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-	TITLE:	PIPELINE AND CABLE CROSSINGS			EDD/EDR	
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B	REVISION OF ITEMS 1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 3, 3.1, 3.2, 4, 4.1, 4.2, 4.2.1 AND 4.2.2, AND INCLUSION OF ITEMS 1.5, 3.3, 3.4, 4.2.3, 4.2.4 AND 4.4					
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TITLE:

PIPELINE AND CABLE CROSSINGS

EDD/EDR

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TABLE OF CONTENTS

1	INTRODUCTION	3
1.1	SCOPE.....	3
1.2	REFERENCES.....	3
1.3	ABBREVIATIONS	4
1.4	DEFINITIONS.....	4
1.5	DEVIATIONS.....	5
2	CROSSING DESIGN AND INSTALLATION	6
2.1	CROSSING DESIGN	6
2.2	CROSSING INSTALLATION.....	8
3	SOLUTIONS AND CROSSING AID STRUCTURES.....	10
3.1	BRIDGE CONFIGURATION USING CONCRETE MATTRESSES	10
3.2	BRIDGE CONFIGURATION USING STEEL SUPPORTS.....	11
3.3	CLEARANCE PROTECTION.....	12
3.4	CONCRETE MATTRESSES BETWEEN LINES.....	14
4	CROSSING DOCUMENTATION	16
4.1	CROSSING LAYOUT DRAWING	16
4.2	CROSSING DESIGN AND INSTALLATION REPORT	17
4.3	STEEL SUPPORT DRAWING (IF APPLICABLE).....	20
4.4	PROTECTION POLYMERIC STRUCTURE DRAWING (IF APPLICABLE).....	20

1 INTRODUCTION

1.1 Scope


The objective of this technical specification is to present the minimum requirements for pipelines and cables crossing design, indicating also solutions and acceptable aid structures to be used, design criteria to be followed and documentation to be issued.

This technical specification covers only pipeline and cable crossings on the seabed. This technical specification does not cover any type of riser interference, i.e. clashing between adjacent risers (rigid and/or flexible lines), clashing between risers and mooring lines, clashing between risers and platform hull, etc.

1.2 References

The following documents were adopted as reference for this technical specification. Whenever the revision is not mentioned the last review of such references is applicable.

- | | | |
|-----|-------------------------------|---|
| [1] | DNV-ST-F101 | Submarine Pipeline Systems |
| [2] | DNV-RP-C212 | Offshore Soil Mechanics and Geotechnical Engineering |
| [3] | API-RP-2GEO | Geotechnical and Foundation Design Considerations
Petroleum and Natural Gas Industries — |
| [4] | ISO-19901-4 | Specific Requirements for Offshore Structures — Part 4: Geotechnical and Foundation Design Considerations |
| [5] | I-ET-0000.00-0000-940-P9U-002 | Rigid Pipeline On-Bottom Roughness and Free Span Design |
| [6] | I-ET-0000.00-0000-970-P9U-001 | Minimum Requirements for Pre-Lay Survey |
| [7] | I-ET-0000.00-0000-970-P9U-002 | Minimum Requirements for Post-Lay Survey |
| [8] | I-ET-0000.00-0000-250-P9U-001 | Sleeper for Lateral Buckling Initiation |
| [9] | I-ET-0000.00-0000-940-P9U-003 | Global Buckling Design of Subsea Pipelines |

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 4 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	

- | | | |
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| [10] | N-381 | Execução de Desenho e Outros Documentos Técnicos em Geral |
| [11] | N-1710 | Codificação de Documentos Técnicos de Engenharia |
| [12] | N-2064 | Emissão e Revisão de Documentos de Projeto |

In case of disparity between the requirements of such references and those established in this document, the specifications of this document shall prevail.


1.3 Abbreviations

The following abbreviations adopted along this technical specification are presented below:

CP	Cathodic Protection
EPCI	Engineering, Procurement, Construction and Installation
LCC	Load Controlled Criteria
FEA	Finite Element Analysis
FOC	Fiber Optical Cable
FPU	Floating Production Unit
HP/HT	High Pressure / High Temperature
ID	Internal Diameter
OD	Outside Diameter
OBR	On-Bottom Roughness
KP	Kilometer Point
ROV	Remotely Operated Vehicle
TDZ	Touchdown Zone
TQF	Technical Query Form
TRF	Riser-Flowline Transition
VIV	Vortex Induced Vibration
WT	Wall Thickness

1.4 Definitions

The following definitions are used for the purpose of this technical specification:

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 5 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

CONTRACTOR	Company responsible for the engineering crossing design and installation.
Crossing aid structure	Steel support or mattresses used to support crossing.
New pipeline	Pipeline to be installed over the crossing aid structures
Existing line	Rigid pipeline or flexible pipe already installed which will be crossed by the new pipeline
Existing cable	Cable already installed which will be crossed by the new pipeline
Shall	Indicates a mandatory requirement for CONTRACTOR
Should	Indicates a preferred course of action for CONTRACTOR
May	Indicates an optional course of action for CONTRACTOR

1.5 Deviations

All deviations to this Technical Specification, and other referenced specifications or attachments listed in the contract, shall require written approval by PETROBRAS prior to execution of the work.

2 CROSSING DESIGN AND INSTALLATION

2.1 Crossing Design

The location of any existing pipeline, cable or other structure along the preliminary pipeline route on seabed shall be previously identified by a preliminary route survey required for design purposes.

Crossing design shall consider the following restrictions: i) It is not acceptable any crossing at riser TDZ location, as well as at on-bottom riser region between TRF and TDZ; ii) Crossing between rigid pipeline and any anchoring chain, even without contact, as well as between rigid pipeline and steel cable, is fully forbidden; iii) Rigid pipeline crossing with FPU mooring line is not allowed.

Pipeline and cable crossing design shall be performed in accordance with the requirements of DNV-ST-F101 [1]. A minimum clearance of 0.3 m shall be kept during installation and the entire design life between the existing lines or cables and the new one to be installed. This clearance is schematically shown in Figure 1.

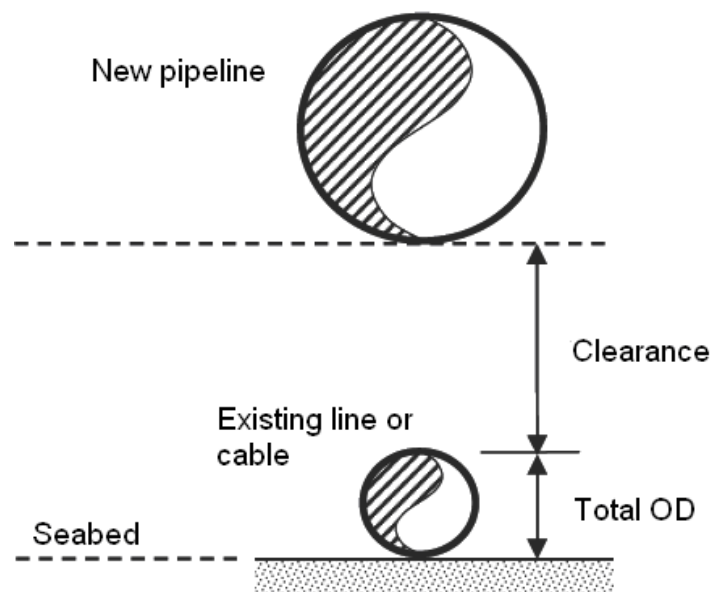


Figure 1 – Clearance between pipelines on crossing location



CONTRACTOR shall evaluate the soil parameters in order to guarantee the minimum clearance between the pipeline and cable. The effect of soil uncertainties shall be analyzed considering the design life.

The clearance shall be verified during installation, short-term and long-term operational conditions. Long-term settlement shall not be neglected due to its influence in crossing arrangement during design life.


The foundation design of the crossing aid structure shall be issued for PETROBRAS approval. The foundation calculation shall be performed in accordance with DNV-RP-C212 [2], API-RP-2GEO [3] or ISO-19901-4 [4].

Potential interference between CP systems of the pipelines, cables and subsea structures included in the crossing arrangement and associated consequences shall be evaluated and prevented.

Crossing design shall properly consider all predicted displacements of the existing pipeline during its design life, mainly for HP/HT pipelines and flowlines with axial displacements predicted due to riser dynamic movements next to non-anchored TRF.

In case the existing line is a flexible one (flexible line or cable), whenever possible the definition of the new pipeline's route shall consider the location of the connection flanges of the flexible pipes or splice boxes of the cables, trying to define a crossing point close to them in order to allow an easier subsea intervention and recovery of the flexible pipe or cable. In this case, the "Total OD" indicated in the figure above shall be considered equal to the OD of the flange closest to the crossing location.

Pipelines at crossing locations are subjected to bending moments, environmental loads, contact forces, etc. The structural analysis for the pipeline shall be properly

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 8 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

included in the On-Bottom Roughness (OBR) Analysis report and shall be performed in accordance with the requirements of PETROBRAS Technical Specification [5].

In this pipeline structural analysis, the embedment of the supporting structures shall be disregarded which will lead to the highest span and consequently a more conservative approach. However, the clearance determination shall consider the short and long term settlements in order to maintain the minimum distance during design life of the lines.


During on-bottom roughness analysis the location of the crossings shall be defined and listed. For each crossing, the type of protection selected for the existing rigid pipelines, cables, flexible pipelines, etc. shall be defined and basic construction drawings for these protections shall be issued.

The design of the crossing aid structures for the existing rigid pipelines, cables, flexible pipelines, etc. shall consider the soil characteristics in situ, the laying process accuracy of the new pipeline, the water depth and environmental conditions and the loadings imposed by the new pipeline during temporary and permanent phases of design life.

2.2 Crossing Installation

The cables and pipelines shall be located by CONTRACTOR before the crossing installation. CONTRACTOR shall consider the possibility of these cables to be buried. The determination of the real position and condition (buried or exposed) of the cables is part of the CONTRACTOR's scope of work.


During pre-lay survey activity (pre-installation survey from DNV-ST-F101 [1]), the crossing installation areas shall be inspected in accordance with technical specification [6] in order to allow suitable definition regarding the locations of crossing aid structures.

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 9 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

The crossing aid structures shall be installed in previous phase to the pipeline laying. The installation of crossing aid structures shall be continuously monitored by ROV which shall make the installation recording. In addition, an as-built drawing of crossing aid structures with their final position and dimensions shall be issued and compared with the assumptions assumed in crossing design.

During the laying, the pipeline shall be continuously monitored by ROV in order to avoid any damage in existing pipelines or cables and to ensure the suitable location of crossing aid structures and consequently the crossing configuration.

During post-lay survey activities (as-laid and as-built surveys from DNV-ST-F101 [1]), the crossing installation areas shall be inspected in accordance with technical specification [7] in order to confirm the compliance with crossing design issues.

	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-		SHEET: 10 de 21
	TITLE: PIPELINE AND CABLE CROSSINGS		EDD/EDR

3 SOLUTIONS AND CROSSING AID STRUCTURES

Whenever possible pipeline route shall be defined considering a crossing angle close to 90° with respect to the existing line or cable to be crossed. This angle may influence the number and type of crossing aid structures to be adopted.


The crossing aid structures shall be defined considering pipeline characteristics, internal fluid, operating and design data, etc. Concrete mattresses and steel supports are the acceptable solutions to be considered as crossing aid structures in bridge configuration. Concrete supports and other support types are not acceptable.

Rock or gravel cover over the existing rigid pipelines keeping the minimum clearance requirement of reference [1] can be also acceptable as methods to crossing solution. Similarly, the seabed preparation using gravel beds, rock installation or burial techniques can be also acceptable as methods to design crossing since the requirements of the design standard [1] are fulfilled. However, all these methods shall be previously issued for evaluation and PETROBRAS approval before starting crossing design via TQF.

The following sections present specific requirements for the adoption of the solution and crossing aid structures.

3.1 Bridge Configuration Using Concrete Mattresses

Crossing using concrete mattresses shall be performed by installing mattress stacks on both sides of the existing line or cable, as supportation base of a bridge configuration. The mattresses layout shall be defined in order to assure that the pipeline will be supported by these stacks on both sides of the crossing and that the entire lay corridor is covered. The distance between the mattresses and the existing line or cable shall consider the former's installation tolerances in order to avoid that the stack of mattresses is installed over the existing line or cable.

	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 11 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

The installation of mattress stacks on only one side of the crossing may be acceptable since crossing engineering design is properly analyzed case by case and issued to verification and PETROBRAS approval.

The number of mattresses in each stack shall be defined considering the conditions that the mattresses will be submitted to and the clearance defined in Section 1.4. The design shall consider soil properties, the calculated long-term embedment, vertical load imposed by the pipeline, mattresses submerged weight, etc. This assessment shall be included within the Crossing Design Report, as indicated in Section 4 below.


This solution and crossing aid structures may be applied for both scenarios, rigid pipeline over or under other line (rigid pipeline, flexible pipeline, umbilical or FOC).

3.2 Bridge Configuration Using Steel Supports

Steel supports are structures similar to sleepers, which are usually designed for lateral buckling initiation, and shall be designed to withstand not only the forces imposed by the pipeline but also other issues related to the surrounding environment. The design of steel supports shall be performed in accordance with the requirements of Ref. [8].

Bridge configuration using steel supports shall be performed by installing supports on both sides of the existing line or cable. The steel supports layout shall be defined in order to assure that the entire lay corridor is covered. The distance between the steel supports and the existing line or cable shall consider the former's installation tolerances in order to avoid that the steel support is installed over the existing line or cable.

The installation of steel supports on only one side of the crossing may be acceptable since crossing engineering design is properly analyzed case by case and issued to verification and PETROBRAS approval.

	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 12 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

Steel supports should not be designed as crossing aid structures for new pipelines that are susceptible to upheaval buckling at the crossing location. However, steel supports can be adopted as crossing aid structures for new pipelines that are susceptible to lateral buckling. In this case, the steel supports shall be designed with stopping device at the ends, in order to avoid any possibility of the pipeline falling off the support along design life. In addition, the LCC of the design standard [1] shall be fulfilled at least in vertical plane. Thus, steel supports can be designed to work as sleepers.

The height of steel supports shall be defined considering in a conservative approach the required clearance defined in Section 4 and the calculated long-term embedment which shall consider the vertical load imposed by the new pipeline.


Special attention shall be given to the contact point between the steel support and the pipeline especially when the project considers new pipelines with high OD/WT values.

The distance between the steel supports and the existing line or cable shall be defined considering installation tolerances in order to avoid any contact between such support and the existing line during or after installation. In addition, the length of the steel supports shall be sufficient to allow the pipelay vessel or barge to safely install the new pipeline over these supports.

This solution and crossing aid structures may be applied for both scenarios, rigid pipeline over or under other line (rigid pipeline, flexible pipeline, umbilical or FOC).

3.3 Clearance Protection

Clearance protection using clamped polymeric structures, similar to Uraduct® or UraGUARD® systems, can be adopted as crossing solution since the requirements from Section 2 of this Technical Specification are fulfilled. However, this solution is

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 13 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

acceptable only for crossing between PETROBRAS' lines (rigid pipelines, cables, flexible pipelines, etc.) from the same EPCI project.

The clearance protection length shall be defined in order to assure that the entire lay corridor is covered.

For both scenarios, rigid pipeline over or under other line (rigid pipeline, flexible pipeline, umbilical or FOC), the following requirements shall be fulfilled:

- Evaluation of rigid pipeline coating integrity shall be presented in crossing design report;
- OBR analyses and global buckling & walking design of the rigid pipelines shall consider properly the loadings and boundary conditions related to this crossing solution, following the requirements of PETROBRAS Technical Specifications, Refs. [5] and [9], respectively;
- Tests of material and clearance protection device shall be performed and approval by PETROBRAS;
- Metallic straps shall be not in contact with the rigid pipeline.

Specifically for scenarios with a line (rigid pipeline, flexible pipeline, umbilical or FOC) over a rigid pipeline, the following additional requirement shall be fulfilled:

- Local analyses (FEA) shall be performed in crossing design and presented in the crossing report, considering the predicted loadings and scenarios, in order to assure the rigid pipeline integrity along the design life. A proper safety factor shall be considered in these analyses and issued for PETROBRAS approval.

This crossing solution using clearance protection shall not be adopted for crossings involving rigid pipeline of ID higher or equal to 10 in.

3.4 Concrete Mattresses between Lines


Concrete mattresses between lines can be considered as crossing solution since the involved rigid pipeline is clamped with additional protection polymeric structures, similar to Uraduct® or UraGUARD® systems, and the requirements from Section 2 of this Technical Specification are fulfilled. However, this solution is acceptable only for crossing between PETROBRAS' lines (rigid pipelines, cables, flexible pipelines, etc.) from the same EPCI project.

The protection polymeric structures' length as well as the concrete mattresses layout shall be defined in order to assure that the entire lay corridor is covered.

For both scenarios, rigid pipeline over or under other line (rigid pipeline, flexible pipeline, umbilical or FOC), the following requirements shall be fulfilled:


- Evaluation of rigid pipeline coating integrity shall be presented in crossing design report;
- OBR analyses and global buckling & walking design of the rigid pipelines shall consider properly the loadings and boundary conditions related to this crossing solution, following the requirements of PETROBRAS Technical Specifications, Refs. [5] and [9], respectively;
- Tests of material and protection device shall be performed and approval by PETROBRAS;
- Metallic straps shall be not in contact with the rigid pipeline.

Specifically for scenarios with a line (rigid pipeline, flexible pipeline, umbilical or FOC) over a rigid pipeline, the following additional requirement shall be fulfilled:

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 15 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

- Local analyses (FEA) shall be performed in crossing design and presented in the crossing report, considering the predicted loadings and scenarios, in order to assure the rigid pipeline integrity along the design life. A proper safety factor shall be considered in these analyses and issued for PETROBRAS approval.

This crossing solution with concrete mattresses between lines shall not be adopted for crossings involving rigid pipeline of ID higher or equal to 10 in.

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 16 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

4 CROSSING DOCUMENTATION

At least the following documents shall be issued for PETROBRAS approval during the design of pipeline and cable crossings:

- Crossing Layout Drawing;
- Crossing Design and Installation Report;
- Steel Support Drawing (see Section 3.2), if applicable;
- Drawing of Clearance Protection (see Section 3.3) or Drawing of Additional Protection Polymeric Structures (see Section 3.4), if applicable.


All documents to be issued shall be in accordance with the last revision of references [10] to [12].

The minimum content of these documents is presented in the following sections.

4.1 Crossing Layout Drawing

Crossing drawing shall present different views of crossing location including, but not limited to, a plan view and an elevation view which shall indicate the clearance that shall be in compliance with Section 2 above. The following information shall be presented within Crossing Layout Drawing, when applicable in accordance with solution and crossing aid support adopted:


- Plan and elevation views;
- Crossing angle, crossing coordinates with related datum and projection, KP and water depth;
- Pipelay corridor;
- Clearance between new and existing line or cable;

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 17 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	

- Information related to the existing line or cable (identification name, OD, WT, etc.);
- Information related to the new pipeline (identification name, OD, WT, etc.);
- Number and distribution of mattresses (see Sections 3.1 or 3.4) or steel structures (see Section 3.2);
- Distance between the existing line (or cable) and the mattresses or steel supports;
- Installation tolerances for the mattresses or steel supports;
- Marker buoy coordinates;
- Mattresses or steel supports main dimensions;
- Main dimensions of the clearance protections (see Section 3.3) or additional protection polymeric structures (see Section 3.4);
- Freespan corrections such as VIV strakes, grout bags, etc.;
- Any other component or relevant information established during crossing design;
- General notes;
- Reference documents.

4.2 Crossing Design and Installation Report

This report shall present all information related to the design and installation of the crossing aid structure. In case of each solution and crossing aid structure have been

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 18 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

specified in Section 3, at least the items indicated in Sections 4.2.1, 4.2.2, 4.2.3 or 4.2.4 shall be included in the report.

All analytical calculation shall be performed using Mathcad and the spreadsheet containing all calculation steps shall be provided to PETROBRAS within the reports.

All structural FEA of steel supports shall be performed using Abaqus or Ansys software.

CONTRACTOR shall provide all input and output electronic/digital files used for crossing design.

The items presented in sections below are related to technical issues. In addition to these items, report's content shall comprise sections with the introduction, scope, abbreviation list, references, results, conclusions, etc.


CONTRACTOR shall cover the following technical analysis at crossing locations in specific design documents: buckle formation, contact forces, stresses, cyclic fatigue, freespan, etc.

4.2.1 Bridge Configuration Using Concrete Mattresses

- Design data (pipeline and operational data, soil and environmental data, etc.);
- Settlement analysis and associated methodology;
- Installation issues;
- Analyses results;
- Mathcad spreadsheets.

4.2.2 Bridge Configuration Using Steel Supports

- Design data (pipeline and operational data, soil and environmental data, etc);

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 19 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
-			


- Analyses methodology;
- Structural design;
- Settlement analysis and associated methodology;
- Lifting analysis and installation issues;
- Painting requirements;
- Cathodic protection design;
- Analyses results;
- Mathcad spreadsheets.

4.2.3 Clearance Protection

- Design data (pipeline and operational data, soil and environmental data, etc.);
- Evaluation of rigid pipeline coating integrity;
- Tests of material and clearance protection device;
- Local analyses (FEA);
- Installation issues;
- Analyses results;
- Mathcad spreadsheets;
- Abaqus or Ansys inputs and outputs files.

4.2.4 Concrete Mattresses between Lines

- Design data (pipeline and operational data, soil and environmental data, etc.);
- Evaluation of rigid pipeline coating integrity;

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 20 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	

- Tests of material and protection device;
- Local analyses (FEA);
- Installation issues;
- Analyses results;
- Mathcad spreadsheets;
- Abaqus or Ansys inputs and outputs files.


4.3 Steel Support Drawing (if applicable)

In case of adopting steel supports as crossing aid structure, a drawing shall be issued for PETROBRAS approval, which shall include, but shall not be limited to the following initial items:

- General and detailed dimensions;
- Painting;
- Anode locations;
- Material list;
- General notes;
- Reference documents.

4.4 Protection Polymeric Structure Drawing (if applicable)

In case of adopting clearance protection or additional protection polymeric structures, a drawing shall be issued for PETROBRAS approval, which shall include, but shall not be limited to the following initial items:

 PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-0000.00-0000-275-P9U-001	REV. B
	-	SHEET: 21 de 21	
	TITLE: PIPELINE AND CABLE CROSSINGS	EDD/EDR	
		-	

- General and detailed dimensions;
- Structure parts;
- Metallic straps, clamping elements, rubber collars and/or pads, etc.;
- Material list;
- General notes;
- Reference documents.