PTT Exploration and Production Public Company Limited

PTTEP Engineering General Specification

(Engineering and Development Group)

Standard

Induction Bends for Carbon Steel Pipelines (Mild, Intermediate and Severe Sour Service)

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1.0 INTRODUCTION

PEGS (PTTEP Engineering General Specification) is the PTT Exploration and Production PCL internal publishes standard. The objective of PEGS is to promote the best practices collecting from all PTTEP execution projects and to standardize those best practice to the future projects.

Every 5 years or upon request by the internal user, PEGS will be reviewed by related subject experts to reach decisions/agreements, then the document will be updated and publish to PTTEP intranet website. This is to ensure that all lesson learns from users can be applied to the future projects as the benefit to PTTEP.

2.0 PURPOSE

The purpose of this specification is to define the COMPANY's general requirements for the manufacture and inspection of butt welding bends that are shop fabricated by induction bending or induction forging for use in "Mild Sour Service", "Intermediate Sour Service" or "Severe Sour Service" (i.e. corresponding respectively to regions 1, 2 and 3 in design specification 10008-STD-6-COR-032, PEGS-0842-COR-032), using seamless mother pipes or longitudinally submerged arc welded pipes.

3.0 SCOPE

The scope of this document applies to bends in Grade X42 up to Grade X70 of API Spec.5L / ISO 3183 Mod. for use in onshore or underwater pipelines.

This specification shall be used in conjunction with a Project Particular Specification (PPS) detailing the additional tests and requirements or the possible modifications to the present specification, based on the particular design conditions of the pipeline Project (see Section 7.1 in this specification).

Requirements are also specifically stated in this specification for bends where the properties of base material and weld (if any) are to be ascertained after a Post Weld Heat Treatment is made.

The present specification shall also apply to mother pipes wherever they are free issued by the COMPANY to the Supplier, or they are directly procured by the Supplier.

Mother pipe and bends shall not be dissociated from main line pipe order (i.e.: the unique supplier for main line pipes, mother pipes and bends).

4.0 RESPONSIBLE ACTION PARTIES

This specification is distributed under the responsibility of the relevant department and divisions in PTTEP engineering entity in accordance with the procedures, approved by the line management.

This specification is applicable for all PTTEP operated assets and new project at the time of the study phase or pre-project or project sanction phase apply.

5.0 DEFINITIONS

A number of different terms are commonly used to describe the work stages, processes, and approvals which take place during the early stages of a development. This can often be a source of confusion so the following section is intended to show the PTTEP preferred terminology as used in this document.

5.1 LANGUAGE

In this document, the words should and shall have the following meanings:

Shall	Indicates a course of action with a mandatory status. The term “shall” shall be used if a requirement is considered to be necessary to claim compliance with a PEGS document.
Should	Indicates a preferred course of action. Should is a non-mandatory word and is not forbidden, but use in the body of the text should be the exception. Where none mandatory terms are used, each paragraph within these clauses shall also have an associated commentary paragraph that provides the rationale for why the stated choices and modifications are appropriate and circumstance under which the stated choices and modifications might be different.

5.2 TERMINOLOGY

Terminology	Description
Approval	The authorization in writing given by the COMPANY to the Contractor to proceed the work without releasing in any way the Contractor from any of his obligations to conform with the technical specifications, requisitions, etc. The words “Approve”, “Approved” and “Approval” shall be construed accordingly
Company	PTT Exploration and Production Public Company Limited and affiliates.
Contract	"CONTRACT" means this signed AGREEMENT together with the Exhibits and Annexes which are made part thereof, and any future amendments thereto
Contractor	Per contract: Contractor – ‘The contractor who is a PARTY to this CONTRACT and where the context so requires including, SUBCONTRACTORS utilized by CONTRACTOR for the performance of the WORK’
Inspector	The COMPANY’s or Supplier’s representative(s), (as applicable), or member(s) from an Inspection Agency duly appointed by the COMPANY or the Contractor or the Supplier (as applicable) to act as its representative(s) for the purpose of the contract.
Manufacturer	The company or its sub-contractors selected by the COMPANY or the Contractor or the Supplier (as applicable) as the Manufacturer of the said material.

Terminology	Description
Mill	The plants, Mills, workshops, laboratories or other locations where the fabrication, inspection and testing of materials and bends are to be performed complete or in part, shall be referred to herein as the "Mill"
Mother Pipe	The original pipe or base pipe used for fabricating the bend or any portion of it shall be referred to herein as the "mother pipe"
PPS	Designates Project Particular Specification detailing the additional tests and requirements or the possible modifications to the present specification, based on the particular design conditions or the local legislation of the project.
Purchaser	The COMPANY or the Contractor or the Supplier (as applicable) which have placed the Purchase Order to the Supplier/Vendor/Manufacturer.
Supplier/Vendor	The company designed on the Purchase Order form or Contract as being the selected supplier of the said materials.

5.3 COMMON ACRONYMS

Set out below in alphabetical order are common acronyms as found within this document:

ASNT	The American Society for Nondestructive Testing
BPQ	Bending Procedure Qualification
BPS	Bending Procedure Specification
HAZ	Heat Affected Zone
HIC	Hydrogen Induced Cracking
HV	Vickers Hardness
ID	Inside Diameter
ITP	Inspection and Test Plan
MPQT	Manufacturing Procedure Qualification Test
MPS	Manufacturing Procedure Specification
NDT	Non-Destructive Testing
NID	Nominal Inside Diameter
OD	Outside Diameter
PBHT	Post Bending Heat Treatment
PPS	Project Particular Specification
PWHT	Post Weld Heat Treatment
QA	Quality Assurance
QC	Quality Control
QCP	Quality Control Plan
SAW (L)	Submerged Arc Welding (Longitudinal)
SSC	Sulphide Stress Cracking
WT	Wall Thickness

6.0 REFERENCES

The reference documents listed below, including Industry Codes and Standards and COMPANY specifications, form an integral part of this Engineering General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published on the effective date of a contract.

The overall order of precedence of the applicable documents shall be:

1. Applicable Laws, Rules and Regulations of the country in which the system/equipment will be operated (if any);
2. Purchase Order/ Service Order/ Contract Documents (Only applicable for direct purchase by COMPANY);
3. Project Particular Specification (PPS), and relevant data sheet(s) if any;
4. COMPANY General Specification;
5. Codes and Standards in reference.

Any conflict between any of the Contract Documents, or between this specification and any other Contract Documents, shall be reported to COMPANY for decision. In such a case, and unless otherwise agreed or decided by COMPANY, it is understood that the more stringent requirement shall apply.

Exceptions to, or deviations from this specification are not permitted unless previously accepted in writing by COMPANY. For this purpose, requests for substitutions or changes of any kind shall be completed with all pertinent information required for COMPANY assessment. COMPANY's approval, nevertheless, will not, in any way, relieve the responsibility of the Contractor to meet the requirements of the industry Codes and Standards referred to and amended herein, in the event of conflict.

6.1 PTTEP INTERNAL REFERENCES

Internal documents applicable to this document are indicated in the table below.

Document Number	Document Title
10008-STD-6-GEN-005, PEGS-12060-ADM-006	Quality Requirements for Contractor/Vendor
10008-STD-6-GEN-007, PEGS-12060-MMA-001	Material Traceability
10008-STD-6-PLR-006, PEGS-12059-PLR-005	Longitudinally submerged arc welded pipes for carbon steel pipelines (mild, intermediate and severe sour service)
10008-STD-6-PLR-025, PEGS-12059-PLR-012	Welding of onshore and offshore carbon steel pipelines to API 1104
10008-STD-6-PLR-005, PEGS-12059-PLR-017	Seamless pipes for carbon steel pipelines (mild, intermediate and severe sour service)
10008-STD-6-COR-032, PEGS-0842-COR-032	Materials for sour service

6.2 INTERNATIONAL STANDARDS

International standards applicable to this document are indicated in the table below i.e. ISO, IEC or ITU.

Document Number	Document Title
ISO 10893-5	Non-destructive testing of steel tubes - Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections
ISO 10893-6	Non-destructive testing of steel tubes - Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections
ISO 10893-8	Non-destructive testing of steel tubes - Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections
ISO 148-1	Metallic materials - Charpy pendulum impact test - Part 1: Test method
ISO 15156-2	Petroleum and natural gas industries - Materials for use in H_2S – containing environments in oil and gas production - Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons
ISO 15590-1	Petroleum and natural gas industries - Induction bends, fittings and flanges for pipeline transportation systems - Part 1: Induction bends
ISO 3183	Petroleum and natural gas industries - Steel pipe for pipeline transportation systems
ISO 6507-1	Metallic materials - Vickers hardness test - Part 1: Test method
ISO 6892	Metallic materials - Tensile testing
ISO 7438	Metallic materials - Bend test

Document Number	Document Title
ISO 7539-2	Corrosion of metals and alloys - Stress corrosion testing - Part 2: Preparation and use of bent-beam specimens
ISO 9712	Non-destructive testing - Qualification and certification of personnel
ISO/TS29001	Petroleum, petrochemical and natural gas industries - Sector-specific quality management systems - Requirements for product and service supply organizations

6.3 CODE AND OTHER STANDARDS

Codes, standards and regional legislation applicable to this document are indicated in the table below.

Document Number	Document Title
API RP 5L1	Recommended Practice for Railroad Transportation of Line Pipe
API RP 5LW	Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels
API Spec 5L	Specification for Line Pipe
ASME B16.9	Factory-Made Wrought Buttwelding Fittings
ASME B31.4	Pipeline Transportation Systems for Liquids and Slurries
ASME B31.8	Gas Transmission and Distribution Piping Systems
ASME Section VIII, Division 1	Boiler and Pressure Vessel Code: Rules for Construction of Pressure Vessels
ASME, Section V	Boiler and Pressure Vessel Code: Nondestructive Examination
ASTM A 370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 578	Standard Specification for Straight-beam ultrasonic examination of Rolled Steel Plates for special applications
ASNT Recommended Practice No. SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing
DNV-OS-F101	Offshore Standard Submarine Pipeline Systems
EN 10204	Types of inspection documents
MSS SP 75	Specification for High Test Wrought Butt-Welding Fittings
NACE TM0177	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments
NACE TM0284	Standard Test Method – Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

7.0 INDUCTION BENDS FOR CARBON STEEL PIPELINE

7.1 PROJECT PARTICULAR SPECIFICATION (PPS)

The following information will be supplied in the Project Particular Specification (PPS):

1) Steel Grade.
2) Specified minimum wall thickness.
3) Nominal Inside Diameter and minimum bore (or gauge) of pipeline and bend.
4) Radius of curvature and angle of bends.
5) Minimum length of tangential ends or welded pup pieces. Minimum length to be not less than 1,000 mm for OD ≥ 16” NPS and 500 mm for OD < 16” NPS (refer to Section 7.6.1 Item 6).
6) The sour service severity and type of pipeline effluent to clarify the H2S test conditions and hardness requirements in weld (if any) (refer to Section 7.6.4 Item 11 and 7.8.5.1).
7) Profile and dimensions of bevelled ends (refer to Section 7.7.8).
8) Simulated Post Weld Heat Treatment (if any) (PWHT is normally requested for WT above 25.4 mm) (refer to Section 7.6.4 Item 8).
9) Routine test temperature for impact tests (refer to Section 7.8.4).
10) If it is confirmed that there are no HIC and SSC tests in production tests (refer to Section 7.8.1).
11) The party (i.e. COMPANY or SUPPLIER) in charge for supplying the mother pipes (refer to Section 7.4).
12) Number of originals and copies of Mill certificates and final production report (refer to Section 7.15.2).

The PPS shall include the bend Data Sheet, if it is not included elsewhere in any other PPS.

7.2 APPROVAL OF SUPPLIER’S PROCEDURES

SUPPLIER shall submit the following documentation for review and Approval by the COMPANY one month, at least, before production commences:

a) A detailed Manufacturing Procedure Specification (MPS), in accordance with MSS SP 75 and ISO 15590-1 describing all proposed fabrication and inspection operations in their correct sequence.

b) The Bending Procedure shall include the essentials parameters and the associated methods of controlling, monitoring and recording such as:

- Nominal OD of mother pipes
- Nominal WT of mother pipes
- Minimum WT of mother pipes
- Steel grade
- Intrados and extrados temperatures during bending sequence
- Distance in between HF inductor and pipe body (Extrados/Intrados)
- Bending Heat Inputs (Volts, Amps, Frequency)
- Travelling speed for bending
- Induction heating to tangent lengths (if any)

The Manufacturing Procedure shall also mention the characteristics of equipment used to carry out above-mentioned operations.

c) Detailed Post Bending Heat Treatment (PBHT) procedures.

d) Non-destructive testing procedures (including inspection procedures to be used on bend body, weld seam and bend ends).

e) Proposals for mechanical testing, namely on trial bends and/or on production bends.

f) Dimensional procedures.

Once the Bending Procedure Specification (BPS) is approved by COMPANY, that procedure shall be qualified, finally, SUPPLIER shall issue the relevant Bending Procedure Qualification (BPQ) for COMPANY approval prior to start with fabrication.

Once a procedure is qualified, SUPPLIER will not be allowed to modify those qualified procedure without the written Approval of the COMPANY.

The SUPPLIER shall submit, at the bid stage, to COMPANY's prior Approval any deviations to requirements specified in applicable technical specifications.

7.3 QUALITY ASSURANCE/QUALITY CONTROL

1) The SUPPLIER shall operate a Quality Assurance system in accordance with ISO/TS 29001, or equivalent, approved by a COMPANY recognised authority. The Quality Assurance Manual shall be submitted to COMPANY before production commences and made available to the Inspector at all times.

2) Four weeks prior to commencement of the bend manufacture, the SUPPLIER shall prepare and submit to the COMPANY a written Quality Control Plan (QCP) (or Inspection and Test Plan-ITP) which describes the inspections to be performed during the fabrication of bends. The Quality Control Plan (QCP) or Inspection and Test Plan (ITP) shall set forth "witness", "hold", "review", and "monitor" points.

3) At bending mills: offices, workshops, laboratory, storage yards etc., information on paper and/or in computers (procedures, working instructions, data, records, tracking system etc.) concerning the manufacturing and inspection of bends, shall be made fully available and comprehensible to Inspector reading. Where the mill country language is not English, all information shall be written in double language, i.e. Mill country language and English language.

4) Just before production starts, Mill QA Representative accompanied by Inspector shall check at every production and inspection station, that the relevant working instructions and procedures are available, complete, conform to the procedures agreed by COMPANY or to COMPANY specification requirements.

7.4 MATERIALS

Pipeline bends shall be manufactured from mother pipes of same source and same manufacturing procedure (where applicable) as the line pipes, with appropriate wall thickness (WT): refer to COMPANY General Specifications 10008-STD-6-PLR-005, PEGS-12059-PLR-017 and 005 (where applicable) and related PPS. Any deviations to line pipe specifications shall be submitted to COMPANY.

When sourcing of mother pipes is different and approved by COMPANY, a full definition of those pipes (chemical composition, as-delivery condition, I.D., WT, etc.) shall be given by the SUPPLIER for prior approval of the COMPANY when the bids are submitted. Chemical composition of weld seam of welded bends shall also be known. The chemical analysis of weld deposit shall not include more than 1.0% Nickel and 0.5% Molybdenum.

There shall be no weld repairs on mother pipes.

HIC tests and SSC tests are not required on mother pipes. However, those tests are required on finished bends (refer to Section 7.6.4 Item 11 and 7.8.1).

Mother pipe microstructure shall not exhibit banded structure in terms of carbon / carbides segregation. Micrography at magnification X 100 in longitudinal direction shall be made available to COMPANY Inspector before starting of production. Refer to Pipe Manufacturing Procedure Qualification Test (MPQT) in Company General Specifications 10008-STD-6-PLR-005, PEGS-12059-PLR-017 and 10008-STD-6-PLR-006, PEGS-12059-PLR-005.

In all cases, the SUPPLIER shall submit the material Mill test certificates of mother pipes for review and Approval of the COMPANY prior to commencing bend manufacture.

Wall thickness of mother pipes shall be selected so that to compensate for the thinning produced by the bending operation and, also, to avoid any internal misalignment in excess of 4 mm (unless otherwise specified) between bend and future pipeline in connection.

No girth weld shall be present in mother pipes.

Welded tangent lengths are not permitted.

7.5 CHECKING OF MOTHER PIPES PRIOR TO BENDING

7.5.1 DIMENSIONAL CHECK

1. The requirements of section 7.5.1 Item 2 and section 7.5.1 Item 3 below apply only where the material procured is of the same nominal thickness as that of the line pipes, or up to plus 15% of this nominal thickness, or otherwise when the mother pipes are not coming from the pipes orders as per the Project Specifications.
2. On receipt of the mother pipes the SUPPLIER shall survey the mother pipe thickness as specified below. Should the pipes not meet the nominal wall thickness at all points, the mother pipe shall be rejected.
3. Wall thickness measurements shall be taken using a suitably approved ultrasonic procedure (minimum accuracy: ± 0.1 mm) at four equally spaced points around the circumference of mother pipe, repeated at intervals equal to two pipe diameters, including the start, middle and stop area of the subsequent bending operation.

7.5.2 ULTRASONIC CHECK

The following applies to COMPANY free issued mother pipes and to any mother pipes not coming from the lines pipes ordered as per the Project specifications. It may not apply, with COMPANY prior approval, when it is so agreed between mother pipe Manufacturer and bend SUPPLIER, under full responsibility of bend SUPPLIER.

1. On receipt of mother pipes, the SUPPLIER shall carry out a confirmation lamination check to an approved ultrasonic procedure. The check shall be carried out along grid spaced at 100 mm centres. Any indication of laminations shall be checked for their dimensions.

   Acceptance criteria of laminar imperfections shall be those stated in Section 7.9.2 Item 3 of this specification.
2. All longitudinal welded seams (if any) shall also be checked by ultrasonics using angle probes as per Section 7.9.2 Item 6 of this specification.

7.6 BEND MANUFACTURE

7.6.1 GENERAL

1. Bends shall be manufactured tested and inspected in accordance with MSS SP 75 and ISO 15590-1, PSL 2S unless otherwise stated in the present specification.
2. Bends shall be produced by induction heating and either forming over a solid internal mandrel (Induction Forging) or forming in a bending machine (Induction Bending). The forming procedure shall include the continuous monitoring and recording of heating temperature at both intrados and extrados (refer also to Section 7.6.2 hereafter).

3. Longitudinally welded pipe shall be oriented so that the weld seam is as close as possible to the neutral fibre of the bend. Position of neutral fibre shall be determined by bend SUPPLIER.
4. During bending, seamless pipe shall be oriented so that the maximum thinning occurs on the thickest wall.
5. Bend shall not include any stop and re-start of heating cycle. In case of interruption of heating cycle during bending process, the bend shall be rejected.
6. Bends shall be fabricated in one piece including tangent lengths (no weld between bend and tangent lengths). Refer to Section 7.1 item 5 for tangent lengths.
7. External and internal reinforcements of longitudinal welds shall be ground flush for a distance of 100 mm from the ends of the bend.
8. Bend manufacturing procedures shall be qualified according to provisions of Section 7.6.4 of this specification.

7.6.2 BENDING HEAT INPUT AND COOLING CONDITIONS

Induction bending shall be carried out within the temperature range 800°C to 1150°C. Temperature control shall be carried out with appropriate device (optical pyrometer and/or emission thermometer) within ± 15°C to the satisfaction of the COMPANY. Heating temperature on the intrados and extrados shall be measured and recorded continuously.

The bending heat input, as a minimum, or the heating temperature shall be automatically recorded on a chart for each bend. Charts shall be made available to the Inspector.

The whole bent section shall be subject to the same induction heating cycle. The SUPPLIER shall state at the bid stage and in bending specification if tangent lengths will be (or not) subject to the same induction heating cycle as that of the bent section.

The bending parameters to be recorded during the MPQT bend are temperatures (as above), bending speed, cooling speed (i.e. water flow rate, water pressure, the surface water cooled - OD only or OD and ID), and the distance of cooling coil. They shall be then recorded and shall be the bending parameters to be applied to production bends.

Reasonable tolerances shall be added to qualification bending parameters as per essential variables indicated in table of Section 7.6.4 Item 2.

7.6.3 POST BENDING HEAT TREATMENT

After induction heating and water cooling at the bending machine, the whole bend may receive (at bend manufacturer's option) a furnace heat treatment (accuracy: ± 15°C max) to achieve the mechanical properties required in this specification.

Heating cycle of heat treatment shall be continuously recorded on a printed chart by thermocouples attached to the bends. Relevant furnace loading sketch with associated thermo-couples locations shall be issued per each heat treatment batch for Company review.

Should post bending heat treatment involve quenching then:

- Weight and distribution of production loading shall comply with qualified loading sketch for quenching (see Section 7.6.4 Item 3),
- Temperature just before quenching shall be monitored / recorded and shall comply with qualified parameters.

Details of this heat treatment, including location of thermocouples, shall be submitted to the COMPANY in the SUPPLIER's Manufacturing Procedure Specification (refer to Section 7.3 Item 3.

The furnace for quality heat treatment shall fulfill all the requirements listed in Appendix 1.

7.6.4 BEND MANUFACTURING PROCEDURE QUALIFICATION TEST (MPQT)

1. For each bend size, steel grade and mother pipe source, a trial bend of the tightest radius/max. wall thickness combination and max CE / P_{cm} shall be dimensionally inspected and destructively tested to qualify the bend manufacturing procedure. Separate qualifications are required for bends fabricated from seamless pipes and bends fabricated from longitudinally seam welded pipes. Grouping of materials and bend sizes may be made with prior approval of the COMPANY before production commences. Procedures established on trial bends shall be fixed for the successive production bends.
2. Tolerances to qualification parameters of bend manufacturing procedure shall be in accordance with here under table, for essential variables and maximum associated permissible variation:

Essential variable	Maximum permissible variations
Forming velocity	± 2.5 mm/min
Forming temperature	± 20°C
Coil design	None
Coolant	None
Coolant flow rate or pressure	± 10 %
Induction heating frequency	± 20 %
Weld seam location	± 5° from the location in the test bend
Post bending heat treatment (quenching)	Method : No change Soaking time : -0 / +15 minutes Quenching temperature :- 0°C / + 25°C
Post bending heat treatment (tempering)	Method : No change Soaking time : -0 / +15 minutes Soaking temperature : ± 15°C

3. Should post bending heat treatment involve quenching then:
   - Relevant sole loading sketch (quenching) to be issued in the MPS,
   - Weight and distribution of qualified loading shall be adjusted as for production loading,
   - Temperature just before quenching shall be recorded.
   - Max time between end of heating and start of quenching.
4. Destructive tests and NDT shall be carried out in accordance with provisions of the present paragraph and Section 7.8 of this specification. Trial bends shall be of sufficient size to accommodate the required test specimens as detailed herein. Test specimens shall be cut after the final heat treatment is carried out. Specimens shall be removed from the bent portion of the bend in accordance with Figure 1 for seamless bends and with Figure 2 for welded bends.

   For WT > 25 mm, the Charpy tests in base metal and weld shall be repeated with specimens cut 2 mm from the pipe internal surface. The number of specimens and location in weld shall be as per Appendix B of DNV-OS-F101.
5. Destructive tests and NDT as above shall be repeated on tangent lengths when they have been heated, whatever the way, during the fabrication process. This can be, for example, the case when tangent lengths have been subject to:
   - The same induction heating cycle as that on the bent portion.
   - A post-bending heat treatment.
   - The two above heating cycles.
6. No destructive tests are required on tangent lengths when they have not been heated whatsoever and that mother pipes used have shown satisfactory mechanical test results against the requirements of the COMPANY line pipe specifications.
7. Dimensional inspection shall be carried out according to COMPANY approved procedures in accordance with the requirements of section 7.7 of this specification.
8. Simulated Post Weld Heat Treatment tests (if required in PPS) and in all cases when WT > 25 mm: Tensile tests and Charpy V-notch impact tests as per section 7.8.2 and 7.8.4 of this specification shall be repeated after a simulated Post Weld Heat Treatment (PWHT) is made.

   All these tests are also acceptance tests and test results shall meet the requirements of this specification. PWHT soaking temperature shall be basically 600°C for one hour per 25 mm wall thickness. The PWHT procedure shall comply with Appendix C, G400 of DNV-OS-F101 and shall be approved by the COMPANY.

9. The performance of trial bends for qualification purposes shall not supersede the requirements for production tests as required in section 7.8 of this specification.

10. With prior agreement of the COMPANY, when ordered bends do not include any tangent lengths, the trial bend may be omitted and replaced by tests made on an over length portion of the first bend produced.

11. HIC tests and SSC tests shall be carried out on test bends in base material and weld, as per specifications 10008-STD-6-PLR-005, PEGS-12059-PLR-017 or 10008-STD-6-PLR-006, PEGS-12059-PLR-005 where applicable, for each trial bend as defined in Section 7.6.4 Item 1 here-above. Tests shall also apply to tangent lengths when they have been heated during bending or HT operation (see Section 7.6.4 Item 5) or when they have not in away been heated but that mother pipes were not H_2S tested.

    For SSC & HIC tests in base material, sampling shall be at Extrados and Intrados of bend.

    SSC tests shall be made under the stress specified in COMPANY specifications 10008-STD-6-PLR-005, PEGS-12059-PLR-017and 10008-STD-6-PLR-006, PEGS-12059-PLR-005, where applicable. Test duration shall be 96 hours for HIC tests and 30 days (720 hours) for SSC tests.

    Acceptance criteria shall be as stated in the said General Specifications.

    Note: HIC and SSC are not required for Mild sour service

12. Micrography on base material.

    Specimens of 30mm long shall be cut longitudinally to bend axis from base material as follows:

    - For SAWL bend, one at 20mm from the weld toe and one at 180^o to the weld seam in the bent portion, and one at start and stop of bending at intrados (i.e. 4 specimens)
    - For seamless bend, one at intrados of bent portion, and one at start and stop of bending at intrados (i.e. 3 specimens)

    Specimens shall be properly polished and etched over their lengths. They shall be examined at 5mm from the external surface and 2mm from the internal surface and at mid-thickness, every 10mm in the longitudinal direction, with a magnification of x 100. The micro structure shall not show:

    - any crack or banded structure in terms of segregated bands of carbides or carbide components. Photography and interpretation of micrography shall be provided.
    - any untempered bainite or martensite.

7.7 DIMENSIONAL INSPECTION

Dimensional inspection, including thickness measurements, shall be made on each bend after final heat treatment and bevel preparation. A report shall be issued for each bend.

7.7.1 WALL THICKNESS

Wall thickness measurements shall be taken using a suitably approved ultrasonic procedure (minimum accuracy: ± 0.1 mm) at four uniformly spaced points around the circumference (including intrados and extrados locations of bend) every 2 x OD of the bend along the length of the bend, in all cases including the start, middle and stop of bent area, and also along the straight portions (tangent lengths).

The wall thickness shall not be less than the specified minimum wall thickness stated in the PPS (basically, this specified minimum WT is that of the related portion of pipeline of same steel grade to which the bend will be connected to later on). The wall thickness plus its tolerance at bend ends (taking into account of the specified nominal (ID) shall be such that the mismatch between internal surfaces of bend and line pipe does not exceed 4 mm (refer to section 7.4 of this specification). Excess material shall be machined back to obtain a taper angle of 10° max. at inside and 14° max. at outside.

7.7.2 DIAMETER AT BEND ENDS

Diameters shall be checked against the specified Nominal Inside Diameter (NID) defined in the PPS. The tolerance on nominal ID at bottom of bevel root face of bend ends shall not exceed ± 1.6 mm.

$$\text{nominal ID} = \text{nominal OD} - 2 \times \text{nominal WT}$$

Internal diameter shall be checked by internal circumferential tape or diameter tape. When calliper gauge is used, measurement shall be made according to 4 equispaced diameters from bottom of bevel root face and the average value shall give the actual inside diameter.

7.7.3 OUT-OF-ROUNDNESS

At any point throughout the body of bend, the difference between the maximum and minimum Outside Diameters shall not exceed 2.5% (3% for 3D bends) of the agreed nominal Outside Diameter. At ends of bend, the internal out-of-roundness shall not exceed 1.5% of the specified nominal Inside Diameter when there are no tangential ends or welded pup pieces, and 1% otherwise.

Nominal Inside Diameter shall be as defined in Section 7.7.2 here above.

7.7.4 RADIUS OF CURVATURE

Radius of curvature of bend shall be correct to within ± 0.6% of the nominal radius, with a maximum of ± 15 mm.

7.7.5 BEND ANGLE

Bend angle shall be measured as the deviation of the straight portions at the ends from a straight line (i.e. bend angle is not the included angle). Bend angle shall be accurate to within ± 0.5° of the nominal bend angle.

7.7.6 OFF-PLANE

The bend off-plane shall be measured by placing the bend on a level surface. Off-plane (in mm) shall not exceed A/9 in mm, where A is the required bend angle in degrees. When the calculated result is less than 5 mm then max. off-plane shall be 5 mm.

7.7.7 CENTRE-TO-END DIMENSION

Tolerances shall be ± 5 mm max. for O.D. < 16” and ± 10 mm max for O.D. ≥ 16”.

7.7.8 BEND END PREPARATION

Bend shall have both ends bevelled to the profile and angle as stated in the P.P.S. or otherwise agreed with the COMPANY. The root face shall be 1.6 mm ± 0.6 mm. Bevelling and taper (if any) shall be carried out by straight machining only.

Taper angle to be max 10° (i.e. 1 in 6 taper) at bend inside and 14° (i.e. 1 in 4) at bend outside.

7.7.9 SQUARENESS

Ends of bend shall be machined perpendicular to the longitudinal axis of the bend. The maximum deviation, as measured with a square, shall be 2 mm across any diameter for OD up to 24" and 2.4 mm otherwise. Only a slight reaming of pipe ends may be permitted with prior approval of the Inspector.

7.7.10 PIG GAUGE TRIAL

A pig gauge shall be passed freely through full length of each bend. The gauge shall have two equispaced and parallel 6 mm aluminum thick circular plates, each having a diameter at least as follows in regard to the connected pipeline nominal ID, separated by a rigid bar of total length once the specified Nominal ID:

- 96% ID for O.D. ≥ 18”
- 95% ID for 12” < OD < 18”
- 94% ID for OD ≤ 12”

If the gauging plates are damaged during the test, the test shall be considered failed and the bend rejected.

All bends shall be suitable for the passage of intelligent pigs.

7.7.11 BULGES, DENTS AND FLAT AREAS

Deviations from the original contour of the bend shall not exceed 3 mm in depth nor shall they exceed 25% of the outside diameter in length. Bulges, dents and flat areas are not acceptable at bend ends. Sharp edged grooves shall be ground out by approved procedures before applying these criteria. Minimum wall thickness requirements shall not be compromised. Bends containing deviations as above shall be rejected.

7.8 PRODUCTION TESTS

7.8.1 GENERAL

Unless otherwise stated in the PPS or agreed at the bid stage, the following destructive tests shall be carried out once per lot of twenty bends in each steel source, grade/size combination, cast of steel and heat treatment batch. Those tests shall be made on the bent portion and repeated on tangent lengths as defined in Section 7.6.4 Item 5 of this specification.

The COMPANY reserves the right to check tests carried out by the SUPPLIER. For this purpose, the COMPANY may request the delivery of the corresponding samples or specimens to be analysed in an independent laboratory chosen by the COMPANY.

There are no HIC and SSC tests to be made as production tests, unless otherwise stated in the PPS.

7.8.2 TENSILE TESTS

Tensile specimens shall be removed as follows:

- One longitudinal specimen from the external radius of bend (for information only, unless otherwise stated in the PPS)
- One transverse specimen from the external radius of bend
- One transverse specimen across the weld of bend (from welded bend only).

Specimens shall be prepared and tested in accordance with API Spec 5L / ISO 3183 Mod.. Unless otherwise agreed, strip specimens shall be used.

All specimens shall meet the minimum yield strength, tensile strength, elongation requirements and the ratio of yield strength to tensile strength, as stated in the related line pipe specification (refer to Section 7.4).

7.8.3 GUIDED BEND TESTS TRANSVERSE TO WELD (IF ANY WELD)

Two guided bend tests shall be conducted transverse to weld seam in accordance with the requirements of clauses 9.7, 10.2.3.6, 10.2.4.6 and figures 8, 9 of ISO 3183.

For wall thickness ≤19.0 mm, one face-bend and one root-bend test, with weld reinforcement removed from both faces, shall be carried out with full thickness specimens. For wall thickness above 19.0 mm, these tests shall be replaced by two side bend tests having full pipe wall thickness and a width of 12.5 mm.

7.8.4 IMPACT TESTS

1. A set of three Charpy V-notch impact specimens shall be extracted from the base material of bend with the longitudinal dimension of the specimens transverse to the axis of bend. These shall be taken from the external radius of bend as indicated in Figure 1 or 2 and cut 2 mm max below outer surface. Specimens shall exhibit the minimum absorbed energy values required in related COMPANY specification for line pipes at the routine test temperature stated herein.

2. For longitudinally welded bends, an additional three sets of three Charpy specimens shall be removed from the weld and tested. Notch positions shall be as shown in Figure 2 of ISO 15590-1 (weld centreline, fusion line, fusion line + 2 mm and fusion line + 5 mm). Charpy test results shall meet the same acceptance criteria as those given in Section 7.8.4 Item 1 above.

7.8.5 HARDNESS TESTS

7.8.5.1 HARDNESS IN WELD (WELDED BENDS)

One transverse macro section shall be removed from the weld after final heat treatment and be subject to VICKERS (5 kg load) hardness testing. Location of macro section shall be as indicated in Figure 2. Hardness survey shall be conducted in accordance with Figure 3.

Hardness shall not exceed the maximum values stated in Table below. The use of portable hardness testing equipment is not acceptable.

Sour service	WM and HAZ
Mild	300
Intermediate	275
Severe	250

7.8.5.2 THROUGH-THICKNESS HARDNESS ON BASE MATERIAL (SEAMLESS AND WELDED BENDS)

Hardness measurements shall be conducted through thickness on macro sections acc. to ISO 6507-1. The specimens shall be sampled from intrados, extrados and both neutral fibbers. These measurements shall also include start, middle and stop of bent heated area (transition area), and straight portion (tangent length). Hardness shall not exceed 250 HV5 or HV10.

7.8.5.3 SURFACE HARDNESS TEST ON BASE MATERIAL (SEAMLESS AND WELDED BENDS)

Hardness testing using a portable equipment and procedure approved by the COMPANY shall be carried out on each bend after final heat treatment, if any. The hardness measurements shall be conducted on the outside surface of bend, at four uniformly spaced points around the bend circumference (including intrados and extrados locations), at start, middle and stop of bent heating area, and also on the straight portions. Hardness shall not exceed 250 HV5 or HV10

(or 237 Brinell B or 22 Rockwell C). This surface hardness test shall be made on all produced bends, even when production tests are not required.

7.8.6 FAILED TESTS

The Inspector will only permit a retest if there is reason to believe that failure was due to some fault in preparation or testing, and that the result was not representative of the test sample. Otherwise, the failed test shall be carried out on every bends in the heat or lot, or alternatively on the entire heat or lot shall be re-heat treated and the full set of tests carried out on one bend.

7.8.7 STORAGE OF TEST SPECIMENS

The test specimens and remaining parts of tested pipes shall be stored by bend manufacturer till the final release of goods. Those pieces may be used for any further investigation or counter tests as addressed in that present specification.

7.9 INSPECTION AND TESTING

7.9.1 GENERAL

1. The SUPPLIER shall bear full responsibility for the conformity of its supply to all clauses of this specification. He shall, for this purpose, take all necessary measures, making use of suitable means, devices and qualified personnel, enabling him to ensure permanent and effective control at each stage of manufacture.

2. The SUPPLIER shall develop a Quality Control Plan (refer to Section 7.3 of this specification) for Approval by COMPANY and shall carry out all inspections and tests required by this specification.

   Any inspection made by the Inspector shall not absolve the SUPPLIER from his responsibility to exercise such quality control procedures so as to ensure that the requirements of this specification are satisfied.

3. The Inspector shall have access to the Mill at all times during work is in progress and shall be at liberty to inspect the manufactured products at any stage and to reject any part not complying with this specification.

4. The inspector reserves the right to witness the sampling and stamp the test sample and to witness the laboratory tests. His stamp shall be maintained traceable up to the testing at laboratory.

5. Before any dimensional surveys or mechanical testing is carried out, the Inspector shall be notified to enable him to witness the tests. Such notification shall be given at least five working days before the tests are to be performed.

6. Visual, dimensional and non-destructive testing for acceptance purposes shall be carried out following final heat treatment and bevelling.

7. All visual inspection, dimensional inspection and Non-Destructive inspection procedures shall have prior approval of the COMPANY and shall be subject to qualification tests under the supervision of Inspector at the first inspection stage. Further to acceptable results, qualification records shall be established by the SUPPLIER, duly signed by the Inspector and filed in the final documentation.

   Note: A qualification review shall be carried out at the very start of production, to implement the approved written procedure in the presence of the mill QA/QC representative and of the Inspector. The Inspector and the mill QA/QC representative shall check that the working instructions are complete and correct, that the procedure has been implemented as it is written, that the environment (e.g. lighting, access ways) is suitable, that tools, equipment are convenient, that the procedure is fully efficient for the inspection purpose in view of specification requirements, that recording and traceability are satisfactory.

8. All Non-Destructive inspection personnel shall be properly certified according to ISO 9712 Std or equivalent COMPANY approved standard and shall have also been approved by the Inspector before any involvement on the order. ASNT SNT-TC-1A in-house qualification is not acceptable, only qualification by an approved third party may be accepted. NDT operators shall be certified level 2, as a minimum. The SUPPLIER shall provide the Inspector with copies of the qualification certificates and a list of inspection personnel showing their scope of qualification and date(s) of certifications.

9. Heat treatment charts of bends shall be made available to Inspector for review at Mill.

7.9.2 VISUAL AND NON-DESTRUCTIVE INSPECTION

1. All bends shall be visually inspected internally to the maximum possible extent and 100% externally to ensure freedom from cracks, gouges, dents, grooves, wrinkles, bulges, kinks or surface spalling. Cosmetic grinding is made as necessary to ease visual inspection.

   Gouges or grooves which do occur shall be removed by grinding providing that the wall thickness is not locally reduced below the specified minimum wall thickness.

   Requirements relating to bulges, dents and flat areas are stated in Section 7.7.11 of this Specification.

2. All bends shall be 100% externally inspected by wet Magnetic Particle Inspection over a longitudinal band covering 90° within the extrados, plus any ground area. The SUPPLIER's procedure shall be in accordance with ASME Section V, Article 7, using the yoke method.

   Acceptance levels shall be in accordance with Appendix 6 of ASME Section VIII, Division 1.

3. An ultrasonic inspection shall be carried out on body of all bends. It shall comprise a 100% survey on both intrados and extrados areas (over two opposite 90° sectors) of the bent portion of bends using both angle and compression probes.

   The inspection of bend body with compression probes shall be carried out in accordance with ASTM A 578 Std. or ISO 10893-8. Any isolated laminar imperfection which is larger than 100 mm^2 for a welded bend or 80 mm^2 for a seamless bend shall not be acceptable.

   The inspection with angle probes (45°, 60° & 70°) shall be carried out in accordance with ASME Section V, the calibration being made using the N10 notch of API SPEC 5L. No cracks or sharp bottom imperfections shall be acceptable, nor any imperfections showing a depth encroaching the specified minimum wall thickness of bend.

4. The portion of tangent length heat affected by the bending beginning and end shall be inspected 100% by angle probes and by MPI.

5. All bend ends shall be ultrasonically examined over 100% of the area within 100 mm of the bend end to check for laminations. Inspection procedure shall be as per ASTM A 578 or ISO 10893-8. Any laminar imperfection exceeding an area of 60 mm2 shall not be acceptable.

6. Longitudinal welded seams shall be 100% inspected by ultrasonic in accordance with ASME VIII, Division 1, clause UW-53 and Appendix 12, for wall thickness exceeding 15 mm.

   For wall thickness equal to or lower than 15 mm, 100% radiography (sensitivity to be 1.8% mini. and ISO wire penetrameter is to be used) shall be made in accordance with ASME, Section V, Article 2, using fine grain films (AGFA type D5, or equivalent) and lead screens, and acceptance criteria contained in ASME VIII, Division 1, clause UW-51, except that imperfections exceeding 6.4 mm in length are not acceptable.

7. All finished weld bevels shall be inspected by wet Magnetic Particle Inspection in accordance with ASME Section V, Article 7 or ISO 10893-5. Any indication exceeding 3 mm in length shall not be acceptable.

7.10 REPAIR OF DEFECTS

1. Repair by welding of bends is not permitted, unless specifically permitted by the COMPANY.

2. Defects including laps, shells and slivers may only be removed by grinding provided that the minimum specified wall thickness is maintained. Any grinding shall leave a smooth surface profile.

3. The locations of any repair work shall be recorded so that independent checks can be made at a later date. This shall not apply to cosmetic grinding.

4. A local MPI shall be carried out to verify that the defect has been completely removed and that the repair is acceptable. Wall thickness checks shall be made on the ground areas with ultrasonics to confirm that the specified minimum wall thickness is maintained. The above does not apply to cosmetic grinding.

7.11 HYDROSTATIC TESTING

Unless otherwise stated in the PPS, Mill hydrostatic testing of fully fabricated bends is not required. However, the SUPPLIER shall certify in writing that all the produced bends can withstand a hydrostatic test pressure at a pressure which develops a hoop stress equal to 90% of the Minimum Specified Yield Strength of bend material (based on Barlow's formula and specified nominal wall thickness of bends) without failure, leakage or impairment of serviceability.

7.12 TEST RINGS

The SUPPLIER shall supply test rings to the COMPANY for qualification of site welding procedures according to 10008-STD-6-PLR-025, PEGS-12059-PLR-012. The rings shall be heat treated with the bends and shall be of the same material and size. Test rings shall have a minimum length of 300 mm. Three rings as a minimum are required for each steel source, bend size and material grade. Both ends of the rings shall have the same weld preparations as those required for the bends in the order.

Test rings are not required when tangent lengths are not heated during bend fabrication process.

Test rings are required when sourcing or chemical compositions of mother pipes are different from that of line pipes of the Project or when a simulated PWHT is required by the PPS of bends.

7.13 MARKING OF BENDS

Each bend shall be stencilled in white paint with the following information at inside (whenever possible) surface of bend end, unless otherwise agreed with the COMPANY. A light clean coat of clear lacquer shall be sprayed over the stencilled area once the paint is dry.

- COMPANY's name
- Project name
- SUPPLIER's name/Brand mark/Logo of Mill
- Purchase Order no.
- Unique bend identification number
- Steel Grade and type of original pipe used (SAW, seamless)
- Inside Diameter and wall thickness
- Bend radius and angle (in degrees)

- Heat number
- Bend weight (calculated).

Height of Digits shall not be less than the following:

- 15 mm for OD $\leq$ 16”
- 20 mm for 16” < OD $\leq$ 24”
- 25 mm for OD > 24”

The bevel ends shall be die stamped, using low stress stamps, with the unique bend number and the mother pipe cast number. The stamping shall be diametrically opposite to longitudinal weld, if any.

7.14 HANDLING, TRANSPORT AND STORAGE

Care shall be taken to ensure that wire ropes, chains, etc., do not come into metallic contact with the bend. It is recommended that broad band non-metallic slings be used to load/unload and support bends when in transit. Bend shall be adequately supported to prevent damage during transit. Storage shall be arranged to avoid accumulation of water inside bends and to allow free circulation of air.

The SUPPLIER shall submit to the COMPANY for review and Approval a handling, transport and storage procedure detailing the proposed methods of handling, storing, and securing bends for transportation and shipment.

Weld end preparations shall be suitably protected against corrosion (e.g. peel-off varnish) and damage during transport and storage. Unless otherwise stated in the PPS, bends shall be delivered with bevel protectors or end caps. These shall be submitted with full details by the SUPPLIER at the bid stage.

7.15 DOCUMENTATION

7.15.1 MILL CERTIFICATES

Unless otherwise stated in the PPS, the required inspection test certificate to support the delivered bends shall be 3.2 according to EN 10204 Std. Mill certificate shall be established by the bend manufacturer.

Mill certificates shall make reference to MSS SP 75 or ISO 15590-1 together with the present General Specification and related PPS.

Mill certificates shall, also, show the following:

- Type and origin of base material
- Ladle analysis including Carbon Equivalent and Pcm
- Bend no. with reference to heat no.

- Mechanical test results and product chemical analysis (including CE and Pcm), with reference to bend no.
- Dimensional inspections with results
- Non-destructive tests performed with results
- Any supplementary tests and inspections carried out.

7.15.2 PRODUCTION REPORT

Upon completion of bend manufacture, the SUPPLIER shall produce a final production report which shall include the following minimum information and documents:

- Mill test certificates of mother pipes and welded pup pieces, if any
- Manufacturing Procedure Specification of bends
- Report of bend MPQT results
- Production test reports (mechanical tests, NDT reports, dimensional reports, etc.)
- Heat treatment batches with no. and HT details
- HIC and SSC reports
- Mill certificates of bends (as per Section 7.15.1 above)
- Mill hydrostatic test certificate of compliance
- Quality Control Plan (or Inspection and Test Plan)
- Compilation of concessions/deviations, if any, granted by the COMPANY.

The PPS shall state the number of originals and copies of the production report which are to be supplied to the COMPANY.

The Inspector shall stamp (rubber-stamp), date and sign the original documents. The copies shall be stamped (as a minimum) by the Inspector.

7.15.3 SCHEDULE

1. The bends shall be dispatched only after a Release Certificate has been issued by the Inspector. Test rings may be released before the bends, when so agreed.
2. Mill certificates shall be supplied at the time of dispatch of the bends.
3. The final production report as above shall be transmitted to the COMPANY without delay after completion of bend production. The latest date of submission of this report shall be three weeks max. after dispatch of bends.

7.15.4 DOCUMENTATION TO SUBMIT BY THE SUPPLIER AT BID STAGE

1. Full technical features of mother pipes: sourcing, aimed tensile properties, aimed chemical composition (including Carbon Equivalent and Pcm), minimum wall thickness, etc.
2. A simplified Manufacturing Procedure Specification (MPS) giving the main features of machine and manufacturing process, parameters that are monitored and recorded (e.g. printed chart), etc.
3. Post-bending heat treatment details.
4. State that bends are manufactured in one piece including tangent lengths, and if tangent lengths are subjected (or not subjected) to the same induction cycle as that of the bent portion of bend.
5. Nominated laboratory for conducting the H_2S embrittlement tests.
6. SSC and HIC test procedures (preliminary).
7. Track record of SUPPLIER in manufacturing bends similar to those of the order.
8. Past experiences of laboratory on HIC and SSC tests as per this specification (including the laboratory's preliminary or typical procedures).
9. Details of bevel protection.
10. Details of bend packing.
11. Quality Assurance certification (ISO / TS 29001, etc.).
12. Deviations to present specification, if any.

7.16 TECHNICAL QUERIES/NON-CONFORMANCE REPORTS

1. Any SUPPLIER's requests for clarifications or deviations to COMPANY specifications shall be submitted to PTTEP authorized technical specialist through Technical Queries (TQ), the format of which shall have prior approval of the COMPANY.
2. A deviation to specifications shall not be considered as accepted if it has not been submitted to and accepted by the specialist here-above through a Technical Query.
3. Approval given by the PTTEP specialist to any SUPPLIER's work procedures, specifications, equipment, etc., shall not release, in any way, the SUPPLIER from his obligation to meet the COMPANY specifications.
4. Any work performance or test result which is found, at a later date, not in conformance with COMPANY specifications or agreed procedure shall be subject to a Non-Conformance Report (NCR) to be issued by the SUPPLIER for submission to COMPANY. NCR report shall indicate the submitted corrective action intended by the SUPPLIER.

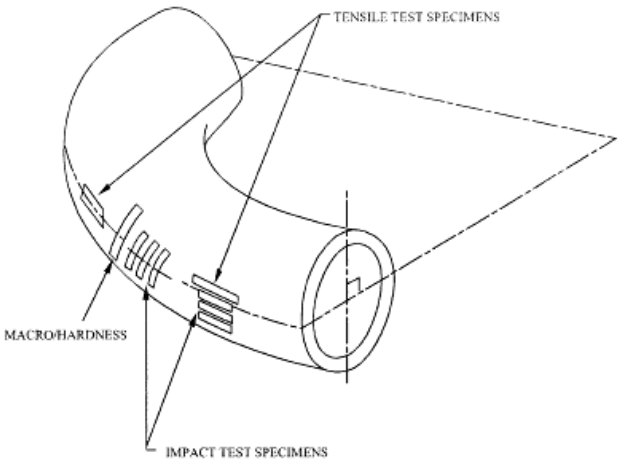

Figure 1 - Location of test specimens in seamless bends

Notes:

(1) Tests on tangent lengths are not shown on sketch.

(2) Longitudinal impact tests are be made only where transverse specimens cannot be cut, with COMPANY prior approval.

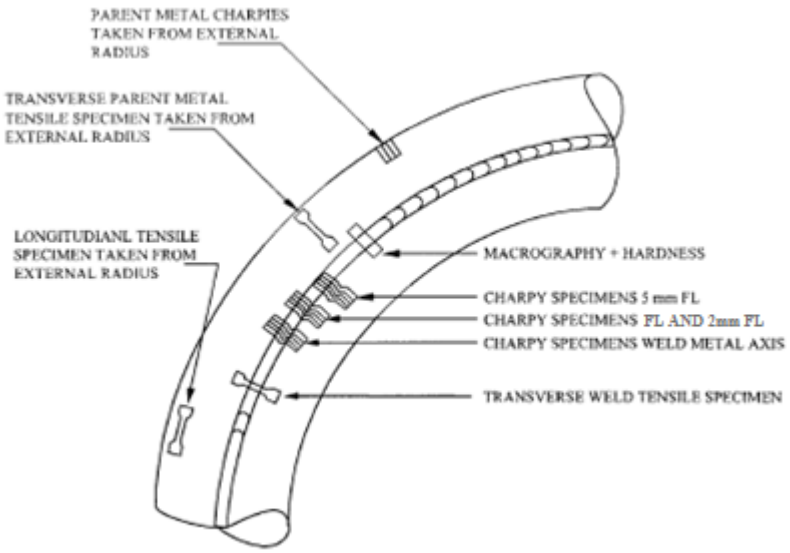

Figure 2 - Location of test specimens in welded bends

Notes:

(1) Parent material Charpy specimens shall be taken from the external radius of the bend.

(2) Tests on tangent lengths are not shown on sketch.

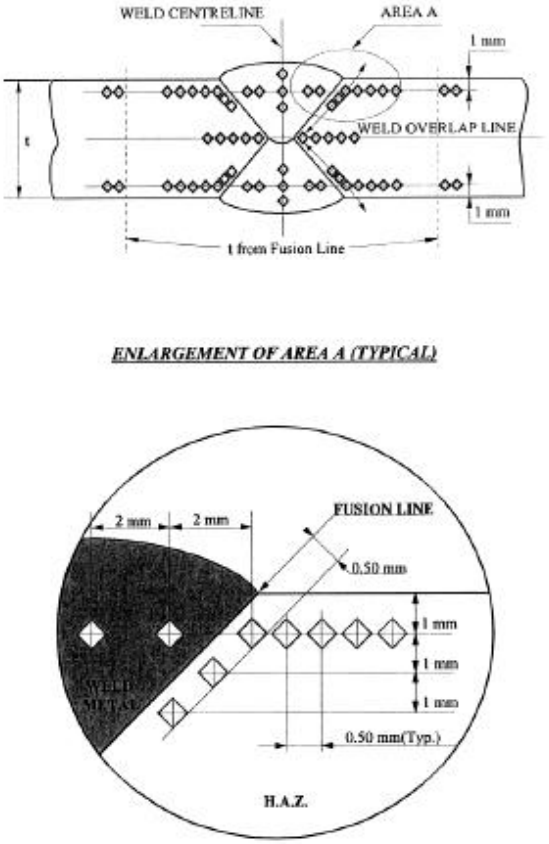

Figure 3 - Vickers hardness survey in weld

8.0 APPENDICES

Appendix 1. Quality heat treatment requirements

Quality assurance

Heat treatment facilities and associated equipment shall be qualified and certified according to the requirements of NORSOK M-650, API SPEC 6A, ASTM A991.

Recording of all quality heat treatment shall be available for review upon Company inspector request.

Equipment minimum requirements

Heat treatment furnaces shall be adequately dimensioned for the loads to be heat treated. Furnaces shall be equipped with systems for fully automated monitoring and recording of temperatures. Thermal sensors shall be calibrated with an accuracy of ± 0.25 % of their full scale.

Quenching baths shall have dimensions and cooling facilities adequate to keep the water temperature below 40 ºC at any time during the quenching operation. The quench tank shall be equipped with pumps, jets or propellers to ensure water circulation both inside and outside the piece. The quenching bath shall be equipped with continuous temperature monitoring and recording devices. An alarm shall be raised if the quenching bath temperature exceeds 40°C.

Staking of bends in the furnace is permitted provided it follows some rules:

- The total load shall not exceed the maximum load,
- Bends are separated by a distance ”d” of minimum 100 mm and from top, bottom and the sides of the furnace by a distance of minimum 500 mm.

The equipment shall be capable of transferring pipes automatically from the heat treatment furnace into the quenching bath within a maximum time of 40 seconds. The transfer time is measured from the time the furnace door is fully open (or the time the pipe starts to exit the furnace) until the piece is completely submerged into the quenching bath.e range.

Heat treatment procedure

A specific heat treatment procedure shall be established. The following information shall be detailed in the procedure:

- Sketch of heat treatment facilities showing furnace(s) and quenching bath relative to each other.
- Type, identification of furnace(s) and sketch of furnace showing, overall dimensions, working zone and location of heat elements.
- Location and identification of thermal sensors in the furnace. Sensors for temperature regulation and sensors for temperature control shall be clearly distinguished. For continuous furnaces the heating zone and the working zone shall be clearly defined.

- Maximum operating temperature of furnace(s).
- Loading temperature, heating rate, temperature set-up and soaking time with associated tolerances.
- Sketch of components' stacking in furnace and during quenching.
- Cooling details, e.g. cooling medium (water, air, gas or a combination thereof, etc. with temperatures of quenching bath etc.), dimensions, volume, pressure, flow rate…
- Maximum transfer time.
- Drawing of the furnace loading. Several pieces can be treated at the same time in the furnace provided:
  - All the pieces are subjected to the same heat treatment (heating speed, cooling speed, soaking time and temperature): in particular, the door of the furnace shall not be opened during the treatment to unload pieces submitted to a different heat treatment
  - The maximum allowable load is not exceed
  - Pieces are not stacked with a minimum clearance of 200 mm on each side, top and bottom.
  - The heat treatment procedure shall be submitted to Company for review and validation before starting production.

Verification

Heat treatment furnaces calibration shall be checked by a third party maximum every 6 months.

This verification shall be carried out furnace empty and with the maximum load to be heat treated.

The verification report shall be available upon Company inspector's request for review.

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