ADNOC GROUP PROJECTS AND ENGINEERING

THERMOPLASTIC LINERS FOR OIL AND WATER PIPELINE SYSTEMS

Specification

AGES-SP-10-004

ص ب 898، أبوظبي، الإمارات العربية المتحدة
PO Box 898, Abu Dhabi, UAE
adnoc.ae

شركة بترول أبوظبي الوطنية
Abu Dhabi National Oil Company

GROUP PROJECTS & ENGINEERING / PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
ADNOC	Specification applicable to ADNOC & ADNOC Group Companies

Group Projects & Engineering is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering is responsible for communication and distribution of any changes to this Specification and its version control.

This specification will be reviewed and updated in case of any changes affecting the activities described in this document.

INTER-RELATIONSHIPS AND STAKEHOLDERS

a) The following are inter-relationships for implementation of this Specification:
   i. ADNOC Upstream and ADNOC Downstream Directorates and
   ii. ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOG Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertilisers, Borouge, Al Dhafra Petroleum, Al Yasat

b) The following are stakeholders for the purpose of this Specification:
   ADNOC PT&CS Directorate.

c) This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group company included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance

d) Each ADNOC Group company must establish/nominate a Technical Authority responsible for compliance with this Specification.

DEFINED TERMS / abbreviations / References

"**ADNOC**" means Abu Dhabi National Oil Company.

"**ADNOC Group**" means ADNOC together with each company in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

"**Approving Authority**" means the decision-making body or employee with the required authority to approve Policies & Procedures or any changes to it.

"**Business Line Directorates**" or "**BLD**" means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

"**Business Support Directorates and Functions**" or "**Non- BLD**" means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

"**CEO**" means chief executive officer.

"**Group Company**" means any company within the ADNOC Group other than ADNOC.

"Specification" means this specification.

CONTROLLED INTRANET COPY

The intranet copy of this document located in the section under Group Policies on One ADNOC is the only controlled document. Copies or extracts of this document, which have been downloaded from the intranet, are uncontrolled copies and cannot be guaranteed to be the latest version.

Table of Contents

I INTRODUCTION

I.1 Scope

This engineering specification (ES) defines the minimum requirements for material selection, design of liner, manufacturing, installation testing & commissioning, operation and maintenance of thermoplastic liner for Oil and Water Pipeline Systems in Onshore and Islands sites. Pipeline Systems cover both buried pipelines and flowlines. This specification currently covers HDPE liners as COMPANY plans to deploy HDPE for liner applications based on the Technology Trial results

In order to cover various operating conditions, other materials such as PE-RT, PA-12, PVDF shall be included in future as Company gains relevant experience by way of Technology Trials / feedback from other Operators.

Thermoplastic liner is an excellent internal corrosion barrier for pipelines / flowlines when applied and operated within specific boundaries stated in this document for each application. Other advantage of thermoplastic liner are lower thermal conductivity compared to carbon steel (lower heat loss by the fluid). Due to low surface roughness and wettability properties of thermoplastic liners, the deposition/adherence of scales is not a concern and liner reduces the flow resistance.

The following shall be considered for application of thermoplastic liner:

i. Hydrocarbons and multiphase flowlines and pipelines including crude oil.

ii. Water supply and water injection flowlines, pipelines

Thermoplastic Liners can be installed on existing as well as new pipelines. As per the current industry capability liners cover a wide range of pipeline sizes (2” – 48”). The application of the liner shall take into consideration the reduction in cross section specially for the small pipe sizes.

Note: Use of Thermoplastic liner for high sour service is restricted in view of environmental concerns with venting of permeated gas. Application to high sour services shall be subject to specific company approval.

This document covers the minimum requirements for selection of candidates for liner application, materials selection, design, manufacturing and installation of thermoplastic liners based on the operating parameters.

I.2 Exclusion

The following structures are excluded from this engineering standard:

i. Plant piping

ii. Valves

iii. High Sour Oil applications

I.3 Definition, Abbreviations and References

I.3.1 General Definitions

COMPANY	Abu Dhabi National Oil Company or any of its Upstream, Midstream and Downstream Operating Companies working in UAE; while the other commonly used terms are ;Owner, End User, Purchaser, Operator, Client, Customer or Appointed Representative.
CONTRACTOR	The party who carries out all or part of the design, engineering, procurement, construction, commissioning or management of the project
Consultant	The specialist party who carry out design of RTP Pipeline from Process, Material Selection and Mechanical disciplines.
VENDOR/ SUPPLIER	The party that manufacturers or supplies equipment and services to perform the duties part of the project.
Third Party Agency	The agency or agencies appointed or nominated to certify the equipment or parts thereof by reference to the standards given in all relevant designs, specifications or procedural documents.
May	Used where alternatives are equally acceptable.
Should	Indicates a strong recommendation to comply with the requirements of this document.
Shall	Indicates mandatory requirement.
LOI	Letter of Intent
Acceptance Criteria	Defined limits placed on characteristics of materials, products or services.
Annulus	Liner annulus is the space that exists between the liner outside surface and the steel carrier pipe internal surface.
Bell hole	Excavated area allowing access to a buried carbon steel pipeline, e.g., for insertion of a section of thermoplastic liner.
Buckling	The onset of elastic instability of the liner. Collapse may follow quickly after buckling. The buckling pressure is typically calculated using known properties of materials
Butt fusion welding	A process of fusing thermoplastic materials that entails squaring and aligning the pipe materials, heating the pipe ends, bringing the two aligned pipe ends together under pressure and a predetermined cooling time resulting in a fused joint having a hydrostatic strength equal to the parent pipe.
Collapse	The large-scale deformation of a liner usually resulting in reduced flow capacity and damage to the liner. Collapse often results in a U shaped cross-section of the liner.
Critical Buckling Pressure (Pcrit)	The external pressure applied to a liner sufficient to initiate structural buckling.
Elastic Modulus	Proportionality constant between applied stress and strain.

Expansion	Increasing the diameter of the inserted liner so it is in contact with the interior surface of the host pipe.
Flange	Steel raised face flanges with bolt circle per ANSI B 16.5. Incorporates use of PE flange and metallic backup ring.
Fusion	The process of joining lengths of liner by melting the plastic at the joint. It also refers to the fusion joint.
Groove	An external groove that is manufactured at the liner pipe Manufacturer/Supplier plant, on the liner pipe external surface.
Hoop Compression	A stress state in which the liner is under uniform radial compressive stress usually caused by external pressure or constraint.
Hoop Tension	A stress state in which the liner is under uniform radial tensile stress usually caused by internal pressure.
Host Pipe	The existing rigid pipe which may be steel or composite.
Hydrocarbon Service	Fluids containing hydrocarbons or water with hydrocarbons.
Hydrostatic Design Basis (HDB)	The categorized long-term hydrostatic strength (LTHS) in the circumferential or hoop direction, for a given set of end use conditions, as established by ASTM Test Method D 2837. The HDB is one of a series of established stress values (specified in Test Method D 2837) for a plastic compound.
Inspector	Individual designated by the Company to act on behalf of the Company for monitoring Contractor's quality control testing and technical acceptance.
Installer	A contractor specializing in liner insertion and termination.
Interference Fit	See “Tight Fit.”
Joint	A length of liner when it is provided as straight pieces.
Liner	The plastic pipe inserted into the host pipe.
Liner Contractor	A Company approved Contractor responsible for the liner installation in accordance with this specification, deemed to be competent in the design, supply, assembly, installation and quality assurance of the non-metallic liner.
Liner Manufacturer	The party that converts thermoplastic polymer material into liner pipe to be used by the installer.
Loose Fit	A liner design case in which the pre-insertion liner outside diameter (OD) is smaller than the host pipe inside diameter (ID). A description can be found in the PPI report on pipeline rehabilitation by slip lining with PE pipe.
LTHS	Long Term Hydrostatic Strength
MAOP	Pressure which the carbon steel pipe may be operated at in actual service
MDPE	Medium Density Poly Ethylene
Multiphase	Fluid containing a mix of different phases or fluid components. In this DEP Multiphase will mean that at least one of the components is a gas.
Neutral Fit	A liner design case in which the pre-insertion liner OD is the same as the host pipe ID.
Ovality	This is a measurement of the dimensions in a cross-section of pipe and is expressed as a percentage. It is measured by taking the maximum measured diameter minus the minimum measured diameter (the out-of-roundness value) and dividing that sum by the average measured diameter and multiplying that result by 100.
PA Liner	Liner based on Polyamide in combination with fillers and plasticizers

PE	Generic group name of polyethylene's that come in different grades like MDPE, HDPE, XLPE/XPE/PEX, or strength classes like: PE-63, PE-80, and PE-100.
PE liner	Liner based on Polyethylene in combination with fillers and plasticizers.
PE-RT	Polyethylene Raised Temperature
Permeation	Gradual diffusion of liquid and gas through a thermoplastic layer under the influence of pressure.
PEX	PEX (also indicated as XPE or XLPE) is a cross-linked high-density polyethylene pipe material.
Point of fusion	The end of pipe which is available for trimming, heating, and pressing together during the heat fusion process.
Raw Material Manufacturer	Party that provides the raw PE material (granulate) to the PE pipe supplier.
Rotational moulding (Rotolining)	Production technique in which a PE lined spool is produced by heating and rotating a carbon steel spool with PE powder inside. The PE powder melts and forms a liner on the surface of the carbon steel pipe.
5% Secant Modulus	Ratio of stress to strain at the 5% strain point on curve in a stress-strain diagram.
Sizing Plate	A pipeline inspection device with an accurately known OD that is normally pulled through the host pipeline before liner insertion for the purpose of determining the minimum ID within the host pipe.
Standard Dimension Ratio (SDR)	A specific ratio of the average specified outside diameter to the minimum specified wall thickness (OD/t) for outside diameter controlled plastic pipe. The SDR is sometimes referred to as DR ratio.
Thermoplastic Materials	Plastic materials, which retain their mechanical properties after heating and cooling within certain limits.
Tight Fit	A liner design case in which the pre-insertion liner OD is larger than the host pipe ID. These liners require special equipment for insertion.
Vent	A vent in a lined pipeline system is a hole that is drilled through the steel pipe to allow passage of any permeated gases or liquids or, to monitor pressure build-up in the liner annulus. The liner integrity is determined by monitoring any pressure accumulations at the vent holes.
Water service	A pipeline may be considered in water service for the purpose of this specification if the total hydrocarbon fraction does not exceed 0.5 vol.% of total fluids and no gas phase is present.
XLPE	XLPE (also indicated as XPE or PEX) is a cross-linked high-density polyethylene grade consisting of long polymer chains in a 3-dimensional structure.

I.3.2 References

The following Standards, Specifications and Codes shall be applied in accordance with the requirement of this specification. All listed documents shall be of the latest issue. In the event of any conflicting requirements COMPANY Engineering Specifications shall prevail.

I.3.2.1 Standard Specification and Guidelines

The engineering, supply and installation of the equipment/ package shall be in compliance with the engineering standard specifications list hereunder; as applicable.

AGES-SP-07-007	Welding of pipelines and related facilities (1)
30-99-23–0114 (AON)	Pre-commissioning of Pipelines (1)
AGES-SP-10-003	Pipeline Design and Construction Guidelines
30-99-12-0036 (AON)	High Density Polyethylene (HDPE) for Utility Water Pipe Systems (2)
30-99-97-0006 (AON)	Projects Quality System Requirements (3)

(1) Document is under preparation of Standards Rationalization Project. OPCO's standard specifications can be utilized till the completion of standard specifications.

(2) This specification is ADNOC Onshore standard specification, however the rationalization of this specification is still under development by Non-metallic team in ADNOC.

(3) Document is under development internally within ADNOC Onshore to include the non-metallic materials.

I.3.2.2 HSE Manual

ADNOC HSE Procedures (i.e. ADNOC Onshore HSE manual Vol.10)

I.3.2.3 International Codes

National Association of Corrosion Engineers (NACE)	
SP-0304	Design, Installation and Operation of Thermoplastic Liners for Oilfield Pipelines
ASME	
B 16.5	Pipe Flanges and Flanged Fittings
ASTM	
D638	Test method for tensile properties of plastics
D1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D1505	Test Method for Density of Plastics by the Density-Gradient Technique
D1599	Test Method for Short-Time, Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings
D1693	Standard Test Method for Environmental Stress Cracking of Ethylene Plastics
D2122	Determining Dimensions of Thermoplastics Pipe and Fittings
D2657	Heat Joining Polyolefin Pipe and Fittings
D2837	Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
D3035	Standard Specification for Polyethylene (PE) Plastic Pipe (DR-

	PR) Based on Controlled Outside Diameter
D3350	PE Plastic Pipe and Fitting Material
D3895	Standard Test Method for Oxidative Induction Time of Polymeric Materials by Differential Scanning Calorimetry
API	
15 LE	Recommended Practice for Polyethylene Line pipe and Fittings
RP 5L1	Recommended Practice for Railroad Transportation of Linepipe
ISO Standards	
ISO 4427	Polyethylene (PE) pipes for Water Supply – Specifications
ISO 13479	Environmental stress crack resistance
ISO 9969	Thermoplastic pipes- Determination of ring stiffness
ISO 9001	Quality Management Systems Requirements
ISO14001	Environmental Management Systems Requirements
ISO 45001	Occupational Health and Safety Management Systems Requirements

I.4 Liner CONTRACTOR

The design of liner system shall be carried out by a professional and experienced Engineering CONTRACTOR / CONSULTANT approved by the COMPANY.

The CONTRACTOR / Engineering CONSULTANT shall have demonstrated the following capability and specific staff requirements:

i. A minimum of 15 years' experience in construction / Engineering consulting
ii. Permanent offices and staff in UAE for planning and operations office support for routine progress meetings, and review of schedules, collected data, and other tasks deliverables during their testing and inspection
iii. Management, Construction and Technical teams

The CONSULTANT shall have staff engineers with experience in:

i. Selection of materials as per the operational parameters.
ii. Design and manufacturing of thermoplastic pipes.
iii. Procurement, Construction and civil works.
iv. Preparation of engineering documentation, including drawings.
v. Pre-commissioning, commissioning testing and evaluation of liner systems.

Proven track record in provision of similar systems for Middle East onshore locations

CVs and valid certificates of personal undertaking design, site and performance surveys, testing and commissioning shall be provided.

Education and experience data (CV or resume) of Contractor's personnel shall be forwarded to Company for approval before work commences.

II QUALITY ASSURANCE

II.1 Scope

The manufacturer shall operate a Quality Management System (QMS) within his organization, which ensures that the requirements of this Specification are fully achieved.

The Liner Manufacturer shall have activated quality system in compliance at least with ISO 9001, ISO 29001, and API Q1 and accredited by API, ISO, ASTM or other accredited international organization.

CONTRACTOR shall plan, establish, implement, and maintain a Quality system for the Engineering, Procurement, Construction and Pre-commissioning of the project.

A Project specific Quality Plan shall be prepared specifically for the project describing the application of the corporate Quality System to the works, and any extension or adaptation necessary to meet the specified contract requirements. Although reference to, and appropriate parts of CONTRACTORS Corporate Quality Manual and Procedures can be utilized, the submission of the Corporate Quality Manual as substitute for a Contract specific Project Quality Plan will not be recognized as fulfilling the project quality plan requirement. A specific Project Quality Plan shall be submitted by CONTRACTOR and shall be subject to approval by Company. It is Contractor's responsibility to ensure the execution of COMPANY approved Project QA / QC plan.

The CONSULTANT / CONTRACTOR shall bring to the attention of COMPANY any requirements of the project documentation which in their opinion are not in accordance with good engineering practices, or otherwise not suitable for the intended service, or areas where potential cost savings could be made without prejudicing operability, availability and maintainability.

In the event of conflict between statutory requirements, project documentation, COMPANY standards, international Codes and Standards, COMPANY shall be intimated by CONSULTANT / CONTRACTOR. The more onerous and more stringent requirements in such a conflict shall be deemed to apply, unless there is formal agreement by the COMPANY to the contrary.

CONTRACTOR shall clearly state every exception to the requirements of the project documentation to which the equipment shall be manufactured and tested. If no exceptions are stated, then full conformity shall be assumed and required.

All components shall be procured from ADNOC approved manufacturers. In case of any item not listed in the Approved Vendor List, special approval shall be obtained from COMPANY before supply. No deviation is acceptable in this regard.

Installation shall be carried out under the supervision of a qualified Engineer having minimum 5 years of experience in site activities.

Commissioning report shall be validated by a liner Specialist having minimum ten years of experience, before being submitted to COMPANY.

II.2 Normative References

For the purpose of this document the documents referenced in quality requirements DOC. Ref. No. 30-99-97-0006 (AON) latest version and those listed below, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9001:2015	Quality management systems - Requirements
API Specification Q1	Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry
ISO 29001: 2018	Petroleum, petrochemical and natural gas industries — Sector-specific quality management systems — Requirements for product and service supply organizations

II.3 Quality Program

A. Quality Manual

The Manufacturer shall maintain a Quality Manual which describes the quality program. All prior revisions shall be retained for a period of not less than five years.

B. Process and Quality Control Requirements

The Quality Manual shall include a documentation program to assure communication of approved manufacturing and inspection procedures to qualified receiving, manufacturing and quality control personnel. The Quality Manual shall be submitted to the COMPANY for review and approval, and shall cover at least the following aspects:

i. Raw material acceptance.
ii. Extrusion procedures.
iii. Pipe manufacturing practices.
iv. Welding procedures and qualifications.

v. Inspection and test procedures.

vi. Acceptance criteria.

vii. Repair procedures.

C. Quality Control Equipment

Equipment used to inspect, test or examine material shall be calibrated at specified intervals in accordance with the Manufacturer's Quality Manual and consistent with referenced industry standards.

D. Conditioning

Unless otherwise specified, all Quality Control (QC) specimens shall be conditioned for a minimum of 4 hours prior to test in air or 1 hour in water at 23 °C + 2 °C.

When conditioning is required for witness tests the specimens shall be conditioned in accordance with Procedure A of ASTM D 618 at 23 °C + 2 °C and at an agreed level of relative humidity and conditioning time.

E. Test conditions

Tests shall be conducted at the Standard Laboratory temperature of 23 °C + 2 °C unless otherwise specified in the test methods.

F. Material property requirements and frequency

The Manufacturer shall be responsible for ensuring that all pipes meet the specified requirements.

Acceptable QC shall be demonstrated by successfully completing the tests listed in (Table 7) of API Spec 15 LE at the specified frequency. Where the Manufacturer has agreed to the supply of pipe produced to ISO 4427, the equivalent quality control tests prescribed by ISO 4427 shall be applied.

NOTE: API Spec 15 LE and ISO 4427 are specific to PE. However, the general principles of quality control through material testing outlined in both API Spec 15 LE and ISO 4427 are also applicable to other thermoplastics. Minimum strength and specific temperatures for elevated temperature tests shall be proposed by the CONTRACTOR and agreed with the COMPANY.

Table 1 lists the quality control tests that are required along with the appropriate standard test procedure, testing frequency and acceptance criterion. The total number of QC tests shall be agreed between CONTRACTOR and COMPANY.

Table 1 - QC requirements on material properties during production

Property	ASTM	Acceptance criteria	Frequency
Outside diameter	D2122	API Spec 15 LE, Table 3	
Wall thickness	D2122	API Spec 15 LE, Table 3	

Burst pressure (up to 100 mm diameter)	D 1559	To be agreed between Contractor and Company	Once every hour or once every coil, whichever is less frequent
Strength (Over 100 mm diameter)	D2122	To be agreed between Contractor and Company	
Hydro-test		See III.9.6	
Out of roundness	D2122	< 5% of quoted value	Once per lot (production run)
Ovality	D2122	< 5% of quoted value	
Density	D1505	< 2% of quoted value	
Melt flow rate	D1238	< 30% of quoted value	
Modulus	D638	< + 5% of quoted value	
ESC resistance	D1693	< 5% of quoted value	
Carbon black	D1603	2% min. unless otherwise agreed.	

II.4 Terms and Definitions

For the purpose of this document, the terms and definitions given in 30-99-97-0006 (AON) and subsequently ISO 9000:2015 (normative to ISO 9001) and the following shall apply.

II.5 Conformity Assessment

Demonstration that requirements relating to a product, process, system, person or body are fulfilled.

Note 1 Conformity assessment (or assessment) includes but is not limited to review, inspection, verification and validation activities.

Note 2 Assessment activities may be undertaken at a manufacturer's or sub-manufacturer's premises, virtually by video link, desktop sharing, etc. or by review of information formally submitted for acceptance or for information.

II.6 Conformity Assessment System (CAS)

Systems providing different levels of assessment of the manufacturer's control activities by the purchaser (second-party) or independent body (third-party) based on evaluation of the manufacturer's capability to conform to the product or service specification and obligatory requirements.

Note CAS A reflects the highest risk and associated extent of verification.

II.6.1 Conformity Assessment – Hold point (H)

The point in the chain of activities beyond which an activity shall not proceed without the approval of the purchaser/purchaser's representative.

II.6.2 Conformity Assessment – Witness point (W)

The point in the chain of activities that the manufacturer shall notify the purchaser/purchaser's representative before proceeding. The operation or process may proceed without witness if the purchaser does not attend after the agreed notice period.

II.6.3 Conformity Assessment – Surveillance (S)

Observation, monitoring or review by the purchaser/purchaser's representative of an activity, operation, process, product or associated information.

II.6.4 Conformity Assessment – Review (R)

Review of the manufacturer's information by the user or the user's representative to verify conformance to requirements.

NOTEInformation review requirements are managed on a surveillance basis and as such do not impose schedule constraints, unless specified as hold points as conditions specified in the associated ITP.

II.6.5 Critical

That deemed by the manufacturer, product specification, or purchaser as mandatory, indispensable or essential, needed for a stated purpose or task, and requiring specific action.

II.6.6 Symbols and Abbreviations

For purposes of this document, the following symbols and abbreviations apply:

CAS conformity assessment system

II.7 Quality Requirements

II.7.1 Quality Management System

The manufacturer shall demonstrate that the quality management arrangements established for the supply of products and services conform to ISO 9001, API Specification Q1 or an equivalent quality management system standard agreed with the purchaser.

All manufacturing and site installation shall be in accordance with quality requirements DOC. Ref. No. 30-99-97-0006 (AON) latest version.

The manufacturer's quality management system shall be based on the latest issue of ISO 9001 (or an equivalent) and accredited by a reputable certifying agency. The manufacturer's quality manual shall provide details for the preparation of a quality plan, which shall include provisions for the QA/QC of all raw materials, pipe manufacture, testing and final inspection. Where an approved Manufacturer revises their Quality Management system that effect any changes to COMPANY approved Quality plan /

Inspection & test plan, then the revised Quality plan / Inspection & test plan shall be submitted for COMPANY approval before initiating any manufacturing process.

The effectiveness of this quality system may be subject to monitoring by the COMPANY or its representative and may be audited following an agreed period of notice.

The manufacturer shall maintain sufficient Inspection and Quality Assurance staff, independent of his production management, to ensure that the Quality plan is correctly implemented and that all related documentation is available.

The manufacturer shall not deviate from specified materials or substitute sources of material supply without prior written consent of technical authority from COMPANY.

Pre-production meetings shall be held between the COMPANY and / or its representatives and the manufacturer, to clarify and resolve any technical issues.

The first pre-production meeting shall be conducted within 14 days after the award of Purchase Order.

Project quality plan (PQP) and inspection test plan (ITP), along with all referenced procedures shall be approved by at least 4 working weeks before production commencement. In addition, at least the following documents and records:

- The products regression curves for pipes, fittings, and connections … etc.
- Track records of similar orders for the last 3 years including the following details; product, service conditions, pipe geometry, produced quantity … etc.
- Technical specifications for resourced raw materials.
- Procedure for non-conformance analysis and corrective actions implementation
- Manufacturing procedure specification (MPS).

Any approved document shall not be modified without the written approval of the COMPANY, all procedures listed in the MPS and ITP shall be made available to the COMPANY for review and comments, manufacturer shall submit for review & approval any deviations to the requirements specified in all applicable technical documents referenced herein.

Just before production commencement, the head of manufacturers' quality with COMPANY Representative, and TPI (as applicable) shall check and review all involved production and inspection stages, and assure that the relevant working instructions and procedures are available, complete in conformance with applicable the approved specifications and this document. A report by manufacturers shall be issued, endorsed and filled in the final dossier.

All procedures shall have prior approval by COMPANY, and all qualification tests shall take place under the supervision of the COMPANY.

Manufacturer shall notify the COMPANY's representative sufficiently in advance to enable him to present at qualification tests and at all other tests/stages of manufacturing which subjected to acceptance in accordance with the specifications.

The manufacturer shall provide COMPANY's representative with full and free access to all parts of the production facility as well as to all information; records and documents relevant to the purchase order under process .all information shall be in English language.

COMPANY's representative shall ensure that materials and pipes are manufactured in accordance with all specified requirements and approved procedures.

Liner Manufacturer shall provide free access to COMPANY's representative for the following information:

- Tracking system of production and inspection
- All data and results of mechanical tests, NDE results
- Any other information considered pertinent by COMPANY's representative as per ITP and referenced procedures
- COMPANY's representative will notify the COMPANY immediately for any difficulty, irregularity, problem, or delay likely to occur during pipe production
- The company reserves the right to check tests carried out by the manufacturer, consequently the COMPANY may request the delivery of the corresponding samples or specimens to be analyzed in independent laboratory chosen by the company any on cost of the manufacturer.

Liner Manufacturer shall not deviate from any part of the manufacturing plan without prior written approval from COMPANY.

Liner CONTRACTOR shall submit the following documents for review and approval at least 4 weeks before site construction commencement:

- Jointing procedure
- Storage and handling procedure
- Handing drawings
- Site-assembly detailed procedure
- Construction operators qualifications and track records
- NDT procedure
- NDT examiners qualifications and certifications
- Hydrotest procedure
- Training and certification of installation crew
- Installation of pipeline at road crossing

COMPANY reserves the right to reject any, or part, or all material and manufacturing anomalies where acceptance of the non-compliance is not adequately justified by the manufacturer's technical argument.

Liner manufacturing documentation shall be retained by the CONTRACTOR / MANUFACTURER and shall be handed over as part of the handing over of the project's documentation.

COMPANY shall approve the manufacturer's specification before to its application.

II.7.2 Conformance Assessment

Quality plans and inspection and test plans developed as outputs to operational planning and control for the products and services shall define the specific controls to be implemented by the manufacturer and when applicable, their sub-manufacturers, to ensure conformance with the specified requirements.

Controls shall address both internally and externally sourced processes, products and services Quality plans and inspection and test plans shall include provisions for the purchaser's conformity assessment system as specified in the project approved ITP.

The manufacturer's performance in meeting the requirements will be routinely assessed during execution of the scope and where appropriate, corrective action requested and conformity assessment activities increased or decreased consistent with criticality and risk.

Irrespective of conformity assessment requirements defined by the purchaser, either, by reference to standard and specification requirements or in the scope, the manufacturer remains responsible for operational planning and control and demonstration of the conformity of products and services with the requirements (see ISO 9001:2015, 8.1 and 8.2).

II.7.3 Quality Control Records Requirements

A. Purpose

Quality control records are necessary to substantiate that all pipe manufactured conforms to the requirements specified in this specification.

B. Records control

i. Quality control records required by this specification shall be legible, identifiable, retrievable and protected from damage, deterioration or loss.

ii. Quality control records required by this specification shall be retained by the pipe supplier and CONTRACTOR for a minimum of five years following the date of manufacture.

iii. All quality control records required by this specification shall be signed and dated by the pipe supplier's designated authorized person.

The following records shall be maintained and supplied by pipe supplier:

i. Quality manual in accordance with (Section II.3 Point. A).

ii. Quality control test results in accordance with (Section II.3 Point D).

iii. Design and material qualification data in accordance with Sections II.7 and III.6.

iv. All procedures utilized by the pipe supplier in the process of fulfilling the order.

v. Quality assurance records for all materials supplied by the pipe supplier.

II.7.4 Equipment Marking

Pipe shall be marked by the Manufacturer. The markings on each length of pipe or fitting shall include in any sequence:

i. Manufacturer's name or trademarks
ii. Base specification shown on purchase order, e.g. API Spec 15 LE or ISO 4427
iii. Nominal pipe size
iv. Date of manufacture
v. SDR
vi. Appropriate material code
vii. Manufacturer's lot number
viii. Additional markings, as agreed between Manufacturer, CONTRACTOR and COMPANY.

Pressure rating shall not be marked on the pipe.

The markings on pipe shall be paint stenciled or printed on the outside surface at intervals of not more than 1.5 m or on each fitting. Indentation marking may be used provided:

i. The marking does not reduce the wall thickness to less than the minimum value.
ii. The marking has no effect on the long-term strength.

II.7.5 Traceability

Material certification and traceability of starting material including billet, plate, coil and welding consumables and production inspection and testing results to finished pipe identification numbers shall be maintained in accordance with 30-99-97-0006 (AON).

II.7.6 Control of nonconforming products and services

Non-conformance with specified requirements identified by or to manufacturer prior to or during the delivery of the products and services shall be corrected such that the specified requirements are satisfied or the purchaser's acceptance of the non-conformance agreed in accordance with purchase order conditions (see ISO 9001:2015, 8.2.3, 8.2.4, 8.5.6 and 8.7).

II.7.7 Evidence (conformance records)

Plans, procedures, methods and resultant records shall be provided in accordance with the associated ITP.

III TECHNICAL REQUIREMENTS

III.1 Thermoplastic Liner for new pipelines

Decision to design and install a thermoplastic liner in a new pipeline shall be based on the evaluation of following factors by COMPANY:

i. Comparison of the total lifecycle costs of the pipeline with and without a liner.
ii. This includes design, installation, procurement, maintenance, inspection and corrosion management costs.
iii. Cost of the liner installation.
iv. This depends on the type of liner chosen. This includes any facilities required for dealing with gases vented from the annulus.
v. Regulatory requirements with respect to activities on the pipeline right-of-way, such as flaring or venting activities, allowable pipeline damage.
vi. In case of permeation of highly corrosive fluids such as H2S or CO2, a corrosion assessment of the annulus should be carried out
vii. Competency of the liner contractor.

III.1.1 Input data for liner application

COMPANY shall provide new pipeline data to Tie-in or EPC CONTRACTOR to facilitate design of liner as part of pipeline installation. These can be listed as under

i. Design and Operating Conditions.
ii. Expected life of pipeline / Design life of liner.
iii. Product Analysis: Oil / Water / Multiphase product and GOR.
iv. Fluid composition including e.g. inhibitors, well stimulation chemicals and concentrations.
v. H2S and CO2, Partial pressure of H2S in gas phase.

All other design information shall be coordinated between EPC CONTRACTOR and Liner applicator under the responsibility of Project EPC CONTRACTOR.

III.2 Thermoplastic liner for existing Pipelines

In addition to the evaluations listed under III.1 above, the cost of Hydrotest, cleaning & drying and premature pipeline replacement shall also be considered for existing pipelines.

III.3 Input data for liner application

The following information is required for liner design:

i. Outer diameter of pipeline
ii. Wall thickness
iii. Length of pipeline
iv. Expected life of pipeline / Design life of liner
v. Pipe materials
vi. Flange rating
vii. Location (onshore/offshore, buried/above ground)
viii. Route map *
ix. Elevation profile of pipeline *
x. Right-of-Way access *

xi. Road crossing details including wall thickness at road crossings, length of crossing, burial depth at crossing *
xii. Expansion loops location, construction details (bend radius, length) *
xiii. Location, radius and angle of all bends *
xiv. Location of any valves and fittings (e.g. tees) installed in the pipeline *
xv. Expected maximum ambient temperatures during installation
xvi. Maximum operating temperature of the system
xvii. Minimum/Maximum operating pressure of the system
xviii. Maximum rate of de-pressurization of the system
xix. Indication of likelihood of large pressure fluctuations
xx. Upset operating conditions
xxi. Product: Oil / Water / Multiphase product
xxii. Fluid composition including e.g. inhibitors, well stimulation chemicals and concentrations
xxiii. GOR
xxiv. H2S and CO2, Partial pressure of H2S in gas phase
xxv. Expected changes in fluid composition and operating conditions during expected life of liner
xxvi. Condition of internal surface of the carbon steel pipeline (new/used, roughness, weld root penetration, etc.)
xxvii. Leak and repair history
xxviii. Inspection reports as applicable
xxix. Possibility and frequency of local venting. **
xxx. Requirements for valves at gas venting points, requirements for gas monitoring, limitations on gas venting rates and any restrictions on venting locations.**

Notes:

* In case this information is not available for the pipeline, CONTRACTOR shall conduct site visit to familiarize with the pipeline route and carry out topographical survey to collect these information.

** CONTRACTOR shall propose the design and installation requirements as part of his scope for Company review and approval.

CONTRACTOR shall take into account different (higher) wall thickness at road crossings and repaired sections and design the liner accordingly. Reducing the wall thickness at road crossings may not be feasible due to higher loads at crossings.

III.4 Liner Material Selection

Polyethylene (PE) is the most commonly applied liner material. Based upon current products and known performance, PE liners should not be exposed to operating temperatures above 80 °C (176 °F) in water service and above 65 °C (149 °F) in hydrocarbon and multiphase service without free gas and above 55°C (131°F) for

hydrocarbon and multiphase service with free gas without a thorough design and operations review with COMPANY.

Table 2 lists the recommended maximum operating temperature as a function of fluid composition. Each pipeline liner design must account for temperature and chemical exposure. These temperatures are the starting point for an engineering design risk analysis. Installed stress state affects these temperatures significantly.

HDPE (PE-3708 and 3710, PE-4708 and 4710, or PE 100) is the basic engineering grade of HDPE used in liners. HDPE has been successfully used in water injection pipelines, multiphase oil and gas gathering pipelines, sour multiphase crude product pipelines, and oil transmission pipelines in Oil Industry. Liner materials shall be selected based on mechanical properties and chemical resistance information provided by the thermoplastic polymer material supplier or other generally accepted information source such as ASTM, ISO, CSA, API or PPI standards. Reported properties of liner materials shall be measured and reported in accordance with the appropriate standard test method.

The properties of liner materials after attaining equilibrium in service are different from the “as new” material properties reported on data sheets. The changes are sometimes significant and might affect liner performance in service. The effects of the service environment should be evaluated as part of the design process. Short-term effects of the service environment, such as swelling or aggressive chemical attack, are relatively easy to determine and standard test methods are available. Longer-term effects, such as slow chemical attack or slow environmental stress cracking, are equally important. Fewer standard test methods are available in this case, but materials suppliers often have useful data to address the concerns. The medium- to long-term properties of the material in the service environment shall be considered when making decisions about liner design.

Fluid chemical compatibility tests should be performed in accordance with the material manufacturer’s or liner supplier’s documented procedures, preferably consistent with applicable NACE, API, ASTM, or ISO test methods. Other test methods may be used, provided that the details of the method are provided to the liner designer. Laboratory exposure testing with extruded samples, representative of the intended liner pipe, should be used to determine whether the polymer liner material is compatible with pipeline product.

Liner materials shall be suitable for joining in the field by butt fusion or other suitable joining methods applicable tor thermoplastic pipe. The joint must not increase the OD of the liner. External fusion beads must be trimmed off. Internal fusion beads may be trimmed off as needed for operating considerations.

Table 2– Non-Metallic liner materials for Pipeline applications

Material	Maximum Operating Temperature Limit (Degree C)			Remarks
	Water	Multiphase Oil (without free gas)	Multiphase Oil with free gas	

HDPE	80	65	55	Temperature Permeation Softening and swelling in HC
PE-RT	90	65	55	Temperature Permeation
PA-12	N/A	80	80	Hydrolysis

Notes:

1. Oil and water flowlines are surface laid. The design temperature shall consider the operating temperature resulting from the thermodynamic calculation of the flowing fluid temperature and the contribution of heat transfer caused by the black body approach.
2. Grooved liner shall be used for multiphase products. , and smooth wall liners shall be used for water applications.
3. In case temperature exceeds above stated limits, it shall be subject to review and approval by COMPANY. Liner contractor shall submit the calculations and advise estimated life at operating temperature based on collapse resistance calculations.

III.4.1 Tests for Polymer materials

Pre-exposure Testing

One sample of liner material, per batch, shall be tested as per details below:

Test	Standard	Acceptance Criteria
Visual Inspection of Internal Surface	N/A	Uniform, no scratches, notches, protrusion, cracks, no colour change
Surface roughness	ISO 4288	
Tensile Testing	ISO 6259-1	+/-20% max deviation from the manufacturer specification complying with the applicable material specification
Oxidation Induction Time (OIT)	ISO 11357 - 6	> 20 min
Hardness Internal Surface	ISO 2039	< 2 units
Melt Flow Rate	ISO 1133	as per the applicable material standards
Reverse Bend Test	ISO 2505	<3%
Attenuated Total Reflectance ATR-FTIR	N/A	Carbonyl and anti-oxidant Uniform across thickness measured each 1mm along thickness, as shown by the intensity of the characteristic IR bands
Calorimetry	ISO 11357 - 3	No change

Note: It shall be the responsibility of the CONTRACTOR, in consultation with the material supplier and COMPANY, to verify that the liner material meets the requirements of this standard.

Post-Field Trial Testing

Performance of the polymer shall be evaluated by COMPANY after it has been in use for certain time (1, 5, 10 years). Test spools shall be installed in each pipeline. No. and location of test spools shall be advised by COMPANY. COMPANY shall retrieve the test samples from test spool and forward the same to test lab for carrying out following tests:

Test	Standard	Acceptance Criteria
Visual Inspection of Internal Surface	N/A	Uniform, no color change, no surface cracks
Tensile Testing	ISO 6259-1	as per the applicable material specification
Oxidation Induction Time (OIT)	ISO 11357 -6	> 20 min
Melt Flow Rate	ISO 1133	+/-20% max deviation from the manufacturer specification complying with the applicable material specification
Mass change	BS 4433	< +10%
Thickness change	N/A	< +10%
Hardness Internal Surface	ISO 2039	< 2 units
Reverse Bend Test	ISO 2505	<3%
Attenuated Total Reflectance ATR-FTIR	N/A	No loss of either Carbonyl or anti-oxidant each 1mm along depth
Internal Surface Roughness	N/A	<10% of the original roughness
Calorimetry	ISO 11357 - 3	No change

Note: COMPANY shall retain samples of unused liner. Samples of each batch used in the pipeline shall be retained. These shall be properly marked and stored indoor, as per liner manufacturer instructions. These shall be tested along with the retrieved samples from test spool.

The tests mentioned above shall be conducted on layers of liner across the thickness. Layer thickness shall be advised by COMPANY.

The test results shall be evaluated by COMPANY to assess remnant life of liner as per the degradation due to exposure to the product.

COMPANY may share these results with HDPE supplier to further improve material.

III.5 Design of the liner

III.5.1 General

A corrosion assessment of pipeline/flowline shall be carried out to assess:

i. The corrosion conditions in the annulus towards the carbon steel pipe, especially for those situations where water and H2S and/or CO2 are present in the fluids to be conveyed.

ii. Annulus bleed-off requirements. Environmental Stress Cracking Resistance (property not involved in mechanical collapse calculations)

A design report shall be submitted with all calculations and assumptions taken. The following approvals shall be required:

i. Mechanical, pull forces and flow calculations: ADNOC OPCOs – Pipeline

ii. Collapse calculations: ADNOC OPCOs – Pipeline.

iii. Corrosion assessment report – Materials & Corrosion

The required liner thickness based on collapse calculations does not take into consideration annular pressure build up, and annular gas management is merely one mitigation methodology.

The below described calculation method is applicable only to HDPE liner.

III.5.2 Design Pressure

The design pressure (P_{des}) for the liner is defined as the maximum operating pressure, (P_{mop}) multiplied by a safety factor, J.

$$P_{des} = JP_{mop} \qquad \text{(Equation 1)}$$

A value of 1.33 is usually recommended for J.

Polymers swell due to fluid uptake when exposed to O&G produced fluids (water, oil, gas) and chemicals incorporated therein. The uptake depends on factors as the type of fluid, time, and temperature.

Similarly, a liner may shrink because of extraction of fugitive components such as plasticizers, low molecular-weight polymer fractions, and stabilizer additives. If the liner material is expected to change dimensions in the expected service, the magnitude of the change should be estimated and accounted for in the design to prevent radial and/or axial buckling of the liner.

Swelling of the liner changes its dimensional as well as mechanical properties, impacting its collapse resistance. Swell and mechanical data for HDPE, from installed systems, shall be provided by COMPANY as and when these are available.

III.5.3 Liner Design

The required wall thickness of the liner is determined from three conditions:

i. Thickness requirement for handling and storage,

ii. Installation (insert and pull through pipeline section),

iii. Collapse, radial or axial.

For calculation purposes, it is conservatively assumed that the pressure in the annulus is the same as the bore pressure.

Minimum required wall thickness calculation shall consider that the liner is of the grooved type, installed in tight fit and considering a intrinsically safe design.

The greatest thickness calculated from the individual above requirements shall be taken as the design liner wall thickness.

Liners can suffer radial and / or axial collapse due to the following reasons:

i. Radial collapse – pressure build-up in the annulus, swelling or shrinking of the liner;

ii. Axial collapse – either from differential thermal expansion, swelling or shrinking of the liner.

A. Radial collapse

Radial collapse occurs when the critical buckling pressure has been exceeded.

Liners shall be designed to be collapse-resistant i.e. resist deformation under the pressure of the annulus relative to the pipeline pressure. Migration of annulus gases, presence of local large volumes caused by corrosion pits, or other locally larger volumes at high pressure may initiate collapse at lower pressures than the annulus pressure-volume product might suggest.

Buckling occurs when the force required to deform the liner ceases to increase with increasing deformation. The critical buckling pressure is the pressure in the annulus at the radial buckling point. Collapse may rapidly ensue after buckling, as less additional force is required to continue the liner wall motion than before buckling.

Collapse-resistant liners have a radial critical buckling pressure (P_{crit}) that is higher than the maximum anticipated annulus pressure. The intent of a collapse-resistant design is to prevent radial buckling as a means of preventing irreversible deformation or rupture of the liner.

The collapse pressure, P_{crit}, shall be greater than P_{des}, so that the liner does not collapse under the degradation of its mechanical or dimensional properties caused by exposure to fluids.

The P_{crit} decreases with decreasing tightness, decreasing liner thickness, and decreasing liner material modulus. The effects of chemical exposure on the material's properties shall be included in calculation of the critical buckling pressure resulting in an equilibrium value of P_{crit} that accounts for changes in properties and fit during use.

B. Axial collapse

The total axial strain is due to contribution of the following sources:

i. Differential thermal induced strain – consequence of temperature differences between the installation and operational temperatures;

ii. Linear swell induced strain – due to uptake of fluid components or lixiviation of polymer components

iii. Hoop strain induced axial strain,

iv. Bend induced strain (if applicable) – occurrence of the resultant strain due to compression at the inner radius of the bend and the pre-tensioning strain of the liner

The total axial strain exerted on the liner is given by Equation 2:

$$\varepsilon_{ax} = (1+\gamma).\sqrt[3]{(\Delta V+1)} - 1 + \alpha.\Delta T + [1-(\frac{R_{bend}-0.5D}{R_{bend}})] \quad \text{(Equation 2)}$$

i. ε_{ax} – Induced axial strain (fraction)

ii. α – Coefficient of thermal expansion (mm2/°C)

iii. ΔV – Volumetric swell (fraction)

iv. ΔT – Temperature difference between installation and design temperatures

v. γ – Poisson's ratio

vi. D – Internal diameter of the steel pipe

vii. R_{bend} – bend radius (The minimum recommended bend radius should be 40D)

The critical axial strain in the liner is the strain that will cause an unstable axial buckling of the liner. The liner will be resistant against axial collapse as long as the induced axial strain in the field application is smaller than this critical strain i.e., this critical axial strain shall be higher than the axial strain exerted during service:

$$\boldsymbol{\varepsilon_{crit} > \varepsilon_{ax}.SF} \quad \text{(Equation 3)}$$

Where:

SF is a design safety factor (SF=1.5 for water; SF= 3 for multiphase oil)

III.5.4 Design calculation procedure

The procedure to determine the design liner thickness shall consist of the following steps:

Step 1. Determine the liner outer diameter

Define the outer diameter of the liner pipe considering the internal diameter of the carbon steel pipe, the requirements of the installation technique and the tightness of the liner.

Note that for grooved liners the external diameter of the liner shall be the dimension of the cylindrical part of the liner only, disregarding the groove height.

Step 2. Determine the wall thickness required for a safe Handling and storing

To maintain roundness of the liner and dimensional stability during storage, possibly for several months and to minimize distortion during handling, Manufacturers recommend a minimum Standard Dimension Ratio (SDR) ranging from 26 to 17. A minimum SDR of 26 is recommended for less onerous applications, for all other applications an SDR of 17 is recommended.

Standard Dimension Ratio (SDR) is defined as

$$SDR = \frac{Ø_{ext}}{t}$$ (Equation 4)

Where:

$Ø_{ext}$ - External diameter of the liner, and

t – Thickness of the liner (disregarding the height of the grooved)

Step 3. Determine the wall thickness from installation requirements

CONTRACTOR shall recommend the minimum wall thickness for handling and installation purposes. However, as liners are installed by pulling a pre-fabricated length of thermoplastic pipe into the carbon steel outer pipe the maximum axial stress carried by the liner shall be limited to 50% of the tensile yield strength of the thermoplastic polymer. The pulling load consists of the friction load of dragging the liner into the carbon steel pipe, the deformation load, which is a function of the installation technique, plus friction loads due to pipe bends etc.

Step 4. Select material properties

Required material properties (modulus of the thermoplastic material and swelling strain) shall be selected for the service conditions based on COMPANY obtained properties (lab or field trial). If these data are not available, standard data presented in the following table shall be considered. Vendor may propose alternative values if collected from reputable document to demonstrate the values taken. Note that these values shall be accepted only if obtained in identical conditions as those found in COMPANY concerned application.

Table 3 – Modulus of the thermoplastic material and swelling in oil environment.

Temperature (°C)	Diffusion coefficient 10^6 (mm^2/sec)	Volumetric swell (%)	Linear swell (%)	5% secant modulus (MPa)
60	0.91	10.7	5.35	116
70	1.54	13.9	6.95	78
80	2.54	17.0	8.50	53

Step 5. Determine the required wall thickness based on radial collapse calculations

In the tight fitting liner case, the steel host pipe provides supporting restraint during collapse. The initial critical buckling pressure Pcrit in MPa can be estimated by Equation (5):

$$P_{crit} = \frac{E}{(1-\gamma^2)}\left(\frac{1}{SDR-1}\right)^{2.2+2.9*\left(\frac{\Delta}{D}\right)}$$ (Equation 5)

Where:

P_{crit} – Critical radial collapse pressure (MPa)

E – 5 % secant modulus (MPa) established under simulated operating conditions (temperature and fluid exposure). The 5 % secant modulus shall be used for the calculations, which shall be corrected for temperature (design temperature value) and fluid uptake.

γ – Poisson's ratio

Δ – Height of the imperfection or distance between liner and pipe in case of an imperfection

(mm). Assume 5mm as default value. This needs to be checked for corroded pipes.

D – Internal diameter of the steel pipe

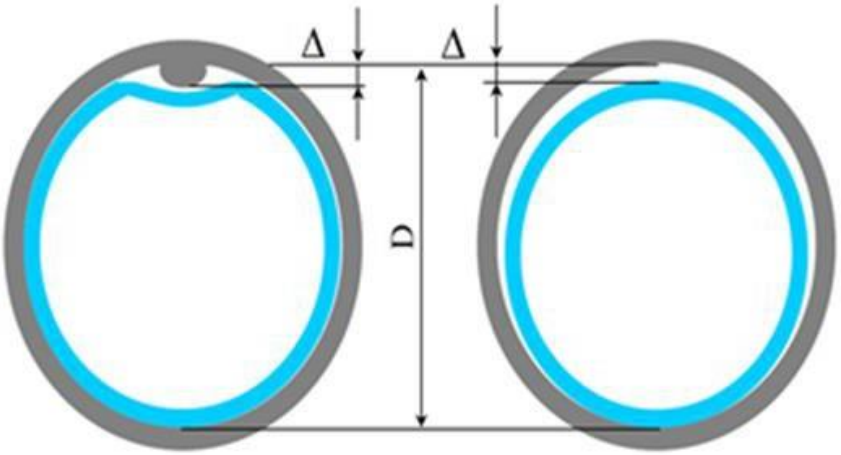

Table 4 – Minimum values for critical collapse pressures as function of the application.

Service	Critical collapse pressure (MPa)	Remarks
Water[NOTE1]	1.5 x (Bore pressure)	Minimum $P_{crit} \geq 0.15$MPa
Multiphase oil	3 x (Bore pressure)	Minimum $P_{crit} \geq 0.3$MPa

Note 1: A pipeline is considered in water service if the total hydrocarbon fraction does not exceed 0.5%vol of total fluids and no gas phase is present.

Step 6. Determine the required wall thickness based on the axial collapse calculations

The critical axial strain in the liner is mathematically defined as:

$$\varepsilon_{crit} = \left(\frac{1}{SDR}\right)^{8.9.\left(\frac{\Delta}{D}\right)+0.708} \quad \text{(Equation 6)}$$

ε_{crit} – Critical axial strain, point of collapse, is the critical strain in axial direction that will cause an unstable axial buckling of the liner

b – Function of liner undersize and/or imperfection = 8.9 x IOD + 0.708 (SI Units)

Δ and D as defined above

The required wall thickness is the value that, after calculation of the resulting SDR, allows condition expressed by Equation 6 to be met. This calculation may require some iteration until the correct required thickness is determined.

The condition resulting in the largest wall thickness (lowest SDR ratio) for all the different calculations shall govern.

Step 7. Confirmation of acceptable flow and pressure drop parameters as per the collapse calculations selected SDR

If a different value than the initial SDR is chosen to meet design criteria, flow calculations for the inner diameter of the liner shall be reviewed and the new liner SDR confirmed. In this case, pressure loss calculations shall be carried out for both the host pipe and the liner to establish whether the difference in pressure loss due to the reduced line diameter is acceptable. A friction factor shall be taken from table below.

Table 5 – Friction Factor for pipelines

	Liner	Steel pipe – internal corrosion condition		
	HDPE	New	Light	Severe
Friction factor (mm)	0.005	0.04	0.4	3.4

III.6 Manufacturing of Polymer Pipes

III.6.1 Process of manufacture

Polyethylene liner pipe shall be produced and classified in accordance with a recognised Industry Standard (API 15LE or ISO 4427); the raw material grade being selected by the liner manufacturer shall be supplied by a PE 100+ Association member and shall meet the specified design, installation and operational requirements. Only bi-modal HDPE materials shall be accepted.

HDPE Manufacturer shall submit, for COMPANY review and approval, raw material Data Sheet showing at least the producer name, origin of raw material, date of manufacturing, resin type, chemical compositions, storing conditions, product code number, material certificates and shipment details.

Raw material shall be stored as per the recommendations of Producer. No raw material, beyond the expiry date of batch as per the Producer shall be utilized to manufacture pipes.

CONTRACTOR shall be responsible for identifying any supplementary requirements, such as special dimensional tolerances, necessary to meet the liner design criteria.

The thermoplastic liner shall be manufactured by extrusion. Extrusion involves melting, converging and forming the thermoplastic into a tubular product.

Other manufacturing processes shall not be used by the Manufacturer to produce the thermoplastic liner unless agreed by COMPANY.

Only virgin polymers shall be used for the production of the liner. Use of reworked (or re-cycled) materials shall not be permitted. The use of colouring agents should be avoided. Manufacturing of the liner shall not proceed until the material qualification program has been completed to the full satisfaction of COMPANY.

The Manufacturer shall complete the data sheets as per Table 6 and supply these as part of the tender documentation. The data provided by the CONTRACTOR shall be used as baseline data for the QC requirements.

Table 6 – Data for Pipe, Flange or Spool

Property	Test Method	Manufacturer Data
Raw Material manufacturer	-	
Material type and grade (unique identification as used by manufacturer)	-	
Pipe supplier	-	
Poisson ratio	-	
Coefficient of thermal expansion (K-1)	-	
Carbon black content (only for PE)	ASTM D 3350	
Density (g/cm3)	ASTM D 1505	
Melt index (g/10min at 190 °C, 2160 g load)	ASTM D 1238	
Modulus (MPa) at 20°C	ISO 9969	
Modulus (MPa) at design temperature	ISO 9969	
Tensile strength (MPa at 50 mm/min)	ASTM D 638	
Environmental stress crack resistance (Condition C for 192 hours)	ASTM D 1693	
Oxygen Induction Temperature (at 2000C)	ASTM D 3895	
Burst pressure (MPa)	ASTM D 1599	

III.6.2 Flange material

Flanges shall be moulded or machined from extruded material and shall be from the same material as the pipe. The wall thickness of the flanges shall be equal to the wall

thickness of the pipe. Flared flanges may be used only for limited lengths which cannot be fitted with fused flanges, and only with the approval of the COMPANY.

III.6.3 Rotational moulded spools

Rotational moulded spools may be used only with the approval of COMPANY. The material used shall have minimum material properties provided by the CONTRACTOR as listed in Table 6 otherwise agreed with the COMPANY.

The wall thickness of the liner in the spools should be equal to the minimum wall thickness determined in Section III.5.4.

Note: There is a maximum wall thickness which can be rotationally moulded.

There shall be no reliance on adhesion of the polymer to the steel surface.

III.6.4 Finish and Workmanship

A. Pipe ends

Pipe ends shall be plain and straight. Cut pipe ends shall be clean without ledges, shaving tails, burrs or cracks. The interior of the pipe shall be blown or washed clean of cuttings and shavings.

B. Finish

The internal and external surfaces of the plastic liner shall be free from defects such as blisters, cracks, scratches, dents, nicks or sharp tool marks which can affect the performance of the liner. Absence of these defects shall be determined visually or with a liquid dye penetrant. One sample per batch shall be tested.

C. Microscopic examination

Microscopic examination at 10 times magnification or visual examination by means of transmitted light shall show no voids, foreign inclusions or other internal defects which affect the performance of the liner. One sample per batch shall be tested.

For alternative non-destructive testing techniques the Company shall be consulted.

III.6.5 Dimensions, Weights and Tolerances

A. Size, tolerances

Pipe furnished to this ES shall comply with the dimensions and tolerances given in Table 3 of API Spec 15 LE or Tables 3 to 6 of ISO 4427.

CONTRACTOR shall specify nominal values of liner outside diameter and wall thickness. Tolerances on the outside diameter are listed in (Table 7):

Table 7 Tolerances on liner outside diameter

Liner Nominal Diameter (ND)	Minimum diameter	Maximum diameter
ND ≤ 60 mm	- 0 mm	+ 0.5 mm
60 < ND ≤ 114 mm	- 0 mm	+ 1 mm
ND > 114 mm	- 0 mm	+ 0.01*ND

The tolerance on the liner wall thickness, excluding groove depth, shall be -0%/+5% of the specified value.

B. Length of liner pipe joints

The length of individual joints of liner pipe shall be as long as possible, to minimize the number of field welds, consistent with transportation, handling and any other project constraints.

No jointers (two pieces fused together to make a length) shall be permitted.

The average, maximum and minimum liner joint lengths shall be agreed between CONTRACTOR and COMPANY with minimum length of 12 m.

C. Ovality and out-of-roundness

The ovality of the pipe shall not exceed 5% when measured as listed in Table-1.

During production both ovality and out-of-roundness shall be monitored and recorded at the frequencies specified in (Table 1).

III.6.6 Hydro-testing

Liner pipe sections shall not show any sign of leakage (burst or weep) or ballooning when subjected to a hydrostatic pressure test. The hydrostatic test pressure shall be agreed between the COMPANY, CONTRACTOR and Manufacturer and is maintained for at least 3 minutes. As a guide the test pressure should be 1.5 times the “rated” pressure for the stand-alone thermoplastic pipe.

Failure is defined as:

Ballooning Any abnormal localised expansion of a pipe specimen while under internal hydraulic pressure.

Burst Failure by a break in the pipe with immediate loss of test liquid and continual leakage of test liquid independent of applied pressure.

Weep Failure that occurs through microscopic breaks in the pipe wall, frequently only at or near the test pressure. At lower pressures, the pipe may maintain its integrity.

III.6.7 Retest and rejection

If a sample fails to meet any of the QC requirements, additional tests shall be made on the previously produced samples back to the previous acceptable sample. Pipes

produced in the interim that do not pass the requirements shall be rejected. Testing frequency shall be every 10th pipe back to the previously acceptable sample.

III.6.8 Inspection and rejection

A. Inspection by the Company

All Quality Control tests shall be witnessed by an Inspector approved by the COMPANY at the start of production and monitored during production at the COMPANY's discretion.

B. Significant defects

Significant defects are those which adversely affect the service life of the liner pipe, e.g. inclusions, bends, dents, scratches, visible cracks, discoloration, foreign material contaminants or any other imperfection reducing the wall thickness below minimum acceptable limits (Table-7).

Material which contains significant defects on inspection shall be rejected. Significant defects include:

Scratches in pipe: Surface scratches and nicks in thermoplastic liner may not exceed a depth of 5% of the nominal wall thickness.

Scratches in flanges: thermoplastic flange surfaces shall be free of scratches and nicks.

Bends: bend angles in thermoplastic liner pipes shall not exceed 5°. Bend radii shall not be less than 5 times the nominal liner diameter.

Dents: The maximum depth shall be the lower of 6.5 mm or 2% of the pipe OD.

C. Repair of defects

Repair of defects is not permitted.

III.6.9 Handling and Storage

A. Storage

Straight lengths shall be stored on horizontal racks and given support to prevent damage. In either storage form, pipe shall not come into contact with hot water or steam and shall be kept away from hot surfaces.

Pipe shall be covered with adequate protection from direct sunlight. If the pipe has to be stored in the open air before, during or after shipment, it shall be protected from environmental contamination.

Pipe end covers shall be used to prevent ingress of moisture or dirt to the inside of the pipe.

B. Handling

All pipes shall be cleaned, dried and packed before handling and transportation. Thermoplastic pipe can be susceptible to damage by abrasion and by sharp objects.

Dragging pipe sections over rough ground shall not be permitted. If, due to unsatisfactory storage or handling, a pipe is damaged it shall be rejected.

C. Transportation

The minimum requirements for transportation shall be as specified in API RP 5L1 for railroad transportation.

III.7 Steel Pipeline Preparation

Whether liner is to be installed in a new pipeline or retro-fitted into an existing pipeline will influence the preparation of the inside surface of the carbon steel pipeline. An accurate assessment of the condition of the host pipeline is critical to ensure a successful lining operation.

Note: Following assessment of existing pipeline / flowline, an eMOC shall be raised by COMPANY for installation of HDPE Liner for subject pipeline / flowline.

For rehabilitation of existing pipelines, the preparation considerations shall include:

i. Corrosion damage.
ii. Presence of leaks.
iii. Internal deposits.
iv. Diameter variations and mismatches.
v. Weld protrusions and misalignment.
vi. General lay-out with bends, road, manifolds … etc.

In particular, the following checks shall be performed.

i. The condition of the steel pipe should be assessed to determine that sufficient mechanical strength is retained to meet the design pressure rating for the proposed service, based on hydrotest and/or inspection survey data. This test should be carried out at a minimum test pressure of 1.5 times the design pressure.
ii. Any leaking areas of pipeline or imperfections that have been repaired as result of pressure test shall be documented and reported to COMPANY.
iii. Following pressure testing of carbon steel pipeline, CONTRACTOR shall remove all testing fluids by pigging:
    a. Pigging procedure shall include separate cleaning and drying runs using appropriate style of pigs (foam pigs).
    b. Following cleaning and dehydration runs, no free water or solid debris shall be observed as the pig exits the pipeline.
iv. The internal condition and dimensions of all lines should be evaluated to ensure that the liner can be pulled through each segment without significant damage e.g. due to excessive local weld penetration (‘icicles’) or use of higher wall thickness pipe at road crossings or repaired section. These should be checked by gauging pigs/plates and/or by pulling a test sample of liner through every pulled pipe section.
v. Locations for cutting of the line and any requirement for separate spooled sections should to be determined. The longest continuous length of liner which

can be installed in straight pipe depends on diameter and wall thickness, but is generally reduced in practice by local curvature of the line. Breaks are also required at road crossings, changes in ID and any bends of radius less than 20D, (recommended minimum where possible is 40D).

vi. Flanges welded to the steel line should be of matching bore and with a minimum radius at the inside edge of about 6 mm.

vii. Two vents, one at either end shall be welded to the line for each lined section.

viii. For lining existing buried pipelines, bellholes should be placed at the ends of the line and at any other locations where breaks in the liner need to be made. In addition to the normal safety considerations in excavating, sizing and ensuring stability of the bellholes, the following factors should also be considered:

ix. The working area within the bellhole should be of sufficient size to accommodate the pipe fusion machine and operator.

x. The entry slope should be sufficiently shallow to enable the liner pipe to bend smoothly from ground level to the pipeline depth without severe abrasion against the steel flange during pull-through. (Provision may also be required for pulling from two directions within a single bellhole).

xi. Provision of sufficient length and width to enable the pipe ends to be offset for flange welding and pulling in of the liner.

For new installations, preparation consideration shall include:

i. Site conditions;

ii. Steel material selection (surface roughness);

iii. Weld specification.

For both a new or existing pipeline, the pipe inner surface shall be thoroughly cleaned before liner installation ensuring removal of any debris/deposits adherent to the pipe internal surface and water.

III.8 Inspection of liner materials

III.8.1 General

Material which shows injurious defects during onsite inspection shall be marked and rejected and the CONTRACTOR so notified.

III.8.2 Defects

i. In pipe, surface scratches and nicks shall not exceed a depth of 5% of the nominal liner wall thickness.

ii. Flange surfaces shall be free of scratches and nicks

iii. The maximum depth of dents shall be the smaller of 6.5 mm or 2% of the pipe OD.

III.8.3 Repair of defects

Defects in any form shall not be repaired. Pipe lengths with defects exceeding the acceptance criteria as listed above shall be discarded and marked as rejects. Manufacturer shall issue a defective material traceability list showing pipe number, type of defects and repairing type.

III.9 Steel Pipeline Preparation – Steel Flanges, Connectors / Flangeless Welded Couplers

i. The locations of raised face flange pairs / flangeless welded couplers required for the liner installation shall be determined by the liner installation CONTRACTOR in consultation with COMPANY.

ii. The steel flange dimensions and any special flange requirements to accommodate the liner shall be specified in a certified engineering drawing by the liner installation CONTRACTOR in the liner proposal.

iii. Welding of the flanges shall be in accordance with COMPANY Standard Specification of Pipeline Welding.

iv. Liner CONTRACTOR shall be responsible for the flange procurement and all flange modifications required for lining.

v. The flange modifications shall include the following:

   a. Installation of a radius on the 90 degree edge at the bore to flange face;

   b. Adjustment of the outer circumference of the raised face to enable the proper fitting of the liner flange anti-extrusion rings;

   c. Assurance that the modified flange has smooth corners at the flange fillet transition to the weld neck.

vi. CONTRACTOR shall be responsible for flange installation.

Note: Flanges in off plot areas are not allowed. These shall be used only at both ends for tie-in and for the test spools. Flangeless welded couplers shall be used for all other locations.

III.9.1 Vent point assemblies

Vent point assemblies shall be installed in accordance with the design and shall be installed prior to installation of the liner.

CONTRACTOR shall install weldolet fittings a maximum of 375 mm (15 in) from the flange face to serve as part of the liner vent piping system.

i. One weldolet vent fitting shall be installed adjacent to each flange / welded coupler, at the 12 O'clock position. The vent tubing should be welded to the weldolet.

ii. Following the installation of the vent weldolet fittings on the pipeline, the drilling out of the vent hole shall be performed by the liner installation Contractor at the size specified in the liner installation CONTRACTOR specifications. Vent holes should be designed such that no extrusion of the liner will occur.

iii. Liner annulus fluid re-injection system shall be installed at both ends of pipeline / flowline in case liner vent is not open to flare system. This is to prevent liner collapse due to pressure built up in the annulus. Re-injection system shall have a double isolation valve to isolate injection system in case re-injection NRV malfunctions.

III.9.2 Liner Joining

A. General

The thermoplastic liner pipe shall be joined using the butt fusion welding process, as defined in ASTM D 2657, Technique II. Full automated butt weld equipment shall be used. The jointing process shall be qualified through NDT Technique such as Microwave and followed by destructive testing.

CONTRACTOR personnel performing the butt fusion welding shall be certified by the liner Manufacturer in the liner joining procedure.

Joining of liners with a wall thickness difference of more than 2 mm shall not be permitted. Procedures requiring the introduction of additional filler may also be used where appropriate. Measures to avoid oxidation and thermal degradation of the liner shall be taken.

After completion of the fusion weld, the internal and external bead of the weld shall be trimmed. After trimming, the surface of the joint shall be visually examined for evidence of good fusion. Nicks, gouges or undercuts caused by bead trimming are not acceptable and shall be removed or cut-out.

B. Butt fusion welding procedure

CONTRACTOR shall prepare a detailed procedure for each type and size of joint and fitting to be welded. Separate procedures shall be prepared for shop and site welding.

Each butt fusion welding procedure shall detail the following information:

i. Welding equipment type and model;
ii. Material grade and Manufacturer;
iii. Pipe/fitting dimensions at the joint;
iv. Welding sequence.

Essential parameters to be controlled as detailed in the welding equipment operating manual for both the pre-heat and fusion stages include temperatures, times, pressures, hot plate condition in terms of roughness and cleanliness;

Weld dimensions and tolerances

For each butt fusion welding procedure a test spool shall be prepared and welded. This shall consist of three pipe sections butt fusion welded together with a flange welded at each end, i.e. 4 circumferential welds in total. The assembly shall be tested as follows:

i. Weld dimensions - within tolerances of approved welding procedure;
ii. Visual inspection - no visible defects;
iii. Ultrasonic and/or radiographic examination when specified by the Company - acceptance criteria to be agreed;
iv. Pressure test using water at the maximum design temperature and at a pressure agreed with COMPANY or 1.5 times the equivalent “rated” pressure for the standalone thermoplastic pipe - no leakage after 2 hours.

For each material grade and weld type, four additional test samples shall be prepared from the largest diameter represented. The test samples shall be tested to short-term

burst pressure according to ASTM D 1599. The acceptance criterion is that the pipe shall not fail at the weld.

All butt fusion welding operators who successfully complete the above welding procedure qualification shall be considered qualified for butt fusion welds of the same type, material grade and diameter range as represented by the procedure.

All qualified welders shall carry an ID card including a pass photo and stating name, validity (end date of project) diameter range, wall thickness and material grade for which they are qualified. The ID card shall be signed by COMPANY.

III.9.3 Testing

CONTRACTOR shall conduct an air test on the fused liner section prior to installation of the liner. A maximum pressure of 0.3 bar shall be applied for a duration of not more than 3 hours unless otherwise specified by COMPANY. The pipe should be anchored at 5 to 7 metre intervals with back-fill material before pressuring. All fusion joints shall be soap-tested in the presence of an Inspector, approved by COMPANY.

Alternatively a water test may be performed. The pressure of the water test shall be 1.5 times the equivalent pressure rated (stand-alone) thermoplastic pipe. This test pressure shall be agreed between COMPANY and CONTRACTOR.

Additional requirements for grooved liners

For externally grooved liners, the liner installation Contractor shall ensure that the grooves are aligned for fusion joining and that excess polyethylene resulting from the fusion is removed from the groove.

i. For externally grooved liners, the liner installation Contractor shall install interconnecting grooves between all of the factory installed longitudinal grooves to provide a clear interconnection pathway between the longitudinal grooves and with the following requirements:
   a. The depth of the interconnecting grooves to be no deeper than the depth of the factory installed grooves.
   b. The orientation of the interconnecting grooves to be at 30 degrees ±10 degrees to the pipe axis.

ii. The function of interconnecting grooves is to assure gas communication between the longitudinal grooves. This is important when e.g., fluids are formed in the grooves at low spots in the line. Interconnecting grooves are circumferential grooves.

iii. The liner installation CONTRACTOR shall install the interconnecting grooves free of loose liner debris, frayed edges, or partially attached liner strips in or adjacent to the circumferential grooves.

iv. The frequency of the interconnecting grooves should be installed on the following basis:
   a. One per liner pipe length
   b. One liner pipe installed through steel hot induction bends sections (90/45 degree bends), one per 3 m (10 ft) at bend section only.

III.9.4 Liner Installation Techniques

There are several commercially available liner installation techniques. There are three generic liner installation techniques:

i. under sizing
ii. consecutive reduction and pull-in
iii. simultaneous reduction and pull-in

Only tight fit liners shall be deployed. The OD of HDPE liner shall be 1-3 % more than ID of host pipe to ensure tightness.

Only simultaneous reduction and pull in technology shall be deployed.

A. Simultaneous reduction and pull-in

Simultaneous reduction and pull-in techniques reduce the liner diameter elastically through a die during the installation process. The immediate elastic recovery forces the liner into a tight fit inside the host pipe. However, to maintain the insertion clearance during pull-in the liner shall remain under tension at all times, implying that the liner shall be fed through the die and straight into the host steel pipe in one continuous pull.

B. Reduction forming (with die)

Reduction forming or swaging (with die) is designed to maximize remaining bore diameter. Using a simple die, diameter reduction is converted into an axial length increase. When the tension is released, the elastic recovery is immediate with the liner length reducing as the liner diameter increases. The annulus is continuously vented with the end result being a very tight interference fit between the liner and the host pipe. This technique provides the tightest possible liner fit but is the most demanding in terms of engineering tolerances.

C. Reduction forming (with rollers)

Reduction forming (with rollers) uses a set of profiled rollers to forge the reduced diameter in several stages, with the reduction deformation imposed more gradually on the liner than by reduction forming (with die). The last set of rollers is powered.

By controlling both the pull-in and roller loads an optimum conversion of length and wall thickness is achieved. Alternatively the rollers may not be powered, in which case the liner is pushed through the rollers.

III.9.5 Liner Installation

All equipment and material required for the installation and testing of the liner shall be provided by CONTRACTOR unless otherwise agreed.

Procedures to cover the installation of the thermoplastic liner inside the carbon steel pipeline shall be prepared by CONTRACTOR and submitted to COMPANY for approval.

A. Preparation

1. Pre-installation communications

CONTRACTOR shall establish communication procedures between the ends of the pull section prior to the start of the liner pull-in.

2. Pull wire

The pull wire shall be certified to a load of at least four times the anticipated maximum pull load.

3. Pipe cleaning

Before installation, CONTRACTOR shall clean the pipeline and demonstrate that the bore of the carbon steel pipeline is free from obstructions (e.g. excessive weld penetration, dents, etc.) that could interfere with or damage the liner during pull-in. A gauging plate shall be used to assess the internal diameter variations within the carbon steel pipeline.

4. Pull head and winch

The design of the pull head shall be such that sufficient clearance between the pull head and the pipe shall be maintained.

The winch shall contain as a minimum a distance indicator and recorder and a calibrated load indicator and recorder.

5. Wireline and pig train

The wireline unit should be suitably instrumented with footage and weight indicators, an overload control set to a maximum of 100% of the calculated maximum allowable pulling force and fitted with a speed controllable reel with cable spooling and braking facility.

CONTRACTOR should provide suitable pigs and launching equipment to propel the wireline and pig train through the pipeline

A typical pig train should include:

i. Sizing pig
ii. Cleaning pig
iii. Cup pig

Once the wireline has been passed through the pipeline section, the pig train is pulled through, the pulling force being continuously monitored to determine the location of any constrictions.

For tight liners, the disc plate should be of sufficient diameter to verify that internal weld beads do not protrude excessively, taking into account the dimensional tolerances of the steel pipe.

The outer diameter of the liner pipe segment should be such that any excess weld penetration which could result in liner puncture during normal operation is detected. For loose liners this could imply that a larger diameter liner pipe may be necessary for test purposes than during operation.

The liner test segment attached to the pig train should emerge without serious damage. Scuffing of the liner surface is permissible but sharp longitudinal scars or other penetration damage exceeding 0.5 mm or 5% of the wall thickness, whichever is larger, is unacceptable and would require rectification by further pigging using a

breaker pig or by other means before continuing with liner installation. After rectification another liner test segment should be pulled through.

B. Insertion

1. General

Installation methods and procedures proposed shall include as a minimum:

i. Description of equipment used.

ii. Length of sections.

iii. Maximum allowable and planned axial pull load. The maximum allowable axial stress in the liner should be limited to 50% of the tensile yield stress.

iv. Type of lubrication – Lubricants can be water or bentonite. The use of grease is not allowed unless by testing it is proven to be compatible with the thermoplastic liner and will not lead to stress cracking.

v. Pull-in rate.

vi. Methods for continuous load monitoring with calibrated equipment.

vii. Precautions shall be taken to ensure that no debris is introduced into the line on the external or internal surface of the liner.

2. Pull-in load

The actual pull-in load shall be continuously monitored during pull-in. It shall not be allowed to exceed the maximum allowable pull-in load

C. Expansion

Thermoplastic polymers have a thermal coefficient of expansion greater than that of carbon steel. Consequently, allowance for thermal expansion and contraction after pull-in and during service shall be considered by Liner CONTRACTOR during the liner expansion phase of installation. A practical allowance shall be added to HDPE Liner.

D. Vent installation smooth wall liners

i. Smooth wall PE lined pipeline shall incorporate a vent point at each end of the lined pipeline segment, near the liner flange or welded coupler.

ii. Vent holes shall be installed by the liner Contractor and designed such that no extrusion of the PE liner will occur.

iii. Vent holes for smooth wall liners shall not be larger than 3.2 mm (1/8”) in diameter.

iv. All liner vents shall be equipped with stainless steel full port valves that have been subject to approval of the COMPANY.

v. Where the vents are designed for continuous venting, they shall be installed with additional stainless steel tubing and manifold valves in accordance with the detailed specifications for the project.

vi. The design of the vent station pipe and valve assemblies shall be subject to approval of the COMPANY before installation.

vii. The vent station piping shall be pressure tested to 150 % of the pipeline design pressure for 15 minutes as specified in III.10.3.

viii. The fillet weld connecting the vent weldolet to the pipeline and the weld connecting the vent tubing to the weldolet shall be welded and inspected in accordance with COMPANY Welding Specification. Pressure testing of the fillet weld between the weldolet and the line pipe shall not be carried out due to the design configuration of the vent.

E. Vent installation grooved liners

i. Grooved PE lined pipeline shall incorporate minimum two vents per liner section located at each flanged end or welded coupler end of the lined pipe section.

ii. Vent holes shall be installed by the liner installation CONTRACTOR and designed such that no extrusion of the PE liner will occur.

iii. Vent holes shall be 3.2 mm (1/8”) in diameter.

iv. All vents shall be equipped with a full port valve based on the design of the vent system piping.

v. The vent stations shall be equipped with stainless steel tubing and valves in accordance with the project detailed specifications.

vi. They are normally designed for either continuous or intermittent manual venting.

vii. The design of the vent station pipe and valve assemblies shall be subject to approval by the COMPANY before installation.

Note: The liner vent fluids shall be diverted to station flare system or drain vessel as applicable. In case flare or drain vessel systems are not available, venting to atmosphere is allowed for sweet service application. Pre-Commissioning

III.9.6 Hydrotesting general

i. CONTRACTOR shall supply water and equipment necessary to perform the pressure test on the installed liner.

ii. The test pressures for the carbon steel host pipe, the liner pipe, the completed lined pipeline and the venting piping shall be as per Table 8. The final pressure test procedure of the completed system shall comply with local regulations.

iii. All variances in the pipeline elevation shall be included in determining the minimum testing pressure required to provide the minimum required test pressure throughout the pipeline.

iv. CONTRACTOR shall supply and install for the duration of the pressure test, a calibrated pressure-recording chart that is suitable for recording the pressure and ambient temperature.

v. CONTRACTOR shall supply and install for the duration of the pressure test, calibrated pressure gauges at each end of the lined pipeline to allow monitoring of the test pressures.

vi. The pressure test shall be witnessed by the COMPANY’s representative.

III.9.7 Hydrostatic pressure test completed system

i. The completed lined pipeline system shall be hydro-tested with water at ambient temperature according to COMPANY Standard Specification for Pipelines Hydrostatic Test.

De-rating of the pipeline might be necessary based on the outcome of the assessment.

For the duration of the pressure test, all of the liner to steel pipeline annulus vents shall be opened and monitored at least once during the hydrostatic test and have no indication of pressure build up or excessive fluid flow.

ii. The test medium for the final liner pressure test shall be water and its quality shall be subject to approval by the COMPANY.

iii. During hydrostatic pressure testing, temperature and pressure shall be recorded continuously.

iv. During the hydrostatic test, the pressure shall be increased initially to three times the liner pipe freestanding pressure rating with all vents open to allow annular fluids to escape.

v. Once all fluids have escaped or after one hour of the hydrostatic test, which ever takes longer, the pressure shall be increased to the required test pressure.

vi. All end terminations and vents shall be visually inspected with acceptance criterion of no weeping at flanges or through vent holes during the test.

vii. At the end of the hydrostatic pressure test, the vents shall all be closed whilst the line is still under pressure.

viii. Between two to four weeks after commissioning, all vents shall be opened and closed again to allow fluids that might have permeated through the annulus to the vents to escape and to check whether any liner defects have developed.

III.9.8 Hydrostatic test vent piping

Annulus vent piping shall be hydrotested with water in the fabrication shop at a minimum pressure of 1.5 x MOP for a test duration of 15 minutes.

Table 8 Pressure testing requirements

Type of test	Applicable standard	Test pressure	Test Medium/Hold period	Documentation
Carbon steel host pipe before lining (new carbon steel pipeline)	COMPANY Standard Specification for Pipelines Hydrotest	New pipelines: as per COMPANY Standard Specification	Strength test only (4 hours) Complete system leak tightness test	CONTRACTOR QA documentation
Carbon steel host pipe before lining (retrofitting existing pipeline)		125 % of Original Design Pressure as per Project Documents	Strength test 4 hours followed by 24 hours of Leak Tightness Test at 88% of Hydro Test Pressure	

Low pressure leak test on fusion welded liner segments (prior to insertion)	Air/Soap leak test OR:	0.03 MPa	Leak Air/Soap test of each fusion joint <= 3 hours.	CONTRACTOR QA documentation
	Hydrostatic pressure test (water)	ES 30-99-12-0036 (AON)	ES 30-99-12-0036 (AON)	
Final lined pipe hydro test		COMPANY Standard Specification for Pipelines Hydrotest	COMPANY Standard Specification for Pipelines Hydrotest	Continuous Pressure Recorder Chart CONTRACTOR QA documentation
Annulus vent piping (shop testing)		1.5 x MOP	Water / 15 minutes	CONTRACTOR QA documentation

III.10 Documentation

III.10.1 General

The liner installation Contractor shall maintain documentation for the fusion welding, inspection, test and as-built details and hand-over to the primary Contractor on completion of the work.

III.10.2 Flanges

i. The location of each flange pair shall be recorded against pipeline alignment drawings, preferably by global positioning system (GPS) coordinates.

ii. Certified engineering drawing of the modified flange design, including the anti-extrusion ring dimensional drawing shall be provided.

iii. Flange assembly procedure and records shall be provided.

III.10.3 Liner

Complete manufacturing data sheets shall be provided as per section III.6 of this specification.

III.11 Hand-Over to Operations

III.11.1 General

Before commissioning, CONTRACTOR shall develop procedures and assign responsibilities for the operation phase covering the following:

a. Normal operation

b. De-pressurization

c. Start-up

d. Monitoring

e. Recovery after collapse

III.11.2 Procedures Handed Over to Operations

Procedures developed and handed over for normal operation shall include the following:

a. Instructions to leave vents open continuously or open at regular time intervals to bleed off the annulus

b. Instructions to measure the fluids that escapes when manually operating valves

c. For liquid hydrocarbons (with or without H2S), instructions for vents to be closed during normal operation and opened during maintenance for releasing gas and liquid in the annulus.

Note: Venting of sour (H2S containing) gas might present an operational hazard and vents shall not be opened where H2S concentration is expected to be more than 10 ppm.

d. Instructions for appropriate safety procedures to be followed during routine venting.

e. Venting requirements for depressurization, re-pressurization and start-up.

III.11.3 Monitoring

A condition-monitoring plan for the PE liner shall be developed and handed over to the operating organization, including the monitoring of pressure drops (to confirm liner collapse) and regular venting of the annulus to establish leaks.

III.11.4 Recovery Plan

The CONTRACTOR shall develop a generic recovery plan to hand over to the operating asset for actions to take in case of a leaking or collapsed liner.

III.11.5 Repair

The CONTRACTOR shall hand over generic maintenance and repair procedures to be used during the operating phase in case of leakage or deterioration.

III.12 Operational Procedure

An operational procedure shall be developed for all lined pipelines and flowlines. This procedure shall as a minimum address the following aspects:

i. System description;

ii. Operating envelope and maximum limits;

iii. Venting procedure and frequency;

iv. Pigging;

v. Start-up procedure;

vi. Routine operations;

vii. De-pressuring.

III.12.1 Start-Up

Immediately prior to starting up lined pipeline systems in gas service, any accumulated pressure shall be bled off at all the vents. As soon as the pipeline is up to operating pressure, the pressure at each vent point shall be checked and recorded. This should be repeated after 48 hours' operation.

III.12.2 Operation during well shut-down

In case of well shut-down for maintenance or other activities, the product shall be completely removed from the flowline so that the liner is not affected by high temperatures of the product due to non-flow.

III.12.3 De-Pressurizing

Before de-pressurizing the pipeline the vent points should be opened for at least one hour.

The rate at which the vent point can relieve the gas trapped in the annulus should be estimated to ensure that the venting rate, during de-pressurization, is sufficient to prevent a positive pressure difference between the annulus and the pipeline, i.e. at no time during de-pressurization should the annulus pressure be greater than the line pressure.

III.12.4 Pigging

Pipelines with liners do not usually require pigging. However, if the line requires pigging to remove fluids, then only foam pigs shall be used.

III.12.5 Venting

Venting procedures are required to prevent liner collapse during process upset conditions (large pressure fluctuations) or shutdowns. Venting is required when gases are present in the pipeline fluids. Venting is not required for liquid lines.

All vents shall be opened in the following conditions:

i. Before changes in the operating conditions;

ii. Before shutdown;

iii. At least monthly to evacuate the permeated gas accumulated in the annulus.

Venting operations shall be recorded in a log and include: date, length of time vent remained open, vent pressure, volume of gas vented and other general observations. The requirement for monthly venting may be revised according to experience using the log entries to justify revising the venting frequency.

Alternatively it may be decided to operate the pipelines with the vents open (assuming approval from the appropriate Health, Safety and Environment authority), i.e. continuously venting the annulus. Open vents shall be inspected at least monthly to check integrity of the thermoplastic liner and blockage of the vent points.

III.12.6 Maintenance

Vent points shall be kept free from paint or other deposits. Blocked vent points, pipes and fittings should be cleaned with low-pressure water only. The use of rods, steam jets or sharp tools for cleaning shall not be permitted.

The vent holes and flange bolt torques shall be checked regularly.

If very toxic gases are present the local HSE authority shall be consulted before venting operations.

III.12.7 Repair

Lined pipes and fittings shall not be repaired by welding, since heat could cause damage to the liner. If damage occurs to a component of an installed lined piping system, the damaged component shall be replaced.

Consideration may be given to returning damaged pipes to the Contractor for relining. Leakage at flanged connections shall be remedied by the measures in the following sequence:

i. Re-torqueing of flange bolts to the specified values. Care shall be taken that these values are not exceeded.

ii. Replacement of the pipe spool having the suspect flange face.

III.13 Information / Documents to be submitted by the CONTRACTOR

The CONTRACTOR shall submit information / relevant documents on the liner system to be used. This information shall contain as a minimum:

i. Liner system identification.

ii. Manufacturer's material data.

iii. Material pre-qualification information.

iv. Type and thickness of liner material.

v. Expected short-term and long-term volumetric swelling or shrinkage for the range of operating conditions.

vi. Expected thermal deformations due to operating temperatures.

vii. Liner manufacturing procedure.

viii. Liner installation procedure.

ix. Liner section based on flowline / pipeline route, bends, expansion loops … etc. (as per the site survey).

x. Anticipated insertion forces for each liner section in relation to liner strength.

xi. Bend limitations for the steel pipe.

xii. Maximum allowable weld penetration of carbon steel pipeline girth welds.

xiii. Vent connection details and spacing.