)	323.9 (12.75)
Approximate Length	km	1.58
Class Location	-	Class 3
Pipeline Status	-	Buried
Design Life	Years	20
Corrosion Allowance	mm	3
Anti-corrosion Coating	-	3LPE
Open-cut Anti-corrosion Thickness	mm	3.5

3.2 Pipeline Operating Data

Pipeline operating data are presented in Table 3-2 [1].

Table 3-2: Pipeline Operating Data [1]

Description	Unit	Value
Fluid	-	Dry Gas
Operating Pressure	barg	85
Design Pressure (DP)	barg	153.2
Hydrotest Pressure	barg	229.8
Operating Temperature (Min./ Max.)	°C	Ambient / 50
Design Temperature (Min./Max.)	°C	-10/70

3.3 Material Data

Pipeline and coating material properties are presented in Table 3-3 [2].

Table 3-3: Pipeline and Coating Material Data [2]

Description	Unit	Value
Pipeline OD	mm (Inch)	323.9 (12.75)
Line Pipe Material	-	API 5L X65 (Sweet Service)
Manufacturing Process	-	HFW / SMLS
Specified Minimum Yield Strength (SMYS)	MPa	450
Specified Minimum Tensile Strength (SMTS)	MPa	535
Poisson's Ratio	-	0.3
Steel Density	kg/m^3	7,850
Elastic Modulus	MPa	2.07×10^5
Coefficient of Linear Expansion	1/°C	1.17×10^{-5}
3LPE Density	kg/m^3	950
Field Joint Density	kg/m^3	127-222 1,025 (saturated)
Concrete Weight Coating Density	kg/m^3	3,040

3.4 Air Properties

Air properties are as given in Table 3-4 . An average of 30°C is selected for installation temperature for the purpose of this report.

Table 3-4: Air Properties

Parameter	Unit	Value
Temperature		
High	°C	38.3
Low	°C	23.3

3.5 Vehicle Load Design Parameters

The vehicle load design parameters for pipeline crossing analysis can be summarized as follows:

Table 3-5: Vehicle Load Design Parameters

Parameter	Unit	Value
Maximum Single Axle Load	tonnes	10(Note1)
Maximum Tandem Axles Load	tonnes	16(Note1)
Contact Area of Wheel	m^2	0.093
Road Pavement Type	-	Flexible Pavement
Cover Depth (min)	m	3.0

Note:

1. Reference values from Myanmar's DOH have been shown in Appendix B.

3.6 Soil Data

Modulus of soil reaction and soil resilient modulus are based on recommended values from API RP 1102 [6]. Stiff to very stiff clays and silts with soil unit weight of 18.9 kN/m^3 (1.93 ton/m^3) as per API RP 1102, Section 4.7.2.1 are considered, conservatively.

3.7 Peak Ground Velocities

PGVs at pipeline end used for calculation of maximum axial strain due to compression seismic wave are presented in Table 3-6.

Table 3-6: Peak Ground Acceleration and Velocities

Pipeline	Mercalli Scale Class	PGA (g)	PGV (cm/s)
APL03	VII	0.2	31

3.8 Assumption

In the pipeline wall thickness verifications performed in this report, the following assumptions are made:

- Minimum air temperature is used as installation temperature.
- Maximum surface water temperature is used as design temperature in case of hydrotest.
- According to Myanmar's maximum allowable vehicle weights as given in Appendix B, design loads as below are used.
    - For truck with 2 axles and maximum vehicle weight of 16 tonnes, design single axle load is assumed as 10 tonnes occurring at the rear wheels.
    - For truck with 3 axles and maximum vehicle weight of 21 tonnes, design tandem axles load is assumed as 16 tonnes occurring at the rear wheels.

4. METHODOLOGY

4.1 Pipeline Wall Thickness Calculation

The methodology for pipeline stresses calculation is in accordance with ASME B31.8 and can be summarized in the following sections.

4.1.1 Hoop Stress Criterion

Hoop stress due to internal pressure shall be used for verifying pipeline wall thickness as per Section 841.1.1, ASME B31.8 [3] requirement.

$$S \cdot F \cdot EF \cdot T = \frac{P \cdot D}{2 \cdot t} \text{ for } \frac{D}{t} \geq 30$$

$$S \cdot F \cdot EF \cdot T = \frac{P \cdot (D - t)}{2 \cdot t} \text{ for } \frac{D}{t} < 30 \qquad (4.1)$$

Where,

P = Internal design pressure

t = Pipeline minimum wall thickness including under-thickness tolerances

S = Specified minimum yield strength

D = Nominal outside diameter of pipe

F = Design factor, 0.5 for class location 3

EF = Longitudinal joint factor, 1 for HFW / SMLS line pipes

T = Temperature derating factor, 1 for T ≤ 121°C.

Note: This formula conservatively ignores the external pressure and minimum wall thickness of pipe is excluded corrosion allowance.

The nominal wall thickness (t_{nom}) shall be selected among standard ASME B36.10M [4] sizes such that:

$$t_{SEL} \geq t + C \qquad (4.2)$$

Where,

C = Corrosion allowance, C = 3 mm for line pipe.

4.2 Wall Thickness Verification of Pipelines Crossing Road and Railway

To ensure safe operation, the stresses affecting the uncased pipeline must be accounted for comprehensively, including both circumferential and longitudinal stresses. The analysis is to ensure that stresses in the pipeline road and railway crossings are within permissible limits according to the recommended design method for uncased road and railway crossings, API RP 1102, Steel Pipelines Crossing Railroads and Highways [6].

A carrier pipe with uncased crossing will be subjected to both internal load from pressurization and external loads from earth force (dead load) and road and railway traffic loads (live load). An impact factor should be applied to the live load. External loading on the carrier pipe will produce both circumferential and longitudinal stresses.

4.2.1 Stress due to Earth Load

The stress at pipeline due to earth load is calculated by the following equation:

$$S_{He} = K_{He} \cdot B_e \cdot E_e \cdot \gamma \cdot D \qquad (4.3)$$

Where,

S_{He} = Circumferential stress from earth load

K_{He} = Stiffness factor for circumferential stress from earth load to be determined from Figure 3 of API RP 1102 [6]

B_e = Burial factor for earth load to be determined from Fig. 4 of API RP 1102 [6]

E_e = Excavation factor for earth load to be determined from Fig. 5 of API RP 1102 [6]

γ = Soil unit weight

D = Pipe outside diameter

4.2.2 Stress due to Live Load (Highway or Railway Cyclic Stress)

The stresses at pipeline due to highway live load are calculated by the following equations:

$$\Delta S_{Hh} = K_{Hh} \cdot G_{Hh} \cdot R \cdot L \cdot F_i \cdot w \qquad (4.4)$$

$$\Delta S_{Lh} = K_{Lh} \cdot G_{Lh} \cdot R \cdot L \cdot F_i \cdot w \qquad (4.5)$$

The stresses at pipeline due to railway live load are calculated by the following equations:

$$\Delta S_{Hr} = K_{Hr} \cdot G_{Hr} \cdot N_H \cdot F_i \cdot w \qquad (4.6)$$

$$\Delta S_{Lr} = K_{Lr} \cdot G_{Lr} \cdot N_L \cdot F_i \cdot w \qquad (4.7)$$

Where,

ΔS_{Hh} = Cyclic circumferential stress due to highway vehicular load

ΔS_{Hr} = Cyclic circumferential stress due to railway vehicular load

ΔS_{LH} = Cyclic longitudinal stress due to highway vehicular load

ΔS_{Lr} = Cyclic longitudinal stress due to railway vehicular load

K_{Hh} = Highway stiffness factor for cyclic circumferential stress to be determined from Fig. 14 of API RP 1102 [6]

K_{Hr} = Railway stiffness factor for cyclic circumferential stress to be determined from Fig. 8 of API RP 1102 [6]

K_{Lh} = Highway stiffness factor for cyclic longitudinal stress to be determined from Fig. 16 of API RP 1102 [6]

K_{Lr} = Railway stiffness factor for cyclic longitudinal stress to be determined from Fig. 11 of API RP 1102 [6]

G_{Hh} = Highway geometry factor for cyclic circumferential stress to be determined from Fig. 15 of API RP 1102 [6]

G_{Hr} = Railway geometry factor for cyclic circumferential stress to be determined from Fig. 9 of API RP 1102 [6]

G_{Lh} = Highway geometry factor for cyclic longitudinal stress to be determined from Fig. 17 of API RP 1102 [6]

G_{Lr} = Railway geometry factor for cyclic longitudinal stress to be determined from Fig. 12 of API RP 1102 [6]

R = Highway pavement type factor to be determined from Table 2 of API RP 1102 [6]

L = Highway axle configuration factor to be determined from Table 2 of API RP 1102 [6]

N_H = Railroad track factor for cyclic circumferential stress from Fig. 10 of API RP 1102 [6]

N_L = Railroad track factor for cyclic longitudinal stress from Fig. 13 of API RP 1102 [6]

F_i = Impact factor to be determined from Fig. 7 of API RP 1102 [6]

w = Applied design surface pressure

4.2.3 Stress due to Internal Load

The stress at pipeline due to internal load is calculated by the following equation:

$$S_{Hi} = \frac{P \cdot (D - t_p)}{2 \cdot t_p} \quad (4.8)$$

Where,

S_{Hi} = Circumferential stress due to internal pressure

P = Internal pressure

tp = Pipeline wall thickness

4.2.4 Hoop Stress Criterion

Please refer to Section 4.1.1 for hoop stress criterion and below Table **4-1**.

Table 4-1 : Design Factors [7]

Location	Design Factor
Onshore Pipeline (Open-Cut Road Crossings)	0.5 for location class 3

4.2.5 Combined Stress Criterion

Total effective stress must be less than the factored specified minimum yield strength, given by the following:

$$S_{eff} = \sqrt{\frac{1}{2}[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2]} \leq F \cdot SMYS \quad (4.9)$$

Where,

S_1 = Maximum circumferential stress,

$S_{He} + \Delta S_{Hh} + S_{Hi}$ for highway

$S_{He} + \Delta S_{Hr} + S_{Hi}$ for railway

S_2 = Maximum longitudinal stress,

$\Delta S_{Lh} + E_s \alpha_T (T_2 - T_1) + v(S_{He} + S_{Hi})$ for highway

$\Delta S_{Lr} + E_s \alpha_T (T_2 - T_1) + v(S_{He} + S_{Hi})$ for railway

S_3 = Maximum radial stress, - *P*

F = Design Factor

E_s = Young's modulus of steel

α_T = Coefficient of thermal expansion

v = Poisson's ratio

4.2.6 Fatigue Criteria (Highway)

GIRTH WELD

The design check against girth weld fatigue is given by the following:

$$\Delta S_{Lh} \leq S_{FG} \cdot F \quad (4.10)$$

Where,

S_{FG} = Fatigue endurance limit of girth weld, to be determined from Table 3, API RP 1102 [6]

LONGITUDINAL WELD

The design check against longitudinal weld fatigue is as follows:

$$\Delta S_{Hh} \leq S_{FL} \cdot F \quad (4.11)$$

Where,

S_{FL} = Fatigue endurance limit of longitudinal weld, to be determined from Table 3, API RP 1102 [6]

4.3 Pipeline Buoyancy Control Utilizing Screw Anchors

4.3.1 Vertical Soil Trench Pressure Acting on Top of Pipeline

Where the pipe is located below the water table and soil is not liquefied, the effect of soil grain buoyancy can be included in the earth load pressure. The following equation is used to determine vertical soil pressure acting on top of pipeline.

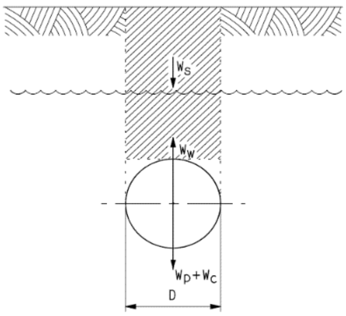

Figure 4-3-1: Resultant Buoyancy Load on Pipe

$$P_v = \gamma_w h_w + R_w \gamma_d C \quad (4.12)$$

Where,

P_v = Vertical soil trench pressure acting on the top of pipe

C = Height of soil above pipe

R_w = Water buoyancy factor,

= $1 - 0.33(h_w / C)$

h_w = Distance between the top of the pipe and the ground water table (zero if the water table is below the top of the pipe and equal to C if the water level is above ground level)

γ_w = Unit weight of water

γ_d = Dry unit weight of soil

4.3.2 Safety Factor

Safety factor is the ratio of total downward force to upward force; safety factor can be defined in the following equation;

$$SF = \frac{W_P + W_C + W_S + \left(\frac{F_R}{L}\right) + W_{SB}}{W_W}$$

Where,

SF = Safety factor

F_R = Screw anchor resistance

L = Spacing between anchors

W_P = Weight of pipe per unit length of pipe

W_C = Weight of pipe contents per unit length of pipe

W_S = Scaled explosive weight per unit length of pipe, $(P_v - \gamma_w \cdot h_w) \cdot D$

W_w = Weight of displaced fluid per unit length of pipe

W_{SB} = Sand bag unit weight per length

D = Pipe outer diameter

Safety factor of 1.2 (minimum of 20% negative buoyancy) shall be used [1].

4.3.3 Stresses in Pipeline Between Screw Anchors

4.3.3.1 Hoop Stress Criterion

Hoop stress due to internal pressure shall be used as per Section 841.1.1, ASME B31.8 [3][3] requirements.

$$S_H = \frac{P \cdot D}{2 \cdot t} \text{ for } \frac{D}{t} \geq 30$$

$$S_H = \frac{P \cdot (D - t)}{2 \cdot t} \text{ for } \frac{D}{t} < 30$$

Where,

S_H = Hoop stress

P = Internal design pressure

D = Pipe outer diameter

t = Pipeline wall thickness

4.3.3.2 Longitudinal Stress Criterion

Longitudinal stress for restrained pipeline is defined in the following equation.

$$S_L = S_P + S_T + S_X + S_B$$

Longitudinal stress for unrestrained pipeline is defined in the following equation.

$$S_L = S_P + S_X + S_B$$

Where,

S_L = Longitudinal stress

S_P = Longitudinal stress due to internal pressure,

$S_P = 0.3 S_H$ for restrained pipeline

$S_P = 0.5 S_H$ for unrestrained pipeline

S_T = Longitudinal stress due to thermal expansion, $S_T = E\alpha(T_1 - T_2)$

S_X = Longitudinal stress due to axial loading other than temperature and pressure (Consider to be 0)

S_B	=	Nominal bending stress in the pipeline
	=	$\pm\frac{F_b L^2}{12Z}$ for restrained pipe with fixed-fixed boundary condition
	=	$\pm\frac{F_b L^2}{8Z}$ for unrestrained pipe with pinned-fixed boundary condition
F_b	=	Net upward buoyancy force per unit length
L	=	Spacing between screw anchors
E	=	Pipe elastic modulus at ambient temperature
α	=	Pipe coefficient of thermal expansion
T_1	=	Pipe temperature at the time of installation
T_2	=	Warmest or coldest pipe design temperature
Z	=	Pipe section modulus, Z = $\frac{2I}{D}$
I	=	Pipe moment of inertia
S	=	Specified Minimum Yield Strength
T	=	Temperature Derating Factor

The maximum permitted values of $|S_L|$ for restrained pipe and unrestrained pipe are 0.9·S·T and 0.75·S·T, respectively.

4.3.3.3 Stress due to Saddle Load

There are local stresses in both longitudinal and circumferential directions due to the load from screw anchor saddle onto the pipe, which can be calculated using the following formula;

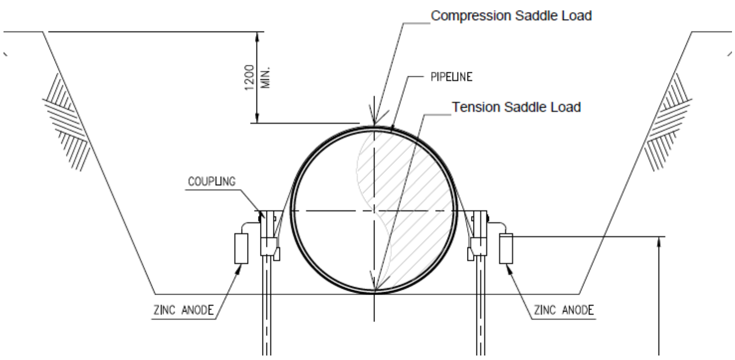

Figure 4-1: Saddle Load

$$S_S = k \cdot \frac{P}{t^2} \cdot \ln\left(\frac{R}{t}\right)$$

Where,

S_S	=	Maximum local stress due to saddle load
P	=	Total saddle reaction force (screw anchor resistance)
R	=	Pipe outer radius
t	=	Pipeline wall thickness
k	=	$0.02 - 0.00012 \cdot (\beta - 90°)$
β	=	Total angle in degrees subtended by arc of contact between pipe and saddle, 90 degrees is considered.

4.3.3.4 Combined Stress Criterion

To comply with Section 833.4, ASME B31.8 [3], stresses shall be combined to verify the following:

$$\sqrt{S_L^2 - S_L S_H + S_L^2} \leq kST \qquad (4.13)$$

Where,

k = 0.9 for operation

4.3.4 Screw Anchor Spacing Criterion

4.3.4.1 Screw Anchor Capacity

Minimum hold down capacity of screw anchor pair is 40,000 lbf (177.9 kN). Screw anchor structural design shall be based on a safety factor of 2.0 [1].

For area where number of screw anchors are more than 3, fixed-fixed boundary condition is considered. Minimum required hold down load of screw anchor pair is calculated based on buoyancy force of given span.

$$F_l = F_b \cdot L$$

Where,

F_b = Net Upward Buoyancy Force per unit length

For area that number of screw anchors are equal or less than 3, pinned-fixed boundary condition is considered, conservatively.

The maximum force acting on one end of single span is calculated as below;

$$F_l = \frac{5F_b \cdot L}{8}$$

The minimum required hold down load per a pair of screw anchors for two spans is calculated by the following equation;

$$F_l = 2 \cdot \frac{5F_b \cdot L}{8}$$

4.3.5 Maximum Deflection

Maximum deflection of pipe can be determined based on distance between screw anchors.

For fixed-fixed boundary condition;

$$\delta_{max} \geq \frac{F_b \cdot L^4}{384 \cdot E \cdot I}$$

For pinned-fixed boundary condition;

$$\delta_{max} \geq \frac{F_b \cdot L^4}{185 \cdot E \cdot I}$$

Where,

$\delta_{\max}$ = Maximum allowable deflection of pipe, 0.2 m

L = Spacing between screw anchors

E = Pipe modulus of elasticity

I = Pipe moment of inertia

F_b = Net upward buoyancy force per unit length, $W_w - [W_P + W_C + W_S]$

5. RESULTS

5.1 Wall Thickness selection

Based on the selected material API5L-X65 and wall thickness of 15.9mm which is available for 12-inch offshore pipeline, given the short length of APL03 pipeline it makes economic sense to expand the purchase and utilize the same line pipe. This enhances procurement as small orders are often refused by Manufacturer (at reasonable cost) due to production line adjustments and PQT time and costs. Summary is presented in Table 5-1 below.

Based on the verification of the material, the follow results are obtained based on ASME B31.8 calculation. Calculation was performed utilizing the largest data variation for worst case scenario check.

API1102 verification was performed excluding corrosion allowance to ensure the pipeline at its end of life will operate safely, whereby the ASME B31.8 calculated sum (11.03mm with 1.87mm margin = 12.9mm) was used to perform the verification and passed. It shall also be noted, despite the pipeline is designed for 153.2 barg to match G03 piping class [9], the foreseen maximum operating pressure is 85 barg, thus leaving further system margin.

Parameter	Min. Code Req. (mm)	CA (mm)	Design min. calculated thickness (mm)	Selected Parameter (mm)	Check
Wall Thickness per ASME B31.8	11.03	3	14.03	15.9 (1.87mm margin)	Pass
API RP 1102	Verified using 12.9mm where corrosion allowance is excluded. (11.03mm + 1.87mm margin = 12.9mm)			15.9	Pass

Table 5-1

5.2 Buoyancy Control Utilizing Screw Anchors

Based on the line pipe and conservative data allowing for liquefied soils and high underground water table elevation exposing the pipeline under constant submersion, it is concluded to select the stringent parameter for field installation.

Distance		Selected Distance
Single Span	Double Span	
48 m.	38.5 m.	38.5 m

Table 5-2

6. REFERENCES

[1] Pipeline Basis of Design, Design Criteria, MM-ASK-1A-APL03-PLR-BOD-0001

[2] Specification for Line Pipe, API Spec 5L

[3] Gas Transmission and Distribution Piping Systems, ASME B31.8

[4] Welded and Seamless Wrought Steel Pipe, ASME B36.10M

[5] Guidelines for the Design of Buried Steel Pipe, ASCE

[6] Steel Pipelines Crossing Railroads and Highways, API RP 1102

[7] Design and Construction of Onshore Pipeline and Rail, Road & Canal Crossings, 10008-STD-6-PLR-029

[8] Seismic Consideration for Onshore Pipelines in Seismic Hazardous Area, MM-ASK-1A-APL01-PLR-BOD-0002

[9] Piping Material Class Specification, MM-ASK-1A-ASK-PIP-SPE-0001

[10] Acceptance Criteria for Helical Foundation System and Devices, AC358, ICC Evaluation Service

[11] Geotechnical Investigation Report for Geotechnical Investigation (GTI) for Onshore Facilities of AUNG SINKHA Development Project by International Integrated Services Company Limited.

[12] McGraw-Hill, Roark's Formula for Stress & Strain, Seventh Edition

APPENDIX A: BATTERY LIMITS FOR PIPELINES

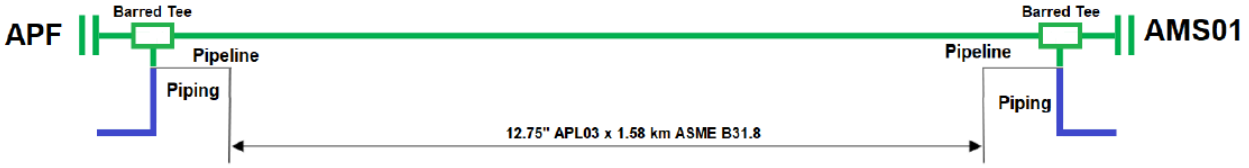

Figure A-1: Pipeline System Design Battery Limits

Note:

1. Scope of this document is APL03.

APPENDIX B: MYANMAR VEHICLE LOADS

		< 1/100 L Lamp	
6.	Min turning radius, max (m)	12	
7.	Elevation of speedometer (%)	-10 to +15	
8.	Exhaust Emission (Smoke)	< 50% Bosch unit	
9.	Depth of groove of tyre min (mm)	1 mm	

MOTOR VEHICLE REQUIREMENT ON AXLE LOAD, WEIGHT & DIMENSION

NO	SUB SUBJECT	STANDARD	REMARKS
1.	Axle load		
	Axle load maximum	10000 Kg	
2.	Vehicle weight		
	(a) Truck with 2 axles	16000 Kg	
	(b) Truck with 3 axles	21000 Kg	
	(c) Articulated Truck (max)	38000 Kg	
3.	Dimension		
	(a) Overall Length (max)	12.2 m	
	(b) Overall Width (max)	2.5 m	
	(c) Overall Height (max)		
	Normal vehicle	3.66 m	
	Container carrier	4.6 m	
4.	Rear overhang	60% of Wheelbase	

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APPENDIX C: PIPELINE WALL THICKNESS CALCULATIONS

Project:	**ASK ACC: APL03 Pipeline**	Revision:	***C1***
Client:	**PTTEP International**	Engineer:	***AH***
Area:	**12 inch, Class 3 Location Class**	Checked:	***RS***
		Date:	***25-06-2024***

WALL THICKNESS CALCULATION

Applicable Code: ***ASME B31.8 - 2022***

1.0 Design data

Material used:	7		(See Material Code Number)
Material Strength (SMYS):	450	N/mm^2 (MPa)	
Location Class:	Class 3		(840.2)
Design Factor:	0.5		(Tables 841.1.6-1 and 841.1.6-2)
Pipe Outside Diameter:	12.75	inches	
Design Pressure:	153.2	barg	
Design Temperature Max:	70	^oC	Only Valid for Temperatures up to 200°C
Design Temperature Min:	-10	^oC	
Longitudinal Joint Factor:	1		(Table 841.1.7-1)
Temperature Derating Factor:	1		(Table 841.1.8-1)

Material Code Number :	1 = API 5L Gr B	4 = API 5L X52	Location Class:	0.80=	Class 1 Division 1
	ASTM A333 Gr 6	5 = API 5L X56		0.72=	Class 1 Division 2
	ASTM A53 Gr B	6 = API 5L X60		0.60=	Class 2
	ASTM A106 Gr B	7 = API 5L X65		0.50=	Class 3
	2 = API 5L X42	8 = API 5L X70		0.40=	Class 4
	3 = API 5L X46	9 = API 5L X80		Others=	Custom

2.0 Formula used

$$t = \frac{PD}{20SFET} + C$$

A derivation of the "Steel Pipe Design Formular" as per para 841.1.1 of ASME B31.8-2022

Where

t **=**	Calculated wall thickness	***14.03***	mm or	***0.552 in***
P **=**	Design pressure	***153.2***	barg	
D **=**	Pipe outside diameter	***323.85***	mm	
S **=**	Specified minimum yield strength	***450***	N/mm^2 (MPa)	
F **=**	Design factor	***0.5***		
E **=**	Longitudinal joint factor	***1***		
T **=**	Temperature derating factor	***1***		
C **=**	Corrosion Allowance (mm)	***3***	***mm***	

Selected wall thickness per ASME B36.10M ***15.88*** mm

APPENDIX D: PIPELINE ROAD CROSSING WALL THICKNESS CALCULATIONS

Project: Aung Sinkha Development Project Phase 1A - APL03 Pipeline
Client: PTTEPI
Area: Location Class 3, Stiff to very stiff clays and silts, 3.0m depth

Uncased Highway Crossing Design Calculations

API Recommended Practice 1102

Pipe, Operational, Installation & Site Characteristics		Values	Units	Values	Units
Steel Grade		X65			
Specified Minimum Yield Strength	SMYS	450.00	N/mm^2		
Young's Modulus	E_s	203.0E+3	N/mm^2		
Poisson's Ratio	v_s	0.30			
Coefficient of Thermal Expansion	α_T	1.17E-05	per °C		
Barlow Design Stress Factor	F	***0.50***			
Outside Diameter	D	***12.75***	inches	323.85	mm
Nominal Wall Thickness	t_w	***12.90***	mm	0.508	in
Depth	H	***3,000***	mm		
Bored Diameter and Type	B_d	***323.9***	mm	Type:	Direct Bury
Maximum Allowable Operating Pressure	P	***153.20***	barg	15.32	N/mm^2
Temperature at time of Installation	T_{max}	***30.00***	°C	86.00	
Design Temperature Max	T_{max}	***70.00***	°C	158.00	°F
Design Temperature Min	T_{min}	***-10.00***	°C	14.00	°F
Temperature Derating Factor	T	1.000		(B31.8 Table 841.116A)	
Spec & Pipe Class		API 5L - Electric Resistance Welded			
Longitudinal Joint Factor	E	1.00		(B31.8 Table 841.115A)	
Soil Type		Stiff to very stiff clays and silts			
Modulus of Soil Reaction	E'	6.9	N/mm^2	(API 1102 Table A-1)	
Resilient Modulus	E_r	69.0	N/mm^2	(API 1102 Table A-2)	
Soil Unit Weight	γ	18.9E-06	N/mm^3		
Pavement Type		Flexible Pavement		Pt (kN) : 39.24	
Critical Axle Configuration		Tandem Axles		(API 1102 Table 1)	
Highway Pavement Type Factor	R	1.00		(API 1102 Table 2)	
Axle Configuration Factor	L	1.00		(API 1102 Table 2)	
Type of Longitudinal Weld		Seamless OR ERW			
Fatigue Endurance Limit of Girth Weld	S_{FG}	82.74	N/mm^2	(API 1102 Table 3)	
F. E. L. of Longitudinal Weld	S_{FL}	158.62	N/mm^2	(API 1102 Table 3)	

Project: Aung Sinkha Development Project Phase 1A - APL03 Pipeline
Client: PTTEPI
Area: Location Class 3, Stiff to very stiff clays and silts, 3.0m depth

Uncased Highway Crossing Design Calculations

Check Allowable Barlow Stresses (API 1102 Equation 8b)		**Values**	**Units**	
Actual Barlow Stress		192.30	N/mm^2	☑
Allowable Barlow Stress		225.00	N/mm^2	
Actual Barlow Stress < Allowable Stress				

4.7.2.1 Stress Due to Earth Load

Values Units

The circumferential stress at the pipeline invert caused by earth load, S_{He}, is determined as follows

$$S_{He} = K_{He} B_e E_e \gamma D$$

- K_{He} = Stiffness factor for circumferential stress from earth load
- B_e = Burial factor for earth load
- E_e = Excavation factor for earth load
- γ = Soil unit weight
- D = Pipe Outside Diameter

Earth Load stiffness Factor, K_{He}, accounts for the interaction between the soil and the pipe

t_w/D		0.040		
Modulus of Soil Reaction	**E'**	6.9	N/mm^2	
Stiffness Factor	K_{He}	575		(API 1102 Figure 3)
Burial Factor, B_e				
H/B_d		9.264		
Soil Type		B		
Burial Factor	B_e	1.140		(API 1102 Figure 4)
Excavation Factor, E_e				
B_d/D		1.000		(1.0 for HDD)
Excavation Factor (1 as Existing pipeline)	E_e	0.825		(API 1102 Figure 5)
Circumferential Stress Due to Earth Load	S_{He}	3.31		(API 1102 Equation 1)

4.7.2.2 Stresses due to Live Loads

Values Units

Surface Live Loads, due to the wheel load applied at the surface of the roadway.

Impact Factor	F_I	1.36		(API 1102 Figure 7)
Applied design Surface Pressure	*w*	0.422	N/mm^2	(API 1102 Para 4.7.2.2.1)
Contact Area which Wheel load is applied	*Ap*	0.093	m2	(API 1102 Para 4.7.2.2.1)

Uncased Highway Crossing Design Calculations

4.7.2.2..4 Highway Cyclic Stresses

Values **Units**

Cyclic Circumferential Stresses

The cyclic circumferential stress due to highway vehicular load, ΔS_{Hh} may be calculated from the following

$$\Delta S_{Hh} = K_{Hh} G_{Hh} RLF_i w$$

K_{Hh}	= Highway stiffness factor for cyclic circumferential stress
G_{Hh}	= Highway geometry factor for cyclic circumferential stress
R	= Highway pavement type
L	= Highway axle configuration
Fi	= Impact factor
w	= Applied design surface pressure

Highway stiffness factor, K_{Hh}				
t_w/D		0.040		
Resilient Soil Modulus	**Er**	69.0	N/mm^2	
Stiffness Factor	$\mathbf{K_{Hh}}$	7.2		(API 1102 Figure 14)
Highway geometry factor, G_{Hh}				
Outside Diameter	**D**	323.85	mm	
Depth	**H**	3,000	mm	
Geometry Factor	$\mathbf{G_{Hh}}$	0.675		(API 1102 Figure 15)
Circumferential Stress Due to Vehicular Load	$\mathbf{S_{Hh}}$	2.78	N/mm^2	(API 1102 Equation 5)

Cyclic Longitudinal Stresses

Values **Units**

The cyclic longitudinal stress due to highway vehicular load, ΔS_{Lh} may be calculated from the following

$$\Delta S_{Lh} = K_{Lh} G_{Lh} RLF_i w$$

K_{Lh}	= Highway stiffness factor for cyclic longitudinal stress
G_{Lh}	= Highway geometry factor for cyclic longitudinal stress
R	= Highway pavement type
L	= Highway axle configuration
Fi	= Impact factor
w	= Applied design surface pressure

Uncased Highway Crossing Design Calculations

Highway stiffness factor, K_{Lh}				
t_w/D		0.040		
Resilient Modulus	**Er**	69.0	N/mm^2	
Stiffness Factor	K_{Lh}	6.4		(API 1102 Figure 16)
Highway geometry factor, G_{Lh}				
Outside Diameter	**D**	323.85	mm	
Depth	**H**	3,000	mm	
Geometry Factor	G_{Lh}	0.75		(API 1102 Figure 17)
Longitudinal Stress Due to Vehicular Load	S_{Lh}	2.749	N/mm^2	(API 1102 Equation 6)

4.7.3 Stresses due to Internal Load

Values Units

The circumferential stress due to internal pressure, S_{Hi} may be calculated from the following;

$$S_{Hi} = p(D - t_w)/2t_w$$

p = Internal pressure taken as MAOP or MOP
D = Pipe outside diameter
T_w = Wall thickness

Circumferential stress due to internal pressure, S_{Hi}				
	S_{Hi}	184.64	N/mm^2	(API 1102 Equation 7)

4.8.1 Check for allowable Stresses

Values Units

Maximum Circumferential Stress

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

Maximum Circumferential Stress	S_1	190.74	N/mm^2	(API 1102 Equation 9)

Maximum Longitudinal Stress

$$S_2 = \Delta S_L - E_s \alpha_T (T_2 - T_1) + \upsilon (S_{He} + S_{Hi})$$

Maximum Longitudinal Stress	S_2	-35.87	N/mm^2	(API 1102 Equation 10)

Maximum Radial Stress

$$S_3 = -p = -MAOP \ or \ -MOP$$

Maximum Radial Stress	S_3	-15.32	N/mm^2	(API 1102 Equation 11)

Total Effective Stress

$$S_{eff} = \sqrt{\tfrac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

The check against the yielding of the pipeline may be accomplished by assuring that the total effective stress is less than the factored specified minimum yield strength, using the following equation;

Applied Factor	***F***	0.50		
Total Effective Stress	S_{eff}	217.06	N/mm^2	(API 1102 Equation 12)
Allowable Effective Stress		225.00	N/mm^2	

$$S_{eff} \le SMYS \times F$$

Actual Effective Stress < Allowable Stress ☑

4.8.2 Check for fatigue

		Values	Units

Girth Welds

The cyclic stress that must be checked for potential fatigue in a girth weld located beneath a highway crossing is the longitudinal stress due to live load.

Girth Welds	S_{Lh}	2.75	N/mm^2
(API 1102 Equation 17)	F x S_{FG}	41.37	N/mm^2

The general form of the design check against girth weld fatigue is given by the following

$$\Delta S_L \leq S_{FG} \times F$$

Longitudinal Stress < Fatigue Endurance Limit ☑

Longitudinal Welds

The cyclic stress that must be checked for potential fatigue in a longitudinal weld located beneath a highway crossing is the circumferential stress due to live load.

Longitudinal Welds	S_{Hh}	2.78	N/mm^2
(API 1102 Equation 20)	F x S_{FL}	79.31	N/mm^2

The general form of the design check against longitudinal weld fatigue is given by the following

$$\Delta S_H \leq S_{FL} \times F$$

Circumferential Stress < Fatigue Endurance Limit ☑

APPENDIX E: BUOYANCY CALCULATION FOR SCREW ANCHOR SPACING

	ASK DEVELOPMENT PROJECT	
PTTEP	**APPENDIX : MAXIMUM SCREW ANCHOR SPACING, STRESS CHECK AND SCREW ANCHOR LOAD**	ASIA PIPELINES
	DOCUMENT NO. MM-ASK-1A-APL03-RPT-0101	
	DOCUMENT TITLE PIPELINE BUOYANCY CONTROL AND SCREW ANCHORS SPACING CALCULATION	
	REVISION A1	

DEFINITION	NOMENCLATURE	FORMULA	UNIT	Pipeline Condition Without Backfill	
				Max. Design Temp.	Min. Design Temp.
INPUT DATA					
PIPELINE DESIGN DATA					
Outside Diameter of Pipeline	OD	*12.75 Inch*	m	0.324	0.324
Inside Diameter of Pipeline	ID	$OD - 2t_w$	m	0.2920	0.2920
Pipeline Wall Thickness	t_w	*PTTEP Design Condition*	mm	15.90	15.90
Pipeline Wall Thickness	t_w	-	m	0.01590	0.01590
Internal Design Pressure, P_i	P_i	*2,208.35 psig (152.3 Barg)*	MPa	15.23	15.23
Specified Minimum Yield Strength	*SMYS, S*	*API 5L X65MS*	MPa	450.00	450.00
Pipeline Design Temperature	T_2	*150 °F (65.56 °C) to 20 °F (-6.67 °C)*	°C	65.56	-6.67
Pipeline Installation Temperature (Ultimate Minimum Soil Temperature)	T_1		°C	27.00	27.00
Constant design factor	k	*ASME B31.8, para. 833.3 and 833.4*	-	0.90	0.90
Pipe Modulus of Elasticity	E	*API Spec 5L*	MPa	207,000.00	207,000.00
Temperature Derating Factor	T	*ASME B31.8, Table 841.1.8-1*	-	1.00	1.00
Poisson's Ratio	v	-	-	0.30	0.30
Pipe Coefficient of Thermal Expansion	α	*ASME B31.8 Clause 832.2*	1/°C	0.0000117	0.0000117
Height of Backfill soil above pipe	C	*Assumed*	m	0.00	0.00
EXTERNAL COATING DATA					
External Coating Thickness	t_c	*PTTEP Design Condition*	m	0.0035	0.0035
External Coating Outside Diameter	ODc	$OD + 2t_c$	m	0.3308	0.3308
External Coating Density	ρ_c	*ASTM D1505*	kg/m³	940.00	940.00
PRINCIPAL PARAMETERS FOR CALCULATION					
Density of Steel	γ_{steel}	*Assumed*	kg/m³	7,850.00	7,850.00
Density of of Ballast (Water)	γ_w	*Assumed*	kg/m³	1,000.00	1,000.00
Density of Mud (fluid) and/or the liquefaction potential soil. Conservative approach.	γ_{mud}	*Assumed*	kg/m³	1,600.00	1,600.00
Density of Dry Soil Backfill	$\gamma_{dry\text{-}soil}$	-	kg/m³	0.00	0.00
Density of Natural Gas Density at P = 640 psig and Temp = 120 F	γ_{gas}	-	kg/m³	0.000	0.000
BUOYANCY CONTROL CALCULATION					
FIND NET BUOYANCY FORCE					
Distance between the top of the pipe and the ground water table (zero if the water table is below the top of the pipe and equal to C if the water level is above ground level)	h_w	*Average from Geo Report*	m	0.50	0.50
Vertical soil trench pressure acting on the top of pipe (dry soil and the semi-liquefied soil)	P_v	$\gamma_w h_w + R_w \gamma_{dry\text{-}soil} C$	N/m²	9,810.00	9,810.00
Vertical soil trench pressure acting on the top of pipe (dry soil and the semi-liquefied soil)	P_v	*Convert to mass per unit area*	kg/m²	1,000.00	1,000.00
Water buoyancy factor	R_w	$1 - 0.33(h_w / C)$	-	0.000	0.000
Effective weight of soil above the pipe (↓)	W_S	$(P_v - \gamma_w g h_w) OD_C$	N/m	0.000	0.000
Effective weight of soil above the pipe (↓)	W_S	*Convert to mass per unit length*	kg/m	0.00	0.00
Calculated Uniform Dry Weight of Pipeline (↓)	W_P	$\gamma_{steel} \pi (OD^2 - ID^2) / 4$	N/m	1,184.39	1,184.39
Calculated the External Coating weight (↓)	W_C	$\gamma_c \pi (ODc^2 - OD^2) / 4$	N/m	33.19	33.19
Calculated Fluid inside pipeline weight (↓)	W_f	$\gamma_{gas} \pi (ID^2 / 4)$	N/m	0.00	0.00
Calculated Weight of Mud Displaced by Pipeline (Upward Force, ↑)	W_{mud}	$\gamma_{mud} \pi (OD_C^2) / 4$	N/m	1,348.99	1,348.99
Net Uniform Buoyancy Force (Positive value, Floating)	W_t	$W_w - (W_S + W_P + W_C + W_f)$	N/m	131.42	131.42
Net Uniform Buoyancy Force (Positive value, Floating)	W_t	***Convert to mass per unit length***	**kg/m**	**13.40**	**13.40**
SCREW ANCHOR LOAD, SPACING AND STRESS CHECK CALCULATION					
Pipe Metal Cross-Sectional Area	A	$(\pi/4)(OD^2 - ID^2)$	m²	0.01538	0.01538
Pipe Moment of Inertia	I	$\pi (OD^4 - ID^4) / 64$	m⁴	0.000183	0.000183
PIPELINE DEFLECTION					
Allowable Pipeline Deflection	δ_{allow}	*Assumed*	mm	100	100
MAXIMUM SCREW ANCHOR SPACING					
Single Span Theory					
Single span – Maximum spacing calculated as	$L_{S\text{-}max}$	$((\delta_{max} 384 EI)/(5W_t))^{1/4}$	m	38.56	38.56
Two Equal Spans Theory					
Two equal spans – Maximum spacing calculated as	$L_{L\text{-}max}$	$((\delta_{max} 185 EI)/(W_t))^{1/4}$	m	48.04	48.04
FIND SCREW ANCHOR LOAD					
For short area, such as small pond, water way, and Khlong crossing, the number of screw anchors is less than 3 locations. The single span will be considered.					
Calculated the minimum force required to hold down per set of screw anchors acting on one end of single span	F_{LS}	$(W_t L_{S\text{-}max}) / 2$	N	2,533.66	2,533.66
For location that requires equal to or more than 3 locations of screw anchors, two equal spans will be assumed.					
Calculated the minimum force required to hold down per set of screw anchors for two equal spans	F_L	$(10W_t L_{L\text{-}max}) / 8$	N	7,891.16	7,891.16

DEFINITION	NOMENCLATURE	FORMULA	UNIT	SINGLE SPAN (Installed < 3 Locations)		TWO EQUAL SPANS (Installed ≥ 3 Locations)	
				Max. Design Temp.	Min. Design Temp.	Max. Design Temp.	Min. Design Temp.
FIND HOOP, LONGITUDINAL AND BENDING STRESSES							
Select the minimum force required to hold down per set of screw anchors	F	F_{Ls} and F_L	N	2,533.66	2,533.66	7,891.16	7,891.16
Calculated Pipe Section Modulus	Z	$\pi(OD^4 - ID^4) / 32\,OD$	m³	0.001129	0.001129	0.001129	0.001129
Calculated Hoop Stress due to Internal Pressure	S_{Hi}	$P_i\,OD / 2t_w$	MPa	87.75	87.75	87.75	87.75
Angle of Contact Between Screw Anchor and Pipeline	β	-	°	90.00	90.00	90.00	90.00
Contact Stress Coefficient	K	$0.02 - 0.00012 (\beta - 90)$	-	0.0200	0.0200	0.0200	0.0200
Calculated Contact Stress due to Saddle	S_c	$K (F/t_w^2) \ln(OD/2t_w)$	MPa	0.47	0.47	1.45	1.45
Calculated Net Resultant Hoop Stress	S_H	$S_{Hi} + S_c$	MPa	88.22	88.22	89.20	89.20
Calculated Longitudinal Stress due to Thermal Expansion	S_T	$E\alpha(T_1 - T_2)$	MPa	-93.39	81.55	-93.39	81.55
Calculated Bending Moment Across Pipe Cross Section	M_R	$(W_t L_{max}^2) / 8$	N.m	24,424.20	24,424.20	37,907.53	37,907.53
Calculated Nominal Bending Stress	S_B	M_R / Z	MPa	21.64	21.64	33.58	33.58
Calculated Longitudinal Stress due to Axial Loading (External Axial Force = 0 N)	S_X	F_e / A	MPa	0.00	0.00	0.00	0.00

DEFINITION	NOMENCLATURE	FORMULA	UNIT	SINGLE SPAN (Installed < 3 Locations)		TWO EQUAL SPANS (Installed ≥ 3 Locations)	
				Max. Design Temp.	Min. Design Temp.	Max. Design Temp.	Min. Design Temp.
SUMMATION OF LONGITUDINAL STRESSES - CHECKED BY ASME B31.8 Para. 833.3							
Allowable Longitudinal Stress	$S_L (Allow)$	$S_L (Allow) = 0.9 \cdot SMYS \cdot T$	MPa	405.00	405.00	405.00	405.00
Calculated Longitudinal Stress (taking bending in tension)	$S_{L\text{-}Tension}$	$vS_H + S_T + S_B + S_X$	MPa	-45.29	129.65	-59.80	115.13
SUMMATION OF LONGITUDINAL STRESSES - CHECK		$\lvert S_{L\text{-}Tension} \rvert \leq S_L\ (Allow)$	%	11.18%	32.01%	14.77%	28.43%
RESULT				PASS	PASS	PASS	PASS
Calculated Longitudinal Stress (taking bending in compression)							
SUMMATION OF LONGITUDINAL STRESSES - CHECK	$S_{L\text{-}Compression}$	$vS_H + S_T - S_B + S_X$	MPa	-88.56	86.37	-100.21	74.72
RESULT		$\lvert S_{L\text{-}Compression} \rvert \leq S_L\ (Allow)$	%	21.87%	21.33%	24.74%	18.45%
COMBINED STRESS - CHECKED BY ASME B31.8 Para. 833.4							
Allowable Combined Stress	$S_{eq} (Allow)$	$S_{eq} (Allow) = k \cdot SMYS \cdot T$	MPa	405.00	405.00	405.00	405.00
Calculated Absolute Differential of Hoop Stress and Longitudinal Stress (for S_L in tension)	-	$\lvert S_L - S_H \rvert$ for S_L in tension	MPa	133.50	41.43	149.01	25.93
Calculated Absolute Differential of Hoop Stress and Longitudinal Stress (for S_L in compression)	-	$\lvert S_L - S_H \rvert$ for S_L in compression	MPa	176.78	1.84	189.41	14.48
	-	Max of $\lvert S_L - S_H \rvert$	MPa	176.78	41.43	189.41	25.93
Calculated Absolute Net Resultant Hoop Stress		$\lvert S_H \rvert$	MPa	88.22	88.22	89.20	89.20
Calculated Absolute Net Longitudinal Stress (Select Max $\lvert S_L \rvert$ between tension and compression)		S_L = max of $\lvert S_{L\text{-}Tension} \rvert, \lvert S_{L\text{-}Compression)} \rvert$	MPa	88.56	129.65	100.21	115.13
The combined stress is in accordance with the maximum shear stress theory as follows:	S_{eq1}	Max. of $(\lvert S_H - S_L \rvert, \lvert S_H \rvert, \lvert S_L \rvert)$	MPa	176.78	129.65	189.41	115.13
COMBINED STRESS - CHECK		$S_{eq1} \leq S_{eq}\ (Allow)$	%	43.65%	32.01%	46.77%	28.43%
RESULT				PASS	PASS	PASS	PASS
Alternatively, the combined stresses may be combined in accordance with the maximum distortion energy theory as follows:	S_{eq2}	$(S_L^2 - S_L S_H + S_H^2)^{0.5}$	MPa	88.39	114.69	95.19	104.60
COMBINED STRESS - CHECK		$S_{eq2} \leq S_{eq}\ (Allow)$	MPa	21.82%	28.32%	23.50%	25.83%
			%	PASS	PASS	PASS	PASS
RESULT							
Maximum of Combined Stress		$Max(S_{eq1}, S_{eq2})$		176.78	129.65	189.41	115.13
COMBINED STRESS - CHECK		$Max(S_{eq1}, S_{eq2}) \leq S_{eq}\ (Allow)$		43.65%	32.01%	46.77%	28.43%
RESULT				PASS	PASS	PASS	PASS
SCREW ANCHOR INSTALLATION TORQUE				**SINGLE SPAN (Installed < 3 Locations)**		**TWO EQUAL SPANS (Installed ≥ 3 Locations)**	
A design safety factor of 2.0 shall be used for allowable stresses in screw anchor structure components and this shall also be the safety factor for whole system.	SF_s	Assumed		2.00	2.00	2.00	2.00
Empirical Factor for Screw Anchor (Square shaft and round shaft anchors less than 3.5 in (89 mm) diameter)	K_T	$10\ ft^{-1}$ or $33\ m^{-1}$	1/m	33.00	33.00	33.00	33.00
Required Minimum Installation Torque per individual screw anchor T_Q = Average installation torque measured during installation	T_Q	$(SF_s F)/(2K_T)$	N.m	76.78	76.78	239.13	239.13
			lbf.ft	**56.63**	**56.63**	**176.37**	**176.37**
FIND SCREW ANCHOR SELECTION							
Required Minimum Load Capacity of Screw Anchors per Set at Maximum Spacing	F_{CAP}	$SF_s F$	N	5,067.32	5,067.32	15,782.32	15,782.32
			lbf	**1,139.18**	**1,139.18**	**3,548.01**	**3,548.01**
PULL TEST LOAD							
The minimum force required to hold down per set of screw anchors	F	F_{Ls} and F_L	N	**2,533.66**	**2,533.66**	**7,891.16**	**7,891.16**
The minimum force required to hold down per individual of screw anchor	$F_{Individual}$	$(F_{Ls}$ and $F_L) / 2$	N	1,266.83	1,266.83	3,945.58	3,945.58
Pull test load per individual of screw anchors	Pull test load	115% of $F_{Individual}$	N	1,456.85	1,456.85	4,537.42	4,537.42
			lbf	**327.51**	**327.51**	**1,020.05**	**1,020.05**

APPENDIX F: SOIL PROPERTY AT PIPELINE ROAD CROSSING LOCATION

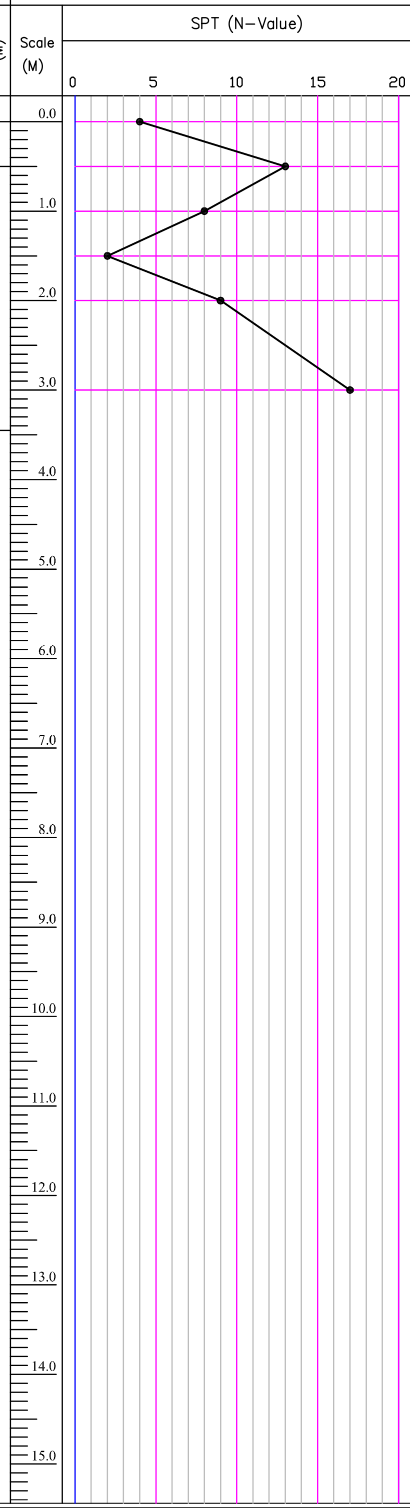
LOG OF BORING

CLIENT: COMPANY	**Borehole No. BH3-13**
PROJECT: MYANMAR DOMESTIC GAS TO POWER PROJECT	
LOCATION: WORK SECTION-1 FROM DAW NYEIN TO KYAIKLAT	SHEET NO: 1 OF 1

DRILLING DATE STARTED: 13-5-2021	BOREHOLE DIA: 100 mm	REDUCED LEVEL: _ M
DRILLING DATE COMPLETED: 13-5-2021	COREHOLE DIA:	NORTHING: - 1760605.00 M
LOG BY: IIS	DRILLING METHOD: AUGER DRILLING	EASTIING: - 778198.00 M
PREPARED BY: IIS	RIG TYPE NO: PORTABLE AUGER DRILL	INCLINATION: VERTICAL
DATE PREPARED: 21-5-2021	DRILLED BY: WAI PHYO AUNG	DIRECTION:

Description	Graphic Log	Depth (Thickness) (M)	Reduced Level (M)	Blows/ 30cm	Legend	Type & No.	Depth (M)	TCR %	RQD %	Water Level (Meter)
GROUND SURFACE		0.0	0.0							
Yellowish Brown, Very Loose, Clayey SAND with a little amount of Silt	SC	(0.5) 0.5	-0.5	4	☒	SPT-1	0.0-0.45			
Yellowish Brown to Grey, Very Loose to Medium Dense, SAND with trace amount of Silt and Clay	SP	(2.95) 3.45	-3.45	13	☒	SPT-2	0.5-0.95			GWL: 0.8M
				8	☒	SPT-3	1.0-1.45			
				2	☒	SPT-4	1.5-1.95			
				9	☒	SPT-5	2.0-2.45			
				17	☒	SPT-6	3.0-3.45			

END OF THE HOLE



CHECKED BY

TIN HTUN (GEOLOGIST)

International Integrated Services Co., Ltd.

REMARKS: WATER LEVEL- (0.8 M) FROM THE EXISTING GROUND LEVEL.

LEGEND:

- Standard Penetration Test (SPT)
- Pressure meter Test (PMT)
- Vane Shear Test (V)
- Permeability Test (PBT)
- Packer Test (PKT)
- Attemped (UD), (OD), (PS), (MZ) & (DS)
- Undisturbed Sample (UD)
- Open Drive Thickwall Sample (OD)
- Mazier Sample (MZ)
- Denison Sample (DS)
- Piston Sample (PS)
- Core Run (CR)
- Gravel
- Sand
- Silt
- Clay
- Water Level