Basic Engineering Study for
Aung Sinkha Development Project Phase 1A

PIPELINE BASIS OF DESIGN AND DESIGN CRITERIA

PTTEP

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

- [x] 1. APPROVED
- [ ] 2. APPROVED with comments (Proceed to IFB)
- [ ] 3. Review with comments
- [ ] 4. Rejected to be reissued
- [ ] 5. Not APPROVED

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PTTEP	**PTTEP INTERNATIONAL LIMITED**	
	Basic Engineering Study for Aung Sinkha Development Project Phase 1A	
	MM-ASK-1A-APL02-PLR-BOD-0001	**REV** C1

T.EN TECHNIP ENERGIES

DOCUMENT TITLE	PIPELINE BASIS OF DESIGN AND DESIGN CRITERIA□ Rev.A1	PTTEPI DOC. NO.	MM-ASK-1A-APL02-PLR-BOD-0001 Rev.A1

Aung Sinkha Development Project PROJECT: Review Comment

PTTEPI		T.EN	
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Aung Sinkha Development Project PROJECT

DO NOT DELETE OTHER REVIEWERS COMMENTS WITHOUT DISCUSSING WITH THEM!

COMMENT NO.	SECT.	PAGE & REF.	CLIENT COMMENTS (REVIEWER)	T.EN RESPONSE	COMMENT STATUS OPEN/CLOSED	Comment by*
1		6	Change to APL02 to jetty.	Noted and incorporated		Surasit Daenrak
2		9	Remove.	Removed		Surasit Daenrak
3		13	Add Standard for-Installation of Steel Pipeline by Horizontal Directional Drilling, 10008-STD-6-PLR-031. -Block Valve Station, 10008-STD-6-PLR-032.	Added		Surasit Daenrak
4		16	0/70	Noted and incorporated		Surasit Daenrak
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6		16	To confirm with process.	Revised and confirmed		Surasit Daenrak

HOLD LIST

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-	-	-

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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 submitted it to MOGE for approval. MOGE approved ASK Field Development Plan in April 2021.

The ASK field is located offshore in the Gulf of Moattama, Myanmar, as illustrated in Figure 1-1. The field is located approximately 70 km from Land Fall Point (LFP) at Daw Nyein village and 200 km south-west of Yangon with a water depth range of 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 the tie-in point at Gas Receiving Station no. 2 (GRS#2), of Domestic Gas to Power Pipeline Development Project, nearby the APF. The condensate will be kept in onshore storage tanks before loading, transporting/ offloading to customers. 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. The gas production is planned to start up by Q4 of 2025.

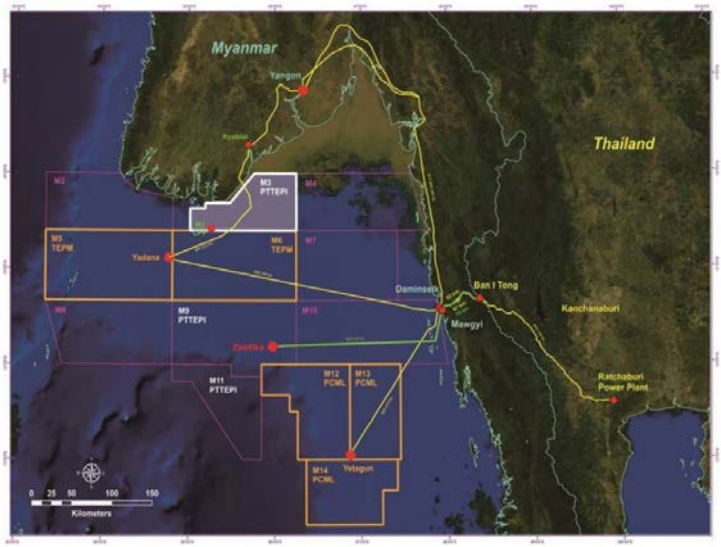

Figure 1-1 Block M3 – Aung Sinkha Field, Offshore Myanmar

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

- 2 Wellhead Platforms (WPA - 1 and WPA - 2)
- 1 Intra - field pipeline which links between WPA - 1 and WPA - 2
- 1 Multiphase export pipeline to transport combined fluid of WPA - 1 and WPA - 2 to ASK Onshore Processing Facilities (APF)
- ASK Onshore Processing Facilities (APF)
- Onshore pipelines from APF to Gas Receiving Station#2 (GRS#2)
- Onshore infrastructure i.e. condensate offtake facilities, accommodation, Personal Material Transfer Facilities, telecommunication system, roads, etc.
- APL01 Onshore pipeline from landfall to APF
- APL02 Onshore pipeline from APF to ACP

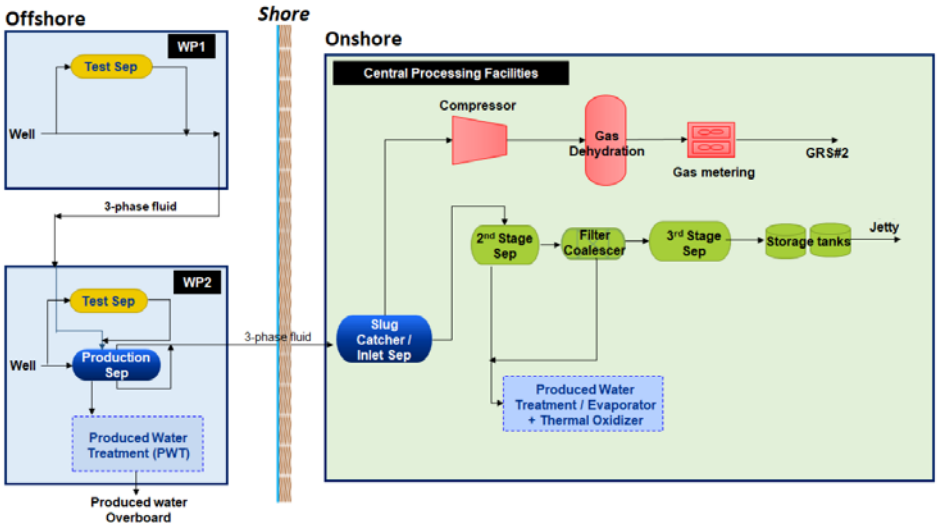

Figure 1-2 Field Block Flow Diagram

1.2 Abbreviation

3LPE	Three Layer Polyethylene
AC	Alternating Current
ACP	ASK Condensate Offloading and Personnel Transfer Facilities
APF	Aung Sinkha Production Facility
API	American Petroleum Institute
ASK	Aung Sinkha
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BPVC	Boiler and Pressure Vessel Code
CWC	Continuous Concrete Weight Coating
CM	Central Meridian
CP	Cathodic Protection
D	Diameter
DP	Design Pressure

E	East
ED	Edition
FEED	Front End Engineering Design
FOC	Fibre Optic Cable
GPS	Global Positioning System
GRS	Gas Receiving Station
HDD	Horizontal Directional Drilling
HFW	High Frequency Weld
ID	Internal Diameter
ISO	International Organization for Standardization
LAT	Latitude
LONG	Longitude
MSL	Mean Sea Level
MSS	Manufacturer's Standardization Society
N	North
NACE	National Association of Corrosion Engineers
NPS	Nominal Pipe Size
OD	Outside Diameter
PEGS	PTTEP Engineering General Specification
PPS	Project Particular Specification
PSC	Production Sharing Contract
PTTEP	PTT Exploration and Production Public Company Limited
ROW	Right of Way
RS	Richter Scale
SAWL	Longitudinally Submerged Arc Weld
SMTS	Specified Minimum Tensile Strength
SMYS	Specified Minimum Yield Strength
SI	International Standard
UTM	Universal Transverse Mercator
WGS	World Geodetic System

1.3 Definitions

The following definitions shall apply to this document:

Company	PTT Exploration & Production PCL. (referred to as PTTEP)
Contractor	Any Company PTTEP has signed a Contract with for the Engineering, Procurement, Construction and Installation of a part of a project
Project	The Provision of Basic Engineering for Pipelines and Onshore Facilities for Myanmar Domestic Gas to Power Project
Shall	Used to indicate that a provision is mandatory
Should	Used to indicate that a provision is not mandatory but is recommended as good practice
May	Used to indicate that a provision is optional

1.4 Purpose of Document

This document summarizes design data, Company specific requirements, assumptions and the methodologies used for design of the onshore pipelines in The Basic Engineering Study for Aung Sinkha Development Project Phase 1A Project.

1.5 Scope of Design

In this project, the onshore scope of design consists of the following item(s):

- 8.625” Condensate Pipeline from APF to ACP

The basis of design for the onshore APL02 onshore pipeline is covered in the following documents:

- Pipeline Buoyancy Control and Anchors Spacing Calculation Report
- Pipeline Wall Thickness, Road Crossing, and Material Grade Selection Report

The following design activities shall be carried out as part of basic engineering design;

- Establish the basis of design (scope of this document)
- Wall thickness selection
- External anti-corrosion coating selection
- Preparation of material take-off report
- Preparation of pipeline system specifications and datasheets
- Preparation of route drawings and alignment sheets
- Seismic and fault crossing analysis (if necessary)

2. GENERAL

2.1 System of Units

SI units shall be used throughout this project with imperial units to be used for clarity in brackets, if required. The following exceptions shall apply:

- Pressure shall be expressed as gauge pressure in barg. Gauge pressure is referenced to standard atmospheric pressure of 1.01325 barg;
- Temperature shall be expressed as degree Celsius (°C).

2.2 Geodetic Datum

All charts and locations shall be mapped in terms of the geodetic reference system as tabulated in Table 2-1.

Table 2-1: Geodetic Parameters

COORDINATE SYSTEM : UTM ZONE 46 MOATTAMA 92 DATUM	
PROJECTION	UNIVERSAL TRANSVERST MERCATOR
ZONE	UTM 46P and 46Q
CENTARL MERADEIN	93 DEGREE EAST
LATITUDE ORIGIN	EQUATOR
FALSE EAST	500,000
FALSE NORTH	0
SCALE FACTOR	0.99960
MOATTAMA DATUM	
LOCAL DATUM	MOATTAMA 92
ELIPSOID	GRS80
SEMI MAJOR AXIS (a)	6,378,137.000
SEMI MINOR AXIS (b)	6,356,752.315
INVERST FALATTENING	1 / 298.2572236
WGS84 DATUM	
SATELITE DATUM	WGS 1984
ELIPSOID	WGS84
SEMI MAJOR AXIS (a)	6,378,137.000
SEMI MINOR AXIS (b)	6,356,752.315
INVERST FALATTENING	1 / 298.2572236
DATUM SHIFTING PARAMETERS FROM MOATTAMA 92 TO WGS 84	
DX = PLUS 1.7 DY = MINUS 8.0 DZ = MINUS 7.7	
MANUAL DATUM SHFITING VALUE FROM MOATTAMA 92 TO WGS 84 (APPROX.)	
DE = MINUS 0.846M DN = MINUS 5.192M	

2.3 Coordinates of Key Facilities

The coordinates of each facility are presented in Table 2-2.

Table 2-2: Summary Onshore Facility and Key Locations

No.	Description	Coordinates		UTM Coordinates		
		LAT (N)	LONG (E)	E (m)	N (m)	ZONE
APF	ASK Onshore Processing Facilities	15°54'12.91"	95°35'53.52”	778,200.00	1,760,000.00	46P
ACP	ASK Condensate Offloading and Personnel Transfer Facilities	16°0'16.34"	95°38'15.87"	782,295.00	1,771,230.00	46Q

2.4 Battery Limits

2.4.1 Design Limits

The battery limits for the design of the onshore pipelines are illustrated in the schematic presented in Appendix A.

2.4.2 Code Limits

The code limits are similar to Design Limits as shown in Appendix A.

3. SPECIFICATIONS, CODES, AND STANDARDS

All onshore pipelines in this project shall be designed in accordance with ASME B31.4 [5], considering the requirements of Company general specification 10008-STD-6-PLR-029, “Design and Construction of Onshore Pipeline and Rail Road & Canal Crossings” [3].

List of applicable Company specifications and international codes and standards are presented in the following section.

3.1 Regulation, Standards and Code of Practice

The Aung Sinkha Development Project Phase 1A shall be designed primarily in accordance with PTTEP’s general specifications (PEGSs) and corporate specifications, as appropriate, and the applicable Myanmar legislative requirements. Where such standards are not applicable, accepted international codes/industry good engineering practices will be adopted. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published on the effective date of a contract.

The order of precedence of the applicable documents shall be:

1) Government Law, Rules and Regulations
2) Purchase Order/ Service Order/ Contract Documents
3) Project Particular Specification (PPS), Datasheets and Drawings
4) PTTEP Engineering General Specification (PEGS)
5) Other Company General Specification Standards and Documents
6) Codes and Standards

In case of conflicts/contradictions between the various codes, standards, regulations and specifications, unless otherwise agreed or decided by Company, it is understood that the more stringent requirement shall apply.

3.2 Project Specifications

The following Project specifications may be used in this project.

Document Number	Document Title
MM-ASK-1A-APF-PRO-BOD-0001	Process Basis of Design
MM-ASK-1A-APL01-PLR-SPE-0003	Project Particular Specification for Field Joint Coating for Onshore Pipeline
MM-ASK-1A-GEN-PLR-SPE-0004	Project Particular Specification for Induction Bends for Pipelines
MM-ASK-1A-GEN-PLR-SPE-0005	Project Particular Specification for Carbon Steel Flanges and Branch Outlet Fittings for Carbon Steel Pipelines
MM-ASK-1A-GEN-PLR-SPE-0006	Project Particular Specification for Forged Pipes, Forged Reducer, and Flat Forgings for Carbon Steel Pipeline
MM-ASK-1A-GEN-PLR-SPE-0007	Project Particular Specification for Barred Tees
MM-ASK-1A-GEN-PLR-SPE-0008	Project Particular Specification for Design, Materials and Fabrication of Pig Launchers and Receivers
MM-ASK-1A-GEN-PLR-SPE-0009	Project Particular Specification for Concrete Coating for Pipelines
MM-ASK-1A-GEN-PLR-SPE-0010	Project Particular Specification for 3LPE Anti-corrosion Coating for Pipelines
MM-ASK-1A-GEN-PLR-SPE-0012	Project Particular Specification for Coating of Bends for Pipelines
MM-ASK-1A-APL01-PLR-SPE-0001	Project Particular Specification for Ball Valves (API 6D)
MM-ASK-1A-APL01-PLR-SPE-0004	Project Particular Specification of Coating for Buried Valves and Fittings
MM-ASK-1A-APL01-PLR-SPE-0005	Project Particular Specification for Hydrostatic Testing & Pre-Commissioning (Dewatering, Drying, Inerting) of Onshore Pipeline
MM-ASK-1A-APL01-PLR-SPE-0006	Project Particular Specification for for Design and Construction of Onshore Pipeline and Railway / Road & Canal Crossings
MM-ASK-1A-APL01-PLR-SPE-0007	Project Particular Specification for Welding & NDE of Onshore Pipeline to API 1104
MM-ASK-1A-APL01-PLR-SPE-0008	Project Particular Specification for AUT of Onshore Pipeline

3.3 Company Standards and Guidelines

The following Company specifications may be used in this project.

Document Number	Document Title	Rev.
10008-STD-6-COR-001	External Anticorrosion Coating for Pipelines	00
10008-STD-6-COR-002	Field Joint Coating for Pipelines	00
10008-STD-6-COR-003	Coating of Bends and Fittings for Pipelines	00
10008-STD-6-COR-034	Corrosion Assessment and Material Selection of Pipelines	00
10008-STD-6-PLR-005	Seamless Pipes for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)	00

Document Number	Document Title	Rev.
10008-STD-6-PLR-006	Longitudinally Submerged Arc Welded (SAWL) Pipes for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)	00
10008-STD-6-PLR-007	High Frequency Welded (HFW) Pipes for Carbon Steel Pipelines	00
10008-STD-6-PLR-008	Induction Bends for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)	00
10008-STD-6-PLR-009	Design, Materials and Fabrication of Flanges and Branch Outlet Fittings for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)	00
10008-STD-6-PLR-011	Design, Materials and Fabrication of Tees for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)	00
10008-STD-6-PLR-012	Design, Materials and Fabrication of Pig Launchers and Receivers (Mild, Intermediate and Severe Sour Service)	00
10008-STD-6-PLR-029	Design and Construction of Onshore Pipeline and Rail Road & Canal Crossings	00
10008-STD-6-PLR-031	Installation of Steel Pipeline by Horizontal Directional Drilling	00
10008-STD-6-PLR-032	Block Valve Station	00

3.4 Industrial Codes, Standards, and Recommended Practices

The following industry codes and standards may be used:

- American Petroleum Institute (API)

Document Number	Codes and Standards Title	Rev.
API Spec 5L	Specification for Line Pipe	46th ED, 2018
API Spec 6D	Specification for Pipeline and Piping Valves	24th ED, 2014
API STD 598	Valve Inspection and Testing	10th ED, 2016
API STD 608	Metal Ball Valves – Flanged, Threaded, and Welding Ends	6th ED, 2020
API RP 1102	Recommended Practice for Steel Pipelines Crossing Railroads and Highways	7th ED, 2007
API STD 1104	Welding of Pipelines and Related Facilities	21st ED, 2013

- American Society of Mechanical Engineers (ASME)

Document Number	Document Title	Rev.
ASME B16.5	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard	2020
ASME B16.9	Factory-Made Wrought Buttwelding Fittings	2018
ASME B16.10	Face to Face and End to End Dimensions of Valves	2017
ASME B16.11	Forged Fitting, Socket Welding & Threaded	2016
ASME B16.20	Metallic Gaskets for Pipe Flanges	2017
ASME B16.21	Nonmetallic Flat Gaskets for Pipe Flanges	2016
ASME B16.25	Butt Welding Ends	2017

Document Number	Document Title	Rev.
ASME B16.34	Valves - Flanged, Threaded, and Welding End	2020
ASME B16.47	Large Diameter Steel Flanges: NPS 26 through NPS 60, Metric/Inch Standard	2020
ASME B31.3	Process Piping	2018
ASME B31.4	Pipeline Transportation Systems for Liquids and Slurries	2019
ASME BPVC.VIII.1	Rules for Construction of Pressure Vessels	2021

- American Society of Testing and Materials (ASTM)

Document Number	Document Title	Rev.
ASTM A105	Standard Specification for Carbon Steel Forgings for Piping Applications	2021
ASTM A106	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service	2019
ASTM A193	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications	2020
ASTM A194	Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both	2020
ASTM A694	Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service	2016
ASTM G5	Standard Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements	2014

- Manufacturer's Standardization Society (MSS)

Document Number	Document Title	Rev.
MSS SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	2017
MSS SP-25	Standard Marking System for Valves, Fittings, Flanges and Unions	2018
MSS SP-44	Steel Pipeline Flanges	2019
MSS SP-75	High-Strength, Wrought, Butt-Welding Fittings	2019

- International Standardization Organization (ISO)

Document Number	Document Title	Rev.
ISO 3183	Petroleum and Natural Gas Industries - Steel Pipe for Pipeline Transportation Systems	4th ED, 2019
ISO 14313	Petroleum and Natural Gas Industries - Pipeline Transportation Systems - Pipeline Valves	2nd ED, 2007
ISO 15156	Petroleum and Natural Gas Industries - Materials for Use in H2S-containing Environments in Oil and Gas Production	4th ED, 2020
ISO 15590-1	Petroleum and Natural Gas Industries - Induction Bends, Fittings and Flanges for Pipeline Transportation Systems - Part 1: Induction Bends	3rd ED, 2018
ISO 15590-3	Petroleum and Natural Gas Industries - Induction Bends, Fittings and Flanges for Pipeline Transportation Systems - Part 3: Flanges	1st ED, 2004
ISO 17636	Non-destructive Testing of Welds-Radiographic Testing	2nd ED, 2013
ISO 17637	Non-destructive Testing of Welds-Visual Testing of Fusion-welded Joints	2nd ED, 2016
ISO 17638	Non-destructive Testing of Welds-Magnetic Particle Testing	2nd ED, 2016

Document Number	Document Title	Rev.
ISO 17640	Non-destructive Testing of Welds-Ultrasonic Testing-Techniques, Testing Levels, and Assessment	4th ED, 2018

- National Association of Corrosion Engineers (NACE)

Document Number	Document Title	Rev.
NACE MR0175	Petroleum and Natural Gas Industries - Materials for Use in H2S-containing Environments in Oil and Gas Production	2015
NACE SP0502	Standard Practice - Pipeline External Corrosion Direct Assessment Methodology	2010

4. DESIGN AND OPERATING DATA

4.1 Pipeline Design Data

Pipeline data are presented in Table 4-1. The pipeline design and operating parameters in table are according to Process Basis of Design, Document No. MM-ASK-1A-APF-PRO-BOD-0001 [1].

Table 4-1: Pipeline Design Data

Description	Unit	Value
Service	-	Onshore Condensate Pipeline
Originating from	-	APF
Terminating at	-	ACP
Pipeline Size	mm (Inch)	219.1 (8.625)
Approximate Length	km	18
Pipeline Status	-	Buried
Design Life	Years	20
Corrosion Allowance	mm	3
Anti-corrosion Coating	-	3LPE
Open-cut Anti-corrosion Thickness	mm	3.5
Boring/HDD Anti-corrosion Thickness	mm	4.5

4.2 Pipeline Operating Data

The design pressure and temperature including the operating production data of the pipelines are presented in Table 4-2.

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The pipeline design and operating parameters shall be in accordance with Process Basis of Design Document No. MM-ASK-1A-APF-PRO-BOD-0001 [1].

Table 4-2: Pipeline Operating Conditions

Description	Unit	Value
Fluid	-	Condensate
Operating Pressure (Min./ Max) [4]	barg	10.4
Design Pressure (DP)	barg	48.7 (1)
Hydrotest Pressure	barg	60.9
Operating Temperature (Min./ Max.) [4]	°C	20.3/44.1
Design Temperature [1] (Min./Max.)	°C	0/70
Max. Content Density [4]	kg/m^3	723.3
Min. Content Density [4]	kg/m^3	689.8

Note: 1. Maximum Pressure for Class Rating #300.

4.3 Material Data

Pipeline material properties are presented in Table 4-3 [6].

Table 4-3: Line Pipe and Coating Material Properties

Description	Unit	Value
Pipeline OD	mm (Inch)	219.1 (8.625)
Line Pipe Material	-	API 5L X65
Manufacturing Process	-	SMLS or HFW
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 x 10^5
Coefficient of Linear Expansion	1/°C	1.17 x 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

5. ENVIRONMENT DATA

5.1 Air Properties

Air properties are as given in Table 5-1[1].

Table 5-1: Air Properties

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

5.2 Seismic Fault Data

Myanmar area is classified as an earthquake zone with the seismic records showing that there have been at least 16 major earthquakes with Richter Scale (RS) $\geqslant$ 7.0 within the territory of Myanmar in the past 170 years. Seismic design data and design criteria are presented in Seismic Consideration for Pipeline in Seismic Hazardous Area, Document No. MM-ASK-1A-APL01-PLR-BOD-0002 [2]. The peak ground acceleration of 0.2 PGA (g) for APL02 pipeline is considered, refer to Figure 3-2 of MM-ASK-1A-APL01-PLR-BOD-0002 [2].

5.3 Geotechnical Data

Soil design data is presented in Reporting on Field Investigation Results, Geotechnical Investigation Report for Geotechnical Investigation Work for AUNG SINKHA Project [9].

6. PIPELINE REQUIREMENTS

6.1 General

ASME B31.4 [5] shall be the Applicable Prime Reference for Myanmar Minimum Facility in conjunction with 10008-STD-6-PLR-029 [3].

Line pipe and mother pipe for bends required for the project pipelines shall be procured by Company in accordance with API Spec 5L [6].

All linepipe materials required for the project station piping, bypass piping, underground piping and any other type of piping, shall be provided by the Contractor.

6.2 Allowable Stress Limits and Design Factors

The stresses induced in the pipelines from the specified load combinations will be checked against the allowable values presented below. The values for hoop stress, longitudinal stress and combined stress will be evaluated at critical locations along the pipelines for each of the

specified load combinations. The design factors for pipelines are presented in the table below:

Table 6-1: Allowable Stresses for Onshore Pipeline

Design Conditions	Product	Allowable Stress Limit as % of SMYS		
		Hoop Stress	Longitudinal Stress	Combined Stress
Operation	Condensate	72	90	90
Hydrotest	Water	90	90	90

Note:

1. Allowable stress equals 90% for functional load.
2. Allowable stress equals 100% for functional load + environmental load.
3. Functional load includes self-weight of pipe, fluid weight, and thermal and pressure loads.

Environmental load includes seismic accelerations due to earthquake.

6.3 Load Combinations

Pipeline stress analysis shall be based on the load combinations presented in Table 6-2.

Table 6-2: Stress Analysis Load Combinations

No.	Load Combination
1	Internal Pressure
2	Internal Pressure + Weight (Sustained)
3	Internal Pressure + Pipe Weight + Pipe End Expansion (Functional)
4	Functional + Seismic in X direction (Two Directions)
5	Functional + Seismic in Z direction (Two Directions)

6.4 Pipe Bends

6.4.1 General

Below is pipe bending criterion.

Natural Bends: If a long radius bend, with a radius of curvature greater than 550D, is required; it shall be accommodated by natural flexure of the pipeline itself. Mechanical bending is not required.

Cold Bends: If a bend with radius of curvature in the range as below, it shall be accommodated by cold bending of selected line pipe. For APL02 cold bend radius range shall be 550D to 18D

Hot Induction Bends: Bends with radius of curvature in the range as below if required, shall be accommodated by hot induction bending of selected line pipe. For APL02 cold bend radius range shall be 18D to 5D

Bends with radius of curvature less than 5D shall not be allowed for installation in the piggable pipeline.

6.4.2 Mother Pipe for Bends

Bare pipes (without externally coating) shall be used as mother pipe for bends. Below are pipe bending criteria (by degree).

- Cold Bends: For bends of equal and less than 90 degrees for 8.625” pipelines, it shall be accommodated by cold bend. The bend angle shall be calculated and converted from 18D criteria for 8.625” pipelines. For this case, mother pipe for bends is not required. Line pipe, which is externally coated by 3LPE, shall be used instead.
- Hot Induction Bends: Hot induction bend can be used when the available space is not enough for the cold bend or the location that specified in the project drawings.

After bending is applied, the hot induction bends shall be externally coated by 3LPE Coating.

6.5 Pipeline Route

The following criteria have been taken into consideration, where appropriate, in the selection of the onshore pipeline routes:

- The pipeline should be routed such that it abides by the rules and regulations set forth by the local authorities;
- The pipeline should be routed, as much as possible, within the right-of-way (ROW) corridor or existing ROW, if available. Recommended ROW width is 15 m.
- Optimization of pipeline length.
- Optimization of installation costs.
- Minimization of failure during operation (i.e. ground slides) or during installation (i.e. high slopes).
- Pipeline minimum curve radius.

6.6 Crossings and Minimum Depth of Cover

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 10008-STD-6-PLR-029, Design and Construction of Onshore Pipeline and Railway, Road & Canal Crossings [3] and API RP 1102, Steel Pipelines Crossing Railroads and Highways [7].

A carrier pipe with uncased crossing will be subjected to both internal load from pressurization and external loads from earth force (dead load) and highway or railway traffic load (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. The highway traffic load will use information of Motor Vehicle Requirement Standard from Myanmar Road Transportation Administration Department, see APPENDIX B.

Unless otherwise specified by Authority requirements or otherwise specified by any other detailed designs, the following criteria shall be applied in the pipeline route design. Moreover, the following criteria shall be indicated in the relevant design alignment sheets and typical drawings.

Table 6-3: Crossings and Minimum Depth of Cover

Type	Minimum Depth of Cover
Normal Areas (e.g., open areas, crops, and agricultures)	1.2 meters below the natural ground level at any open cut sections unless otherwise noted
Parallel to Roads	1.5 meters below the road surface and 1.2 meters below the natural grade level, whichever is deeper, unless otherwise specified by Authority requirements
Road Crossings (e.g., Paved Road Crossings, Parallel to and underneath Roads, and Unpaved Road Crossings)	2.0 meters below the road surface and 1.2 meters below the lowest point along the crossing, whichever is deeper. Additional requirements from the Authority shall be considered. If open cut method is approved by Company/Authority, the pipeline shall be protected by concrete slabs.
Railway Crossings	2.0 meters below the existing ground level of the railway and 1.2 meters below the lowest point along the crossing.
Wide Waterways (width > 2 m), Canal or River	2.0 meters below the lowest bed elevation of canals, streams, waterways, rivers, etc. If open cut method is approved by Company/Authority, the pipeline shall be protected by concrete coating.
Narrow Waterways (width < 2 m) or Ditch	2.0 meters below the lowest bed elevation of canals, streams, waterways, etc. If open cut method is approved by Company/Authority, the pipeline shall be protected by concrete slabs.
Natural Ponds & Private Ponds	2.0 meters below the lowest bed elevation of ponds. If open cut method is approved by Company/Authority, the pipeline shall be protected by concrete coating.

Type	Minimum Depth of Cover
Shrimp Ponds & Fish Ponds	2.0 meters below the lowest bed elevation of ponds. If open cut method is approved by Company/Authority, the pipeline shall be protected by concrete slabs.

6.7 Mechanical Protection

6.7.1 Open Cut (Pre-cast Concrete Slabs)

A portion of open cut sections shall require that pre-cast concrete slabs be installed above the pipeline and FOC as mechanical protection. Conditions / sections of pipeline, which require such concrete slabs, shall be as follows:

- Pipeline to be installed across public roads
- Pipeline to be installed across private roads
- Pipeline to be installed across narrow waterways (width < 2 m) or across ditches
- Pipeline to be installed across fish ponds or shrimp ponds

When pipeline will not be installed under roads, waterways, ditches, fish ponds or shrimp ponds as above conditions, pre-cast concrete slabs shall not be required.

6.7.2 Open Cut (Continuous Concrete Weight Coating)

For any areas in which pipeline requires concrete coating, such as when the pipeline is installed by open cut construction method, across natural ponds, private ponds, waterways, ditches or canals; the marking symbols shall be as noted on the Project Alignment Sheets.

When any part of the pipeline which crosses under ponds, waterways, ditches or canals by conventional open cut method with continuous concrete weight coating (CWC), as specified in the Project Alignment Sheets, Contractor shall provide and apply the continuous concrete weight coating to suit as mechanical protection. Contractor shall also be responsible to improve the corrosion coating as necessary, to suit the supplied continuous concrete weight coating and installation conditions.

6.8 Boring/ Jacking

Normally, uncased boring or uncased jacking method shall be chosen for installation across general crossings (i.e. roads, railways, ponds, waterways or canals). However, except for rock areas, when pipeline sections pass through such areas or crossings, the line pipe may be installed by cased boring or cased jacking method. For cased boring or cased jacking method, when boring or jacking is completed, the space between the gas pipeline and the

enveloper pipe (casing) shall be filled with grout. However, if uncased boring or uncased jacking method is chosen for installation across rock areas, rock shield protection shall be provided to protect the corrosion coating of the line pipe.

When Contractor performs any boring or jacking, the boring pits (both entry pit and exit pit) shall be excavated away from the crossing utilities (e.g. highways, roads, railways, waterways, canals, rivers, and any other utilities). The edge of the boring pit shall be away from the toe of slope of the crossing at least 3 meters or justified by slope stability to prevent damage of the crossing facilities.

The line pipe which is used as boring pipe or jacking pipe shall have at least 4.5 mm thickness of 3LPE coating.

Alternatively, a combined method of micro-tunneling and HDD technology to install the prefabricated pipeline in one step, with the required boreholes excavated at the same time can be applied where applicable.

6.9 Horizontal Directional Drilling (HDD)

Some pipeline sections, which pass through long crossings and / or other environmentally sensitive areas, shall be installed by HDD method as indicated in the Project Alignment Sheets. HDD linepipe shall have 4.5 mm thickness of 3LPE coating.

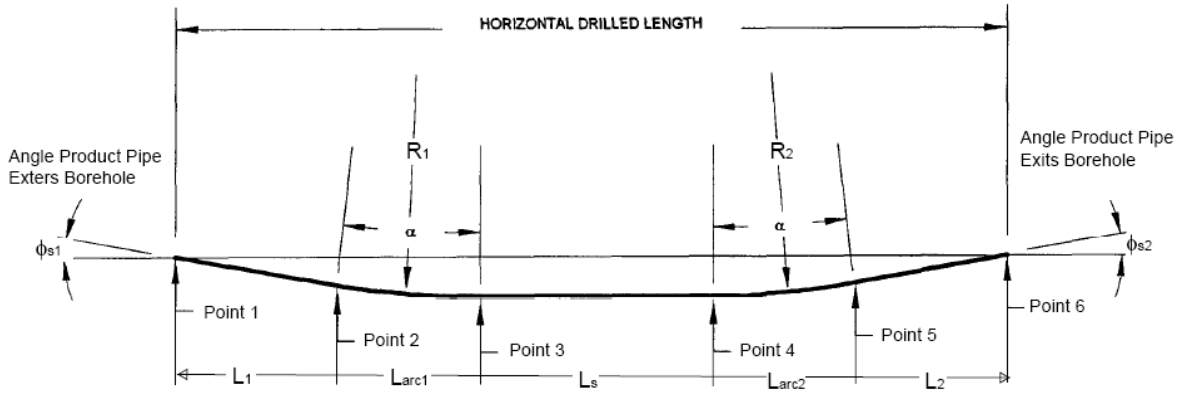

Figure 6-1: HDD Configuration

HDD guidelines for design are as below according to 10008-STD-6-PLR-029 Design and Construction of Onshore Pipeline and Railway, Road & Canal Crossings [3].

- Entry angle shall be 12° (± 4°) from horizontal reference. Other angles can be proposed with Company approval based on soil condition and HDD profile design.
- Exit angle shall be 10° (± 4°) from horizontal reference. Other angles can be proposed with Company approval based on soil condition and HDD profile design.

- Radius of curvature shall be such that the longitudinal stress is less than:
- 60% of the SMYS when pipe is at its maximum design pressure and temperature,
- 80% of the SMYS when pipe is pulled,
- 90% of the SMYS when pipe is hydrotested.
- Radius of curvature shall be such that the combined stress is always less than 90% of SMYS.
- Radius of curvature shall always be greater than 1000 x OD.
- The cover on top of pipe shall be minimum 5 m below obstacle being crossed and shall ensure that a mud breakout does not occur.
- The distance between entry point or exit point and the first obstacle (road, river, ditch, etc.) shall be at least 50 m.
- The length of straight pipe at entry and exit points shall be 10 m minimum.
- Required HDD minimum reaming sizes are 1.5 times the pipeline ODs, which is 13" for 8.625" pipelines.
- Additional specific material for wrapping, such as fiber glass/ scar guard may be provided.
- Testing method of coating quality after pullback shall be approved by the Company.
- Pullback of multiple steel pipe strings in the same drilling hole is not allowed.

6.10 Pipeline Marker and ROW Marker

Aerial marker posts shall be installed at every full KP number (e.g. 1+000, 2+000, etc.) and at all changes of direction greater than 10 degrees. Intermediate marker posts shall be spaced at line of sight, crossings, and magnetic marker locations. Maximum spacing of intermediate marker posts shall not exceed 200 m. For paved road crossings, railway crossings and/or medium waterway crossings: aerial marker posts shall be installed, as a minimum, 0.3 m outside of the edge of ROW of the crossing at both sides of crossing.

For main river crossings and landfalls: Navigable Sign Boards shall be installed on both sides of river and at a landfall point.

ROW markers shall also be installed at maximum spacing of 200 meters on both sides of the pipeline corridor.

Magnetic Markers shall be installed for intelligent pig reference, and buried magnetic markers, heavy duty version providing reference coordinates, shall be installed every 2 km along the pipeline route. The magnetic markers shall be installed at every HDD entry and exit points at overbend tie-ins.

6.11 Buoyancy Control

The calculation methodology for buoyancy control shall be based on ASCE Guideline for the Design of Buried Steel Pipe [8] with consideration summarized in the following bullet points:

- 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.
- Safety factor of 1.2 (minimum of 20% negative buoyancy) shall be used to calculate the screw anchor spacing.
- Minimum hold down capacity of screw anchor pair shall be 8 kN. Screw anchor structural design shall be based on a safety factor of 2.0.
- Minimum required hold down load of screw anchor pair shall be calculated based on buoyancy force of given span.
- Maximum allowable pipeline deflection is 200 mm.
- For area that number of screw anchors is equal or less than 3, pinned-fixed boundary condition is considered, conservatively.
- For area where number of screw anchors is more than 3, fixed-fixed boundary condition may be considered.

Buoyancy control measure shall be required at any location meeting one of the following criteria:

- Where soil is liquefied or saturated
- Where natural grade level (MSL) – the highest water table level (MSL) $\leqslant$ 2.0 m
- In areas subject to frequent flooding or prone to flooding
- Through rice paddies or other flooded-type crop areas
- Through areas designated as “swamp”
- At any water crossings where HDD is not used

The preferred method of buoyancy control is screw anchoring or sand bags. Other weight methods, such as concrete set-on or bolt-on weights, shall not be permitted. The principal parameters for screw anchor calculation and design are as follows:

- Negative buoyancy, where required, shall be assessed based on fully submerged, the soil characteristics such as the mud (fluid) density and/or the liquefaction potential of the soils along the pipeline routes where buoyancy control is required.
- Maximum allowable screw anchor spacing shall be assessed based on the allowable pipe stresses, anchor design and the anchor holding capacity in the soil.

Screw anchor saddles shall be polyester and be provided complete with sacrificial anodes to provide sufficient corrosion protection.

Continuous concrete weight coating (CWC) may be used with Company's explicit approval where their use is more suitable.

6.12 External Coating

For pipeline coating, external coating on linepipe shall be 3 layers coating (3LPE) type. The thickness of the 3LPE coating shall be 3.5 mm for pipeline, which is constructed by the open-cut method and shall be 4.5 mm for pipeline, which is constructed by the trenchless method.

For mother pipe for bends, external coating shall be applied after completion of heat induction bending. External coating on the hot induction bends shall be 3 layers coating (3LPE) type. The thickness of the 3LPE coating shall be 3.5 mm.

Additional protection for trenchless installation used for horizontal directional drill, slick bore, and other trenchless installation methods may be required to resist abrasion and other damage that may occur due to rocks and other obstructions encountered by this installation technique.

7. REFERENCES

[1] Process Basis of Design, MM-ASK-1A-APF-PRO-BOD-0001

[2] Seismic Consideration for Pipeline in Seismic Hazardous Area, MM-ASK-1A-APL01-PLR-BOD-0002

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

[4] Heat and Material Balance, MM-ASK-1A-APF-PRO-HMB-0001-1

[5] Pipeline Transportation Systems for Liquids and Slurries, ASME B31.4

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

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

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

[9] Reporting on Field Investigation Results, Geotechnical Investigation Report for Geotechnical Investigation Work for AUNG SINKHA Project, International Integrated Services Company Limited.

APPENDIX A: BATTERY LIMITS FOR ONSHORE PIPELINES

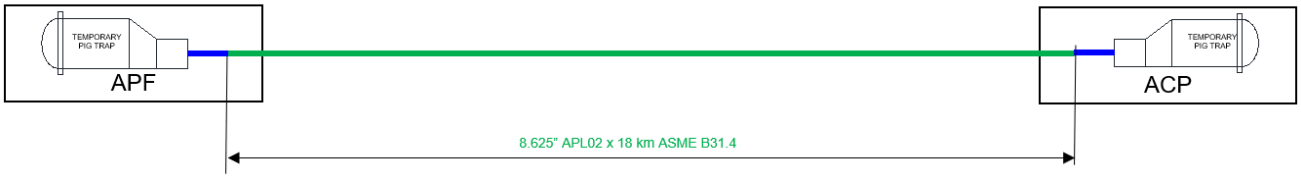

Figure A-1: Pipeline System Design Battery Limits

Note:

1. Scope of this document is APL02.

APPENDIX B: MYANMAR VEHICLE LOADS FOR PIPELINE CROSSING DESIGN

		< 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	