Poseidon Pipeline Project - Offshore Section Update

Onshore Pipeline Mechanical Design Report - Italy

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PROJECT 406010-00159 - ONSHORE PIPELINE MECHANICAL DESIGN REPORT - ITALY

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CONTENTS

1 INTRODUCTION

1.1 Background

The Poseidon Pipeline Project, developed by IGI Poseidon S.A., will be designed for the supply of gas from Turkey and the Eastern Mediterranean region to the European market through the interconnection of the Greek and Italian gas networks.

The Poseidon Pipeline consists of two sections:

- An onshore section, stretching from Kipi (north-east of Greece, next to the Greek Turkish border) to the north western coast of Greece (Thesprotia area);
- An offshore section, from the north-western coast of Greece to Italy (Figure 1-1).

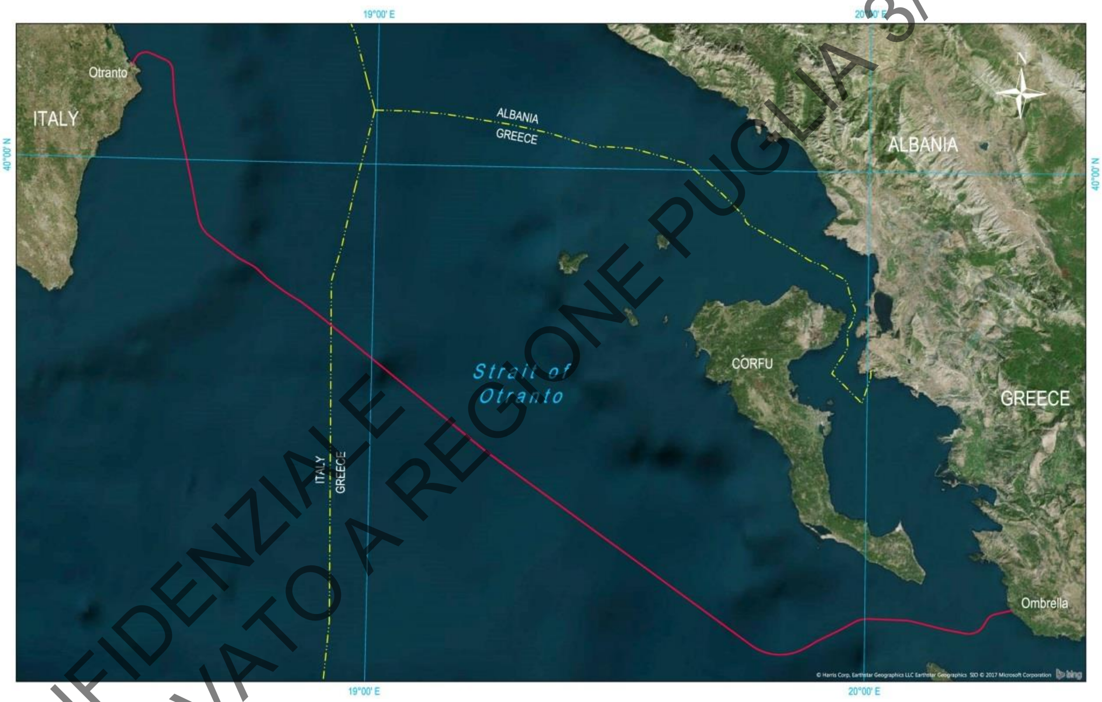

Figure 1-1 Poseidon Pipeline Project – Offshore Section

The offshore section of the Poseidon pipeline comprises:

- A compressor and fiscal metering station next to the Greek landfall (Thesprotia area);
- A deep water offshore pipeline from the Greek landfall to Italy (Otranto, Apulia region). The offshore section (about 200 km, ca. 1,370 m water depth) will cross the Greek shelf, descend the slope into the north Ionian Basin and then ascend the Italian slope, to make landfall east of Otranto;
- A receiving fiscal metering and pressure reduction station in Italy (Otranto, Apulia region);
- Two short buried onshore pipeline sections connecting compressor station in Greece and metering station in Italy to the respective landfalls, including associated scraper launching and receiving facilities.

The FEED phase of the offshore section of the Poseidon Pipeline Project was completed in 2013 and designed for a maximum flow rate of 12 BNCMA of gas (12.66 BSCMA).

ENGINEER's scope of work is named the Poseidon Pipeline Project - Offshore Section Update (the PROJECT). It concerns the Design Update to accommodate a maximum flow rate of 20 BSCMA of gas (which represents a potential development of the gas pipeline, not yet authorized, but evaluated for the maximum design capacity and related technical aspects) for the deep water offshore pipeline from the Greek landfall to Italy (Otranto) and the short onshore buried pipelines connecting compressor station in Greece and fiscal metering and pressure reduction station in Italy to the respective landfalls. Updating of FEED specific aspects for the Greek onshore section, such as the geological, geotechnical, route selection and civil design aspects is not included in the scope.

The document numbers for the FEED Revision have a new CTR number (1000 series).

1.2 Document Scope

This document presents the results of wall thickness calculations according to Ministerial Decree of 17/04/2008 (Ref. [1]) and the European Standard EN1594 (Ref. [2]) for the Italian onshore pipeline section from Otranto Landfall (OLF) location to the gas receiving facility area.

1.3 Codes and Standards

The mechanical design of the Italian onshore pipeline section is in accordance with the codes as described in Ref. [3] and listed in Table 1-1.

Table 1-1 Codes used for Mechanical Pipeline Design Onshore Italy

Code	Title
Ministerial Decree of 17/04/2008	Decreto del Ministero dello sviluppo economic 17 aprile 2008, Regola tecnica per la progettazione, construzione, collaudo, esercizio e sorveglianza delle opera e degli impianti di transporto di gas naturale con densità non superiore a 0,8
EN 1594	European Standard, Gas supply systems – Pipelines for maximum operating pressure over 16 bar – Functional requirements, 2013

2 DEFINITIONS AND ABBREVIATIONS

2.1 Definitions

Definitions applicable to the Project are provided in Table 2-1.

Table 2-1 Project Definitions

WORK	Scope of Services per CONTRACT for “Poseidon Pipeline Project – Offshore Section Update”
CONTRACT	The CONTRACT between IGI Poseidon and ENGINEER for WORK as detailed in the CONTRACT documents
CLIENT	IGI Poseidon (50% EDISON S.p.A. and 50% DEPA)
INTECSEA	INTECSEA B.V, the engineering company appointed by CLIENT to carry out the WORK
ENGINEER	INTECSEA
Project	The official title of the Project is “Poseidon Pipeline Project – Offshore Section Update”
INTECSEA Project No.	406010-00159

2.2 Abbreviations

The following abbreviations are used throughout this document.

D	Nominal Diameter
DM	Ministerial Decree
DNV	Det Norske Veritas
DP	Design Pressure
EN	European Standard
FEED	Front End Engineering Design
ID	Inside Diameter
N/A	Not Applicable
MIP	Maximum Incidental Pressure
MOP	Maximum Operating Pressure
OD	Outside Diameter
OLF	Otranto Landfall
SAWL	Submerged Arc-Welding Longitudinal

SMYS	Specified Minimum Yield Strength
SMTS	Specified Minimum Tensile Strength
TP	Test Pressure
WT	Wall Thickness

3 DESIGN DATA

The design data used for this analysis are extracted from the Design Basis Memorandum (Ref. [3]), unless otherwise stated.

3.1 Pipe Dimensional Data

The Italian onshore pipeline section is short in comparison with the offshore pipeline section, and it is therefore practicable to combine material purchase for both onshore and offshore line pipe in a single activity. Therefore, one line pipe specification is foreseen for the complete pipeline system including both offshore and onshore pipeline sections. For the line pipe specification, reference is made to Ref. [4]. This line pipe specification is based on DNV-ST-F101 (Ref. [8]).

The Poseidon 32-inch pipeline section is designed based on a constant outside diameter (OD).

The line pipe dimensional data are summarized in Table 3-1.

Table 3-1 Pipe Dimensional Data

Parameter (-)	Symbol (-)	Value (mm)
Pipe nominal outside diameter	OD	812.8
Pipe nominal inside diameter	ID	To be determined
Internal or external corrosion allowance	c_A	0
Wall thickness fabrication tolerance	t_{fab}	±1

3.2 Material Properties

The line pipe material properties of the selected steel grade are summarized in Table 3-2.

Table 3-2 Steel Properties

Parameter	Symbol	Unit	Value
Steel density	ρ_s	kg/m^3	7,850
Young's modulus	E	MPa	$2.07 \cdot 10^5$
Poisson's ratio	v	-	0.3
Material grade (per DNV-ST-F101)	-	-	SAWL 485 FDU
SMYS	f_y	MPa	485
SMTS	f_u	MPa	570

3.3 Operating Parameters

The selected parameters and the associated values, which are used in the wall thickness calculations, are presented in Table 3-3.

For the hydrotest pressure, reference is made to Section 5.2.

Table 3-3 Operating Parameters

Parameter	Unit	Value	
		DM 17/04/2008	EN 1594
Maximum operating pressure; MOP[1]	barg	151	
Maximum operating pressure for wall thickness calculation; MOP[2]	barg	151 + 25% = 189	151
Maximum incidental pressure; MIP	barg	1.1 x 189 = 208	151 + 15% = 174
Design pressure; DP[1]	barg	189	170
Maximum product density	kg/m³	130	
Maximum seawater density (hydrotest)	kg/m³	1,035	
Elevation – compressor station	m	400	
Maximum elevation onshore Italy[3]	m	76	

Notes: 1. Pressure reference elevation is 400m.

2. As per Section 2.5.2 and Section 2.5.3 of Ref. [1] the wall thickness of the pipeline shall be calculated for a maximum operating pressure which is increased by 25% to account for a distance less than 100m to settlements and/or concentration of people.

3. Pipeline Alignment Sheets – Italy (Ref. [6]).

4 METHODOLOGY

4.1 Introduction

The mechanical design for the Italian onshore pipeline requires wall thickness calculations that satisfy the hoop stress as specified in the applicable standards, being DM 17/04/2008 (Ref. [1]) and EN 1594 (Ref. [2]). These codes use similar formulae, but different values for the safety factor.

Another difference, although insignificant for this particular case, is that, unlike the Italian code, the European code specifically states to account for a temperature de-rating effect when design temperature exceeds 60°C. As the design temperature for the Italian onshore pipeline section is below 60°C, this de-rating effect does not need to be taken into account.

4.2 Hoop stress formulae

4.2.1 Straight Pipe

According to the in Section 4.1 mentioned standards, hoop stress formulae are as follows:

DM 17/04/2008 $$t_{\min} = \frac{DP \cdot OD}{20 \cdot F \cdot R_{t0.5}}$$

EN 1594 $$t_{\min} = \frac{DP \cdot OD}{20 \cdot f_o \cdot R_{t0.5}(\theta)}$$

Where:

symbol	**unit**	**quantity**
$t_{\min}$	mm	Minimum wall thickness
DP	barg	Design pressure; for DM 17/04/2008 the design pressure is taken equal to 189 barg at 400m elevation (see Table 3-3)
OD	mm	Outside diameter, where $OD = ID + 2 \cdot t_{\min}$
ID	mm	Internal diameter
F	-	Utilization factor, 0.57 as per Ref. [1]
f_o	-	Design factor, 0.72 as per Ref. [2]
$R_{t0,5}$	MPa	Specified minimum yield strength
$R_{t0,5}(\theta)$	MPa	Specified minimum yield strength at the design temperature. Since temperature onshore Italy is less than 60°C $R_{t0,5}(\theta) = R_{t0,5}$

EN 1594 defines the nominal wall thickness as follows:

$$t_{nom} = t_{\min} + t_{fab} + t_{corr}$$

In which t_{fab} and t_{corr} t_{corr} are the wall thickness fabrication tolerance and the wall thickness corrosion allowance, respectively. These values are presented in Table 3-1.

4.2.2 Bends

The Italian onshore pipeline route contains several bends which are anticipated to be 5D hot (induction) bends and 40D cold (field) bends (Ref. [6]).

Especially induction bending affects the dimensions of the pipe; distortion of the pipe in the bend area includes a decrease in wall thickness (wall thinning) at the outer bend, the bend extrados, and an increase in wall thickness (wall thickening) at the inner bend, the bend intrados. Actual distortions may vary from predicted values due to the particular induction bending process requirements such as bend angle, radius, diameter, speed of bending, temperature, cooling method, coil design and material type. A larger bend radius will result in a smaller wall thickness variation. For a 5D bend radius, approximately 8% wall thinning in the outer bend is expected.

In addition, the additional circumferential stress component for the bend intrados due to the bending radius shall be taken into account. The minimum required wall thickness shall be calculated, in accordance to EN 1594 (Ref. [2]) using the following factors:

<u>Bend intrados</u>

$$t_{\min Innerbend} = f_{in} \cdot t_{\min}$$

$$f_{in} = \frac{2R - 0.5OD}{2R - OD}$$

<u>Bend extrados</u>

$$t_{\min Outerbend} = f_{ex} \cdot t_{\min}$$

$$f_{ex} = \frac{2R + 0.5OD}{2R + OD}$$

Where:

symbol	unit	description
f_{in}	-	Wall thickness factor for a bend intrados
f_{ex}	-	Wall thickness factor for a bend extrados
R	mm	Bend radius along the centre line of bend (5xOD / 40xOD)

OD	mm	Outside diameter

Table 4-1 presents the intrados and extrados factors for the bend wall thicknesses for the 5D hot (induction) bends and the 40D cold (field) bends.

Table 4-1 Wall Thickness Factor for Bends

Bend Location	**Bend Radius**	
(-)	**(5D)**	**(40D)**
Intrados	1.056	1.006
Extrados	0.955	0.994

Both effects (i.e. bend thinning and circumferential stress correction factors) shall be accounted for in the wall thickness selection for the bends; see Section 5.1.2.

5 ANALYSIS RESULTS

5.1 Wall Thickness

5.1.1 Straight Pipe

The results of the required wall thickness calculation for the Italian onshore section of the Poseidon pipeline are summarized in Table 5-1.

Table 5-1 Nominal Wall Thickness

Design Code (-)	Calculated Wall Thickness (mm)	Selected Wall Thickness (mm)
DM 17/04/2008	29.4	30.7
EN 1594	20.9	

Note: 1. Selected wall thickness value to be confirmed by the in-place stress analysis.

As can be seen from Table 5-1, the Italian code DM 17/04/2008 is more stringent than the EN 1594 regarding the wall thickness requirement. This has two causes:

- Requirement of 25% increase in maximum working pressure (MOP) near settlements, for safety reasons;
- Utilization factor F (DM 17/04/2008) is approximately 25% smaller than design factor f_0 (EN 1594) to allow for a safety corridor width of 20m.

As the length of onshore line pipe represents only a small percentage of the overall project requirement, it is not considered economical to purchase a small amount of line pipe with a project unique wall thickness.

As such, the offshore wall thickness that satisfies the wall thickness requirements as presented in Table 5-1 is applied. The selected wall thickness of 30.7 mm is equal to the wall thickness as selected for the offshore section on the Italian continental slope and the shore approach; see Ref. [4] for more details.

The selected wall thickness is shown on the Alignment Sheets (Ref. [6]) and included in the Material Take-Off (Ref. [7]).

5.1.2 Bends

For the minimum nominal wall thickness calculations of the bends the bend wall thickness factors, as presented in Table 4-1 are taken into account. In Table 5-2 the minimum required nominal bend wall thickness (after bending), at the intrados and extrados, are presented.

Table 5-2 Minimum Nominal Bend Wall Thickness (after Bending)

Design Code	Bend Radius and Type	Calculated Wall Thickness	
		Intrados	Extrados
(-)	(-)	(mm)	(mm)
DM 17/04/2008	5D Hot Induction	31.0	28.1
	40D Cold field	29.6	29.2
EN 1594	5D Hot Induction	22.0	20.0
	40D Cold field	21.0	20.8

Accounting for 8% wall thinning in the outer bend for 5D hot induction bends, the minimum nominal wall thickness after bending will be 28.2 mm using mother pipe with a wall thickness of 30.7 mm. This is acceptable from a design code perspective since the required wall thickness is 28.1 mm for the outer bend according to Table 5-2.

Accounting for wall thickening in the inner bend for 5D hot induction bends, the nominal wall thickness after bending will be 32.2 mm using a mother pipe with wall thickness of 30.7 mm and a conservative estimate of 5% increment of wall thickness at the inner bend. This is acceptable from a design code perspective since the required wall thickness is 31.0 mm for the inner bend according to Table 5-2.

During cold field bending the bend thinning is typically limited to 1.5% of the wall thickness which results in a nominal wall thickness in bend extrados of 30.2 mm. This is acceptable from a design code perspective since the required wall thickness is 29.2 mm for the outer bend according to Table 5-2.

5.2 Hoop Stress during Hydrotest

Both design codes states that the hydrotest pressure shall not result in uncontrolled yielding. The hoop stress during hydrotesting is calculated with the same formulae as presented in Section 4.2. The selected wall thickness of 30.7 mm is applied and the utilization factor is taken one (1). This results in the following formula:

$$\sigma_{hoop} = \frac{TP \cdot OD}{20 \cdot t}$$

Where TP is the test pressure in barg and t the selected wall thickness in mm

The test pressures have been determined in accordance with both the Italian Ministerial Decree 17/04/2008 and EN 1594.

Following the code requirements, the following is applicable for the Italian onshore section:

- Italian Ministerial Decree 17/04/2008 – For the entire onshore section, the test pressure should be 1.30 x maximum operating pressure (MOP) or higher;

  MOP = 151 barg (400m elevation, Greece compressor station);

  ➔ MOP = 155.1 barg (76m elevation, highest Italian onshore location);

  ➔ $p_{hydrotest, 76m}$ = 1.3 * 155.1 = 201.7 barg (76m elevation, highest Italian onshore location);

➔ $p_{hydrotest,\ 0m}$ = 201.7 + (H*$\rho_{seawater}$*g)*10^{-6} = 209.4 ≈ 210 barg (0m elevation, at Italian shoreline);

- EN 1594 – For the full onshore section, the test pressure should be the maximum incidental pressure (MIP) + 0.05 * design pressure (DP) or higher; at the lowest position of the onshore section the test pressure should be MIP + 0.15 * DP or higher. The second requirement is governing and used to determine the maximum test pressure at sea level.

  DP = 170 barg (400m elevation, Greece compressor station);

  ➔ DP = 170 + (H*ρ_{gas}*g)*10^{-6} = 175.1 barg (0m elevation, at Italian shoreline);

  MIP = 1.15 * MOP = 1.15 * (151 + H*ρ_{gas}*g)*10^{-6} = 179.5 barg (0m elevation, at Italian shoreline);

  ➔ $p_{hydrotest,\ 0m}$ = MIP + 0.15*DP = 179.5 + 0.15*175.1 = 205.8 ≈ 206 barg (0m elevation, at Italian shoreline);

In summary, the maximum test pressures are calculated along the Italian onshore route section, i.e. at the lowest position along the route (at shore). The test pressures are presented in Table 5-3.

Table 5-3 Maximum Test Pressure

Design code **(-)**	**Test Pressure** **(barg)**
DM 17/04/2008	210
EN 1594	206

Notes: 1. Assuming the Italian onshore pipeline section is tested separately from the offshore section and Greek onshore section. Otherwise, extra pressure due to elevated Greek part has to be accounted for.

2. Presented test pressures are at sea level.

The obtained hoop stress for both design codes are presented in Table 5-4.

Table 5-4 Hoop Stress – Testing Requirement

Design code **(-)**	**Hoop Stress** **(N/mm²)**	**SMYS** **(%)**
DM 17/04/2008	286	59
EN 1594	281	58

With this result, prevention of uncontrolled yielding is secured. Note that a hoop stress of 59% of the SMYS can also be interpreted as a utilization factor of 0.59.

6 CONCLUSIONS

- Selected wall thickness for the Italian onshore pipeline is 30.7 mm, satisfying requirements of DM 17/04/2008 and EN 1594; this wall thickness will be used for further Italian onshore pipeline design activities,
- Combined with a constant outside pipeline diameter of 812.8 mm, this wall thickness results in an inner pipeline diameter of 751.4 mm (coating thickness excluded),
- Assuming 8% wall thinning at the outer bend and 5% wall thickening at the inner bend introduced by the induction bending process, the selected wall thickness satisfies the code requirements for bends;
- The selected wall thickness combined with hydrostatic test pressures as reported in Section 5.2 result in hoop stresses according to DM 17/04/2008 and EN 1594 of 59% and 58% of the carbon steel SMYS, respectively.

7 REFERENCES

Ref. [1] Decreto del Ministero dello sviluppo economic 17 aprile 2008, Regola tecnica per la progettazione, construzione, collaudo, esercizio e sorveglianza delle opera e degli impianti di transporto di gas naturale con densità non superiore a 0,8

Ref. [2] EN 1594, Gas supply systems – Pipelines for maximum operating pressure over 16 bar – Functional requirements, 2013

Ref. [3] INTECSEA, Poseidon Pipeline Project – Offshore Section Update, Design Basis Memorandum, IGI-1201-10-PL-BOD-001

Ref. [4] INTECSEA, Poseidon Pipeline Project – Offshore Section Update, Specification for Line Pipe, IGI-1207-10-PL-SPC-001

Ref. [5] INTECSEA, Poseidon Pipeline Project – Offshore Section Update, Pipeline Mechanical Design Report, IGI-1308-30-PL-RPT-001

Ref. [6] INTECSEA, Poseidon Pipeline Project – Offshore Section Update, Pipeline Alignment Sheets – Italy, IGI-1410-46-PL-DWG-002

Ref. [7] INTECSEA, Poseidon Pipeline Project – Offshore Section Update, Material Take-Off, IGI-1207-10-PL-MTO-001

Ref. [8] DNVGL-ST-F101, Submarine Pipeline Systems, 2017