Shell E&P Ireland Limited

CORRIB FIELD DEVELOPMENT PROJECT

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Corrib natural gas

CORRIB ONSHORE PIPELINE DESIGN BASIS

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1 INTRODUCTION

1.1 General

Corrib Field Development Project is being implemented by Shell E&P Ireland Limited (SEPIL) and is a gas field located in 350m of water some 65km off the County Mayo coastline in Ireland. The field is being developed as a long-range subsea tieback to an onshore terminal. The gas will then be treated to meet the defined gas specification before onward transportation to the Bord Gais Eireann (BGE) grid via a new cross-country pipeline.

The pipeline system for the Corrib Field Development Project is 83km 20-inch subsea pipeline from the offshore manifold to a Landfall Valve Installation at the landfall at Broadhaven Bay in County Mayo, plus a further 9.2km onshore to the terminal.

A SIL-3 rated shutoff system at the Landfall Valve Installation will ensure the design pressure of the onshore pipeline is not exceeded. The Landfall Valve Installation will also provide local and remote manual isolation of the onshore pipeline.

1.2 Objectives

The purpose of this document is to provide the design basis for the onshore section of the Corrib pipeline which was re-designed to address recommendations by TAG May 2006 following the Independent Safety Review carried out by Advantica.

1.3 Abbreviations

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BS	British Standard
BGE	Bord Gais Eireann
BWPD	Barrels of Water Per Day
CSA	Canadian Standards Association
DCMNR	Department of Communications, Marine and Natural Resources This department name has changed.
DCENR	Department of Communications, Energy and Natural Resources
DCS	Distributed Control System
DEP	Design and Engineering Practice
DNV	Det Norske Veritas
EN	European Norms
ETRF89	European Terrestrial Reference Frame 1989

EPA	Environmental Protection Agency
HDPE	High Density Polyethylene
IPPC	Integrated Pollution Prevention and Control
I.S.	Irish Standard
ISO	International Organization for Standardization
JPK	J P Kenny Limited
MDPE	Medium Density Polyethylene
MeOH	Methanol
mg/l	Milligram per litre
MMSCFD	Million Standard Cubic Feet per Day
NBP	Normal Boiling Point
OEM	Original Equipment Manufacturer
OTU	Onshore Termination Unit
PD	Published Document
SDR	Standard Dimension Ratio
SEPIL	Shell E & P Ireland Limited
SG	Specific Gravity
SMYS	Specified Minimum Yield Strength
TAG	Corrib Technical Advisory Group
WGS84	World Geodetic System 1984

1.4 Document History

This document was previously issued as document number 05-2102-02-P-3-800 Rev 03 (Allseas doc no 8820/D800-01) as the design basis of the onshore section of the Corrib Pipeline System.

The Design Basis was then revised following issue by the DCENR of detailed recommendations arising from the Independent Safety Review of the onshore section of pipeline by Advantica (Ref 2). There are various recommendations, which have been accepted by SEPIL, and a review and update of the Basis of Design for the onshore section of pipeline was required.

2 DESIGN-OPERATIONAL PARAMETERS

2.1 Flow Rates

Design Flow Rate	350 MMSCFD (dry sales gas)
Maximum Flow Rate:	350 MMSCFD (dry sales gas)

2.2 Pressures

Design Pressure:	144 barg
Normal Operating Pressure (onshore section, at start of field life):	90-110 barg
Wellhead Shut in Pressure: (at start of field life):	345 bara
Wellhead Flowing Pressure: (at start of field life):	272 bara
Hydrostatic Test Pressure	504 barg

2.3 Temperatures

Maximum Design Temperature:	50°C
Minimum Design Temperature	
20 inch pipeline from LVI to ~1000m downstream LVI	-20°C
20 inch pipeline from ~1000 m downstream of the LVI to Terminal	-10°C

For design conditions at the Landfall Valve Installation refer to the Landfall Valve Installation - Design Overview (Ref 8).

2.4 Fatigue

Normal Diurnal Pressure Range:	90-110 barg
Number of Cycles Between Diurnal Pressure Range:	11000
Number of Cycles Between Design Pressure Range:	30

Pressure cycles in the pipeline will be recorded via the DCS at the Terminal. This data will be evaluated on an annual basis and the pressure cycles will be counted. The actual pressure cycles will be compared with the allowable pressure cycles to assess potential fatigue.

2.5 Hydrostatic Testing

Prior to commissioning, the onshore pipeline will be hydrostatically tested to a pressure of 504 barg measured at the lowest point of the pipeline. The test pressure will be maintained for a period of 24 hours.

2.6 Design Life

The pipeline, outfall & umbilical and all attachments shall have a design life of 30 years.

2.7 Process

The Corrib field gas will be produced as water saturated gas with small quantities of free water. Early production (approximately the first 4 years) including start-up will require use of choke valves. Cooling of the gas subsea reduces the temperature to below the hydrate formation point at normal operating pressure. Methanol is used during start-up and in normal operation to prevent hydrate formation.

For information on well product composition, produced water and production profile refer to the Offshore Design Basis (Ref 1).

No operational blowdowns of the pipe are planned. If required under upset conditions, a venting procedure at the terminal will be undertaken in such a manner so as not to induce hydrate formation.

2.8 Environmental Data

Environmental data for the pipeline route is listed below, for years 1991 to 2000. Data received from Met Eireann (Ref 3).

Max air temperature:	28 deg C
Monthly mean max temperature range:	8.9 to 18.2 deg C
Min air temperature:	-5.5 deg C
Monthly mean min. temperature range:	3.9 to 12.2 deg C
Mean annual rainfall:	1269 mm
Max daily rainfall:	40 mm
Max hourly rainfall:	25.9 mm
Mean days ≥ 0.2mm rainfall:	254 days/year
Mean monthly wind speed range:	11.7 to 16.2 knots
Max wind speed (gust):	93 knots

3 CODES AND STANDARDS

3.1 General

The pipeline systems shall comply with the prevailing legislation applicable to the planning, design, construction, testing, commissioning and operation of pipelines in the Republic of Ireland.

The latest editions of all codes including revisions and addenda shall be applied.

3.2 Primary Code

The primary code for the design, construction, testing, commissioning and operation of the onshore section of the Corrib Gas Pipeline shall be:

I.S. EN 14161:2004	Petroleum and Natural Gas Industries – Pipeline Transportation Systems (ISO 13623:2000 Modified)

A recommendation and requirement by TAG is to identify, by exception, items within I.S. EN 14161 where relevant sections of I.S. 328:2003 or PD 8010-1:2004 will be used.

I.S. 328:2003	Petroleum and Natural Gas Industries – Pipeline Transportation Systems (ISO 13623:2000 Modified)
PD 8010-1:2004	Code of Practice for Pipelines – Part 1: Steel Pipelines on Land

This is detailed within document no 05-2377-01-P-3-019 Design Code Review Onshore Pipeline Section (Ref 5), which shall be used as the reference point for all design code issues to be able to identify which sections apply and to note where the other codes provide good guidance.

4 PIPELINE DESIGN

4.1 General

This section defines the approaches to be taken in the detailed design of the pipeline.

Process design will use the design data to confirm the pipeline size to accommodate the required flow, taking into account pressure losses, velocity limits, installation requirements and supply and demand cycles amongst other considerations. Pipeline size has been determined as a nominal 20” outside diameter.

4.2 Onshore / Offshore design limits

The primary design code covers the onshore design requirements.

Please refer to the Offshore Design Basis (Ref 1) for details of the offshore pipeline design.

The interface between the Offshore pipeline and the Onshore pipeline is the Landfall Valve Installation system. More details of this system are provided in the Landfall Valve Installation – Design Overview (Ref 8)

The interface between the Offshore Pipeline and the LVI is at the upstream tie-in weld.

The interface between the LVI and the Onshore Pipeline is at the downstream tie-in weld.

4.3 Onshore Pipeline Terminal Limits

The onshore pipeline extends through to the Bellanaboy Bridge Gas Terminal up to a point immediately upstream of the first isolation valve within the Terminal.

4.4 Wall Thickness

Following the acceptance of the recommendations of the Independent Safety Review, the design factor for the onshore pipeline downstream of the Landfall Valve Installation has been set at 0.3, classified as an urban pipeline.

Pipe wall thickness calculations are made in accordance with I.S. 328 (code selected in accordance with Design Code Review – Onshore Pipeline Section (Ref 5)).

The design pressure of the onshore pipeline section is 144 barg, design factor is 0.3, which, based on material quality DNV OS-F101 SMYS 485 MPa, results in a wall thickness (including corrosion allowance) of 27.1 mm.

In practice, the line pipe wall thicknesses are the same for both the offshore and onshore sections.

4.5 Corrosion

Following the corrosion analysis, a corrosion allowance of 1.0mm is included in the overall wall thickness of 27.1mm. This analysis is based on the report, Internal Corrosion Rate Assessment (Ref 6) that defined the corrosion allowance requirements.

This report concluded that the corrosion rates for the Corrib pipeline will be below 0.05 mm/yr and the 1 mm corrosion allowance will be more than sufficient to mitigate the internal corrosion threat to the onshore pipeline for the anticipated operating field life of 20 years provided corrosion mitigation with corrosion inhibitor and methanol is applied.

Corrosion inhibitor is mixed with the methanol, used for hydrate prevention, to minimise overall corrosion rates. Predicted corrosion rates therefore allow the use of carbon steel line pipe without internal coating.

4.6 Cathodic Protection

The pipeline will be primarily protected against external corrosion by a high integrity external coating. Secondary protection will be provided by cathodic protection. Cathodic protection is maintained in two distinct stages:

- Temporary cathodic protection shall be provided for the pipeline during installation, if the pre-installation soils resistivity survey indicates a requirement. It will also be ensured that no part of the pipeline is exposed to the environment unprotected for more than thirty days after backfill.

- The completed onshore pipeline installation shall be cathodically protected by a permanent impressed current system consisting of mains powered rectifier units. The system will include test facilities for proper adjustment and monitoring to ensure that it does not interfere with and cause corrosion to third party facilities encountered along the pipeline route. Anode ground beds supported by carbonaceous backfill will be installed at appropriate intervals along the pipeline route.

The conclusion of the report Onshore Cathodic Protection – Response to Findings of Independent Safety Review (Ref 7) is that an Isolation Joint should not be installed at the interface with the offshore and onshore pipelines.

The report states that the installation of an Isolation Joint at the landfall would compromise the structural integrity of the pipeline system and provide a point susceptible to internal corrosion damage. Furthermore Burial of the Isolation Joint was not considered best practice in referenced International Standards and would present another point of corrosion attack and an additional drain on the CP system current.

The report confirmed that validation of the effectiveness of the cathodic protection onshore can be achieved through use of ‘Polarisation Coupons’ installed at frequent points along the pipeline route. Current drain of the onshore impressed current CP system from the offshore pipeline was considered unlikely but could be mitigated by appropriate design of the onshore CP system.

Electrical isolation will be provided upstream of the terminal by means of a monolithic isolation joint. Electrical isolation will be provided for any above ground, earthed or bare connections at the Landfall Valve Installation or any other metallic connection to the pipeline.

4.7 Bends

The minimum bend radius for factory made hot bends shall be 5D. The minimum bend radius for cold field bends shall be 40D.

4.8 Pigging

The onshore pipeline shall be designed to permit intelligent pigging. Pipeline internal diameters shall meet the requirements for the operation of all forms of pigs. There is no normal operational requirement to run pigs.

4.9 Landfall Valve Installation

The Landfall Valve Installation will comprise two fluid flow paths. A normally closed but piggable in-line 20" full-bore block valve with a 16" bypass around the 20" block valve. Two high integrity fail closed shutoff valves in the bypass will be SIL-3 rated and will automatically close to limit the pressure in the onshore pipeline to a maximum pressure of 144 barg.

Details are given in the Landfall Valve Installation – Design Overview (Ref 8).

The Landfall Valve Installation will enable isolation of the onshore section from the offshore section.

The pig receiver at the Terminal will be equipped with full-bore isolation valves and other valves as required for the receipt of pigs.

4.10 Summary of Design Requirements

Table 4-1 summarises the key design factors associated with the design of the onshore pipeline.

Table 4-1 – Onshore Pipeline Design Factors

Design Factor	Requirements
Design Life	30 years
Length of Onshore Pipeline	9.2 km
Internal Coating	None
External Coating	3 layer polypropylene
External Thermal Insulation	None
Concrete Coating	Requirements to be confirmed at water crossings
Cathodic Protection	Impressed current scheme
Onshore Design Pressure	144 barg
Onshore Design Temperature (Max/Min)	
20 inch pipeline from LVI to ~1000m downstream LVI	50°C/ -20°C

Design Factor	Requirements
20 inch pipeline from ~1000 m downstream of the LVI to Terminal 50°C/ 0°C	
Design Factor	0.3
Design Flow Rate	350 MMSCFD

5 ROUTING PHILOSOPHY

The onshore section of the Corrib pipeline will be routed from the landfall in Glengad to the terminal at Bellanaboy Bridge.

5.1 Co-ordinate Systems

The landfall and onshore parts of the pipelines will be designed using the Irish National Grid, based on the Airy Modified Spheroid. The co-ordinate set is that referred to as the 1975 adjustment.

The offshore engineering work is to be carried out in terms of the ETRF89 geodetic reference frame, which for all practical purposes can be assumed to be based on WGS84.

Where there is an overlap or interface between onshore & offshore systems co-ordinates should be shown in both systems.

5.2 Area Classification

The area classification has been determined by the DCENR recommendation, to be regarded as a Type S area according to I.S. 328.

5.3 Crossings

The onshore pipeline route includes estuary, river, stream and road crossings.

Engineering for the protection of the pipeline at road crossings will be carried out during detailed design.

In addition, road crossings will be in accordance with the requirements of the appropriate regional or local highways agency. Crossings of minor roads will generally be open cut unless indicated otherwise.

Ditches and minor waterways will be crossed using the open cut method with cofferdams and the pipe laid under the base of the watercourse and protected where dredging and cleaning of the channels is expected.

Other buried services will be crossed in accordance with the individual owner's requirements but will follow the convention of crossing beneath existing services with protection between them unless indicated otherwise.

Pipeline protection will be considered where required against external interference.

5.4 Construction

Construction in farmland is envisaged mainly to take place within a standard pipeline working strip of a width of approximately 40m, with reductions at certain points, e.g. at hedge boundaries. Additional areas will be required for plant lay down, material storage areas (pipe dumps) and any satellite construction offices – main construction offices will be located at the terminal site. Pipeline construction will, in general, follow standard procedures of working with soil strip, line pipe stringing, welding, ditching, laying and reinstatement. Special construction areas will be identified separately although they will generally be designed to use similar quantities of land.

Where the pipeline is routed in peat bog, consideration will need to be given to construction techniques, with particular attention given to pipeline stability and soil bearing capacity associated with heavy equipment to be used for construction.

The route of the onshore pipeline includes pipeline installation through the Sruwaddacon bay. Trenchless crossing techniques are to be considered. The design of the trenchless construction is subject to detailed design.

The pipeline will be buried with a minimum cover of 1.2 m for the land based part of the route.

Minimum pipeline cover in the Sruwaddacon bay estuary and watercourses is 1.6 m.

5.5 Baseline Survey

A baseline survey, using an intelligent pig is to be undertaken during pre-commissioning in accordance with DCENR recommendations and TAG requirements.

5.6 Reinstatement

The aim of reinstatement is to replace the ground to as near the condition as that which existed before. Care with land drains and strict segregation of topsoil and sub soil will form the principal means of ensuring that problems in later years will not materialise. Special measures may be required in environmentally sensitive areas including techniques such as strip, store and replace.

6 MATERIALS

6.1 General

The line pipe has been manufactured from Carbon Steel as specified in DNV code OS-F101, Allseas Material Data Sheet 208820 and supplemented by the Particular Specification Number H00/46/05 as agreed between Allseas and Corus. The specification includes the following main points.

SMYS:	485 N/mm^2
Wall thickness manufacturing tolerance:	+/- 1 mm
Corrosion allowance:	1 mm
Nominal Wall thickness (onshore section):	27.1mm (inclusive of 1mm corrosion allowance)
Nominal outside diameter:	20”

7 OUTFALL

7.1 General

The outfall pipeline will be designed to carry treated surface drainage water from the Terminal to a suitable offshore location. It is envisaged that the onshore sections of the pipeline, outfall pipeline and umbilical will be laid adjacent to each other within a common easement.

The outfall will normally be full of water once testing and commissioning has taken place.

7.2 Operational Parameters

The outfall pipeline is designed for the following:

Design Maximum Flow Rate:	85 m^3/hr
Minimum Pump Flow	3 m^3/hr
Design Pressure:	16 barg
Maximum Operating Pressure:	8.5 barg
Minimum Operating Pressure	0 barg
Maximum Design temperature:	35° C
Minimum Design Temperature:	0° C
Design Life	30 years

7.3 Codes and Standards

The primary code applicable to the planning, design, construction and commissioning of the onshore section of the outfall pipeline shall be:

I.S. EN 14161	2004 Petroleum and Natural Gas Industries – Pipeline Transportation Systems (ISO 13623:2000 Modified)

The following standards shall also be deemed to apply:

I.S. 4427-2007	Plastic piping systems – Polyethylene (PE) pipes and fittings for water supply.

7.4 Outfall Design

Taking into account pressure losses, velocity limits, installation requirements and flow cycles amongst other considerations the outside diameter selected for the onshore outfall is 225mm.

Polyethylene (PE) pipe is selected with grade (MDPE offshore / HDPE onshore) and thickness or SDR to be determined during detailed design. Buoyancy calculations shall consider both empty and flooded conditions. Final selection of outfall materials will be confirmed with SEPIL.

8 UMBILICAL

8.1 General

The onshore umbilical system will run between the Landfall Valve Installation at Glengad, where a connection with the offshore umbilical shall be made, and the gas processing terminal, a distance in the region of 9.2 km. The umbilical will be a composite system containing methanol injection system cores,control system lines (communication signals, electrical and hydraulic power) and produced water. The onshore section of the umbilical will be split into three bundles with intermediate connections at suitable intervals between 1 to 1.5 km. Although the detail design and manufacturing of the umbilical has been undertaken by Nexans as a sub contract to Stolt Offshore, a thorough review is required to make sure the actual requirements of the system are met.

Detail information on the umbilical is by reference to Nexans documents:

36029-KTU-XC-140162 – Onshore Umbilical #2 & #3 Cross Section

36029-KTU-XC-140160 – Onshore Umbilical #1 Cross Section

In addition to the umbilical, two other cables will be installed along the same route, a fibre optic cable & additional two core copper cable. These two additional cables are associated with the Landfall Valve Installation.

The sections that follow provide umbilical summary information only.

8.2 Operational Parameters

The detail of elements that make up the umbilical system are as follows:

Electrical Power and Communications Systems

2 x Electrical Power Supply Cables:	Screened Twisted Pairs
2 x Data Communications Cables:	Screened Twisted Pairs
1 x Common Spare Cable:	Screened Twisted Pair

All cables are 15mm CSA.

Hydraulic Fluid Supply Systems

2 x 210 barg rated LP Supply Lines:	19mm ID Steel Tubes
2 x 610 barg rated HP Supply Lines:	12.7mm ID Steel Tubes

Methanol Supply System

All four of the methanol supply lines in the Onshore Umbilical System are 25.4mm ID steel tubes rated to 345 barg. Methanol lines will carry a mixture of methanol, corrosion inhibitor and scale inhibitor.

Produced Water Disposal System

1 x 610 barg rated:	19mm ID Steel Tube
1 x 345 barg rated:	25.4mm ID Steel Tube

8.3 Connectors

Only proven fully qualified connector designs and systems within umbilical terminations or in-line connection systems shall be used.

8.4 Service Fluids

The umbilical cores shall be designed for use with the following fluids:

8.4.1 *Control Fluid*

Water / Glycol based hydraulic fluid.

The actual fluid to be used within the hydraulic lines has been confirmed as Castrol Transaqua HT2.

8.4.2 *Chemical Fluids*

Methanol

A combined corrosion and scale inhibitor product is to be mixed in appropriate proportions into the methanol supplied from the onshore terminal distribution system.

A product qualification programme has been initiated and will be completed by the end of Q3 2008. The qualification programme will consider product performance limitations, material and chemical compatibility, environmental impact characteristics and process impact.

Any potential limitations and/or material compatibility issues associated with known corrosion inhibitor products used in similar subsea developments shall be identified.

8.4.3 *Treated Produced Water*

Two cores that were previously designated as “spare cores” will now be used to transport treated produced water from the onshore terminal to the offshore manifold, where it will be dispersed subsea.

8.5 Codes and Standards

The primary standards for the umbilical system shall be:

ISO/CD 13628 – 5	Design and Operation of subsea production systems – subsea control umbilicals.
ISO/CD 13628 – 6	Design and Operation of subsea production systems – subsea production control systems.

Other standards to which reference should be made if necessary are listed in Section 10.

The latest editions of all codes including revisions and addenda shall be applied.

8.6 Materials

The materials selected for the Onshore Umbilical System shall be fully compatible with the fluids with which they are to be used. Steel tubes shall comply with the requirements of ISO standard 13628-part 5 or API 17E.

All hydraulic and methanol supply and produced water disposal cores and electrical cables within the Onshore Umbilical System shall be uniquely identified using an agreed marking system.

8.7 Tubing Material

Steel tubes for the hydraulic, methanol and water supply services shall be seamless ferritic-austenitic (super duplex) stainless steel as specified by Nexans.

The minimum allowable wall thickness for each of the hydraulic and chemical lines and allowable working pressures given the strength of steel to be used, based on the requirements of ISO 13628 part 5, shall be calculated.

8.8 Landfall Valve Installation Offtake

An Onshore Termination Unit (OTU) located at the Landfall Valve Installation will provide the connection between the onshore and offshore umbilicals. At the OTU offtakes will be provided to supply methanol and hydraulic fluid to the Landfall Valve Installation.

9 REFERENCES

1. Addendum No. 1 to Offshore Design Basis, document no. 05-2377-01-P-3-027
2. Advantica – “Independent Safety Review of the Onshore Section of the Proposed Corrib Gas Pipeline” – Report Number R8391 Issue 1.0.
3. Basis of Design SEPIL Doc. No. COR-10-SP-001-8
4. Environmental Impact Statement, Corrib Field Development (Offshore Field to Terminal) – Project P8069 dated October 2001 – RSK Environment Ltd
5. Design Code Review – Onshore Pipeline Section, Document No. 05-2377-01-P-3-019
6. Internal Corrosion Rate Assessment, doc no: COR-39-SH-0012
7. Onshore Cathodic Protection – Response to Findings of Independent Safety Review, Hockway Document No. REP-18277-1001
8. Landfall Valve Installation - Design Overview, Document No. 05-2377-01-G-3-002

10 SUPPLEMENTAL CODES AND STANDARDS

API SPEC 17E	Specification for Subsea Production Control Umbilicals
BS EN 60079	Electrical Apparatus for Explosive Gas Atmospheres
DNV-OS-F101	Submarine Pipeline Systems
I.S. 328	Code of Practice for Gas Transmission Pipelines and Pipeline Installations
I.S. 4427-2007	Plastic piping systems – Polyethylene (PE) pipes and fittings for water supply.
ISO/CD 13628-5	Design and Operation of Subsea Production Systems – Part 5: Subsea Control Umbilicals
ISO/CD 13628-6	Design and Operation of Subsea Production Systems – Part 6: Subsea Production Control Systems
ITU-T	Recommendations G601-G699 Transmission Media and Optical Systems Characteristics
BS PD 8010-1	Code of Practice for Pipelines – Part 1: Steel Pipelines on Land