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NATIONAL IRANIAN OIL REFINING & DISTRIBUTION COMPANY
NATIONAL IRANIAN OIL ENGINEERING
& CONSTRUCTION COMPANY

NIOEC SP

NIOEC SPECIFICATION FOR WELDING OF PLANT PIPING SYSTEMS

SECOND EDITION

JULY, 2009

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IN THE NAME OF GOD

FOREWORD

By their very nature, technical specifications are continuously subject to modifications and revisions. To strengthen their merit and usefulness, continuous improvements, addendum, deletion of disparate information and consequently provision of updated revisions are to be made in order to ascertain that such Specifications meet the current requirements, inclusive of Iranian Petroleum Standards (IPS) and the recognized and acceptable national and international Standards, as well as the optimal codes and practices based on the accumulated in-house know how and plant knowledge and experiences.

However, in reality, due to several reasons, not to mention the complexity of the matter, the ultimate goal of continuous direct embedment of the required changes on the relevant Specifications may be far reaching. Therefore, in the interim periods between the officially issued revisions, the required changes will appear in other documents related to the engineering and design work of the ongoing projects.

In response to the initiative of the Design Division and Directorate, and considering that the task of the execution of several important and mega projects for the realization of the new oil refineries, pipelines and oil terminals as well as improvements of the existing facilities, has been assigned to NIOEC, it was decided to update the NIOEC Specifications and to issue new official revisions.

The Design and Engineering Directorate was itself entrusted to carry out this important task, and as such by forming several special technical committees, working in close co-operation and cohesion and sharing their expertise and knowledge, the updated and revised NIOEC Specifications were successfully prepared and compiled.

These Specifications are intended to be used for Oil Refineries, Distribution Depots, Oil Terminals, Pipelines and Pump Stations within NIOEC projects, and have been proven to be of high value for such purposes. It must however be appreciated that these Specifications represent the minimum requirements and should in no way be interpreted as a restriction on the use of better procedures, engineering and design practices or materials.

We encourage and highly appreciate the users and other clear sighted and experts to send their comments on the Specifications to the Design and Engineering Director of NIOEC for evaluation and approval.

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NOTES:

- 1) THIS SHEET IS A RECORD OF ALL REVISIONS TO THIS SPECIFICATION.
- 2) WHEN APPROVED EACH REVISION SHALL BE CONSIDERED AS A PART OF THE ORIGINAL DOCUMENT.
- 3) NUMBER OF PAGES EXCLUDES THIS SHEET AND THE COVER SHEET.

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1. SCOPE

This specification covers the welding, heat treatment, and welds inspection requirements for shop and field fabrication of carbon and alloy steel piping.

Deviations from this specification will only be permitted on obtaining written approval from NIOEC.

Resolution on cases not explicitly stipulated in this Specification, or on cases where conflicts may arise among the requirements of the referenced IPS/ relevant and the international standards, shall be made through written consent and approval of NIOEC.

2. REFERENCES

The following standards, codes, and specifications, to the extent specified hereinafter, shall constitute a part of this NIOEC Specification. Latest edition of the undated referenced documents and the cited edition of the dated references shall apply. The applicability of changes made to the dated references, after the cited date shall be mutually agreed upon between NIOEC and the Vendor/Contractor.

ASME (American Society of Mechanical Engineers)

ASME Sec II Part C	"Welding Consumables"
ASME Sec V	"Nondestructive Examination"
ASME Sec IX	"Welding and Brazing Qualifications"
ASME B 31.3	"Process Piping"

API (American Petroleum Institute)

API 945	" Avoiding Environmental Cracking in Amine Units"
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ASNT (American Society of Nondestructive Testing)

ASNT Recommended Practice No.SNT-TC-1A	"Personnel Qualification and Certification in Nondestructive Testing"
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AWS (American Welding Society)

AWS 3.0	"Terms and definitions"
AWS/ANSI Z49.1	"Safety in Welding, Cutting and Allied Processes"
AWS D10.10	"Recommended Practices for local Heating of Welds in Piping and Tubing"

IPS (Iranian petroleum standards)

IPS-G-SF-110	"General standard for protection against radioactive sealed source"
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NACE (National Association of Corrosion Engineers)

NACE MR0103	"Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments"
NACE RP0472	"Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments"

NACE RP0403

"Avoiding Caustic Stress Corrosion Cracking of Carbon Steel Refinery Equipment and Piping"

NIOEC (National Iranian oil Engineering and Construction)

NIOEC-SP-50-02

"General Piping-Process and Utility Fabrication"

NIOEC-SP-50-04

"Piping Material Specification"

3. UNITS

International System of Units (SI) shall be used in accordance with NIOEC-SP-00-10, unless otherwise specified.

4. DEFINITIONS AND TERMINOLOGY

Definitions and terms used in this Standard conform to those adopted by AWS A3.0. In addition, following definition shall be considered:

Filler Metal: The material to be added in making metallic or nonmetallic joints.

Gas Metal Arc Welding (GMAW): An arc-welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas, or gas mixture. Some variations of this process are called MIG or CO2 welding (non-preferred terms).

Gas Tungsten Arc Welding (GTAW): An arc-welding process which produces coalescence of metals by heating them with an arc between a single tungsten (non-consumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used. (This process has sometimes been called TIG welding.)

Procedure Qualification Record (PQR): A document listing all pertinent data, including the essential variables employed and the test results, used in qualifying the welding procedure specification.

Shielded Metal Arc Welding (SMAW): An arc welding process which produces coalescence of metals by heating them with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

Sour Water Service: Process streams containing H₂S either as a gas or dissolved in an aqueous (liquid water) phase with or without the presence of hydrocarbon which meets the environmental conditions known to cause sulfide stress cracking (SSC) should consider as Sour Service. To determine the margins of sour service environment, NACE MR0103 shall be followed.

Welding Procedure Specification (WPS): The document which lists the parameters to be used in construction of weldments.

5. GENERAL REQUIREMENTS

5.1. All welding shall conform to the requirements of ASME BPV Sec.IX and ASME B31.3.

5.2. Welding procedure qualifications and welder's performance qualifications shall conform to the requirements of Section IX of the ASME BPV Code, latest edition, and to the additional requirements of this specification.

5.3. Safety measures for the protection of welders and operators involved in Welding and cutting

shall be in accordance with the practices specified in the American National Standard Institute Z 49.1.

- 5.4. Procedure qualification for chromium-molybdenum and straight chromium Piping, P-4, P-5, and P6 shall include Brinell hardness tests.(Refer to para.10.2.6)
- 5.5. Procedure qualification for P-1 and P-3 steels using submerged arc welding process shall include hardness tests.
- 5.6. Procedure qualifications for material subjected to low temperature service as defined in ASME B31.3 shall include impact tests.
- 5.7. For double-welded butt joints, (joints welded on both sides) the welding procedure shall specify fabricator's standard inspection procedure used to assure metal soundness after gouging and cleaning the backside of the weld.
- 5.8. Table 1(attached) summarizes heat treatment related requirements and notes 1 to 16, for shop and field welds, contractor shall complete field weld procedures.
- 5.9. Table 2(attached) is the summary of recommended welding procedures with related requirements for shop/field fabrication piping.
- 5.10. Table 3(attached) is the list of recommended filler metal/covered electrodes for pipe welding.
- 5.11. Recommended WPS (WPS NO.P001 to P017) for existing piping classes, as defined in NIOEC SP-50-4, are given in APPENDIX A.
For new piping class (es), if any, contractor shall supplement the recommended welding procedures and related requirements as required.
- 5.12. Contractor shall review the aforementioned recommended WPS(s), complete them with detailed information, and submit them with his comments to Employer/Contractor for approval.

6. WELDING PROCEDURE SPECIFICATION (WPS), WELDING PROCEDURE QUALIFICATION (PQR) AND WELDER PERFORMANCE QUALIFICATION (WPQ)

- 6.1. No production welding shall be carried out before approval of Welding Procedure Specification and Welder Performance Qualification in accordance with requirements of ASME BPV, Section IX and this specification.
- 6.2. The WPSs in this specification or those proposed by the Contractor for the main welding / weld repair procedures shall be approved by Employer.
- 6.3. All essential variables of WPS shall be listed in accordance with ASME BPV Sec. IX. If a change is made in any essential variable, requalification of the procedure is required. If a change is made in a non essential variable; the procedure need only be revised or amended to address the non essential variable change. When notch toughness is required by the construction code, the supplementary essential variables become additional essential variables and a change requires requalification of the procedure.
- 6.4. Irrespective of the design code, under the following conditions the WPS shall be requalified:

Joints

- A change from double sided to single sided welding, but not the converse.
- A decrease in welding groove angle of more than 10 degrees.

Consumables

- Any change of consumable classification.
- Any change in consumable brand name when impact testing is required.
- Any change in size of consumable in the root run of single sided welds.

- 6.5.** For mechanical testing, the type and number of specimens which shall be tested to qualify a welding procedure and a welder performance are given in QW-451 and QW-452, ASME IX.
- 6.6.** Procedure qualification for low temperature service shall include Charpy V-Notch Impact tests as per ASME B31.3 of the weld metal and heat affected zone at the lowest design temperature for the equipment. A change in the electrodes or wire classification shall need requalification.
- 6.7.** Tests required for qualification of WPS shall be organized by the Contractor taking the followings into consideration:
- 6.7.1.** All materials and equipment required for preparation and welding of test piece, including measuring instruments, etc. shall be supplied by the Contractor unless otherwise specified.
- 6.7.2.** After completion of welding, the Contractor shall prepare test specimens for delivery to a test centre for approval of Employer. All NDTs/ DTs (destructive tests) shall be carried out with elapse time not less 24 hours after welding.
- 6.7.3.** After completion of mechanical tests, three copies of WPS(s) and related PQR(s) approved by the Employer Inspector shall be submitted to the Employer.
- 6.7.4.** Weld performance test, preparation of test specimens and conducting of the mechanical test shall be in the presence of the Inspector, unless otherwise specified.
- 6.7.5.** All expenses involved in preparation of test weld, test specimen and conducting mechanical test shall be incurred by the Contractor unless otherwise specified.
- 6.8.** All welders shall be qualified in accordance with the requirements of ASME BPV Sec. IX and requirements of this specification before commencement of production welding. The Contractor shall provide the nominated welder list to client, at least one week before final approval.
- 6.9.** Welder test arrangement shall be carried out in charge of contractor and supervised by Employer.
- 6.10.** If a welder cannot pass the test, retesting is under Employer authority. For this welder further training before retest is necessary.
- 6.11.** Welder re-qualification is required whenever his ability cannot meet the requirements of this Specification and ASME Sec. IX or he has no any welding activity for a period of two months.
- 6.12.** Test pieces to qualify the welder(s) shall be selected from pipe diameter, wall thickness ranges and position of welding that will be involved in production welding.

6.13. The welder qualification test may be terminated at any stage of the testing wherever it becomes apparent to the inspector supervising the test that the welder is not following the welding procedures or does not have the skill required to produce satisfactory results.

6.14. Unless otherwise specified by Employer, for piping / spools which fabricated in vendor's shop, WPSs and PQRs shall be submitted for Employer approval.

7. USE OF BACKING RINGS AND CONSUMABLE INSERTS

High quality root pass welds should be made using a butt joint without backing. Backing rings, when used, shall conform to requirements of ASME B 31.3.

Permanent back-up rings are not permitted. If back-up rings are used and then removed, the weld area shall be dressed and examined for cracks by the magnetic particle method or by the liquid penetrant method if the base material is non-ferromagnetic.

8. ACCEPTABLE WELDING PROCESSES

8.1. Shield Metal Arc Welding (SMAW)

8.2. Manual and automatic Inert Gas Arc Welding (GTAW)

8.3. Automatic Submerged Arc Welding (SAW)

8.4. A combination of the above processes.

8.5. Manual Submerged Arc Welding process shall not be used for pressure containing parts.

8.6. Other processes, such as Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW), are accepted upon specific approval. Contractor shall submit all of the pertinent data and application of the mentioned process for Employer evaluation.

9. PRODUCTION WELDING

a) Before production welding, WPS(s) and PQR(s) shall be approved by Employer.

b) Welders are only permitted for welding in their certified position. Otherwise, the welds shall be removed, completed and replaced at the Contractor's expense by a qualified welder.

9.1. Filler Metal Requirements

9.1.1. All welding consumables shall conform to ASME BPV Sec II Part C or approved equivalent.

9.1.2. Electrodes or filler wires and bags of flux shall be kept in clean and dry room, according to manufacturer recommendation. Each lot or batch shall have production certificate.

9.1.3. The Contractor shall protect all electrodes from any deterioration or damage. Each pack of electrodes or filler wires and bags of flux shall be clearly marked with the respective Batch No. Electrodes that show the deterioration or damage evidence shall be rejected and replaced at Contractor's expenses. Welding machines shall be operated in the specified amperage and voltage ranges recommended by the manufacturer for each size and type of electrode.

9.1.4. The nominal composition of consumables shall be the same as base metal, except as specified in 9.1.6, 9.1.8, 9.1.9 and 9.1.10.

9.1.5. The use of carbon-1/2 moly filler metal for welding carbon steel materials is not permitted

without Employer approval.

- 9.1.6.** For welding of dissimilar ferritic or austenitic joints , the filler metal shall be selected as per AWS D10.8 .
- 9.1.7.** For dissimilar joints consisting of ferritic materials on one side and austenitic stainless steel, higher chrome-nickel and nickel-chrome, including monel on the other side; the filler metal shall meet the requirements of ASME Classification NiCrFe-2 or NiCrFe-3, except that type 309, 309L 309Cb, or 310 filler metal may be used upon specific approval by Employer.
- 9.1.8.** For field fabrication, type 309 filler metal may be used for socket and seal welds on carbon-1/2 moly through 12 chrome piping where the service temperature does not exceed 428°C. For design temperatures of 428°C to 815°C, ENiCrFe-2 or ENiCrFe-3 filler metals shall be used. For design temperatures greater than 815°C, ENiCrMo-3 or ErNiCrMo-3 shall be used. In this condition, preheating is necessary but post weld heat treatment is not permitted.
- 9.1.9.** Where post weld heat treatment is mandatory, paragraph 9.1.8 does not apply.
- 9.1.10.** For ferritic weld deposits, filler wire for automatic welding processes shall contain the principal elements in the wire. Ferritic welds which made submerged arc process shall use a neutral flux, which does not increase the alloy content of the weld metal, compared to the filler metal.
- 9.1.11.** Electrodes of the following classifications are not acceptable for pressure containing welds: E-6012, E-6013, E-7014, E-7020 and E-7024.
- 9.1.12.** Argon gas used in GTAW process for shielding and purging purposes shall be 99.995% pure. The purity of the gas shall be certified by the manufacturer.

9.2.Weld Joint Preparation

- 9.2.1.** Joint preparation shall be made according to approved WPS and/or ASME B 31.3.
- 9.2.2.** Weld bevels shall be made by machining, grinding, plasma or thermal cutting. The surfaces shall be reasonably smooth and true for good fit-up. Materials that require preheat for welding shall be preheated in the same manner for tack-welding, thermal cutting or gouging.
- 9.2.3.** Flame cutting of austenitic stainless steel pipe is not allowed. When thermal cutting is used on austenitic stainless or other high alloys, the bevel surfaces shall be ground to bright metal before welding. The surfaces shall be reasonably smooth and true. Grinding wheels and stainless steel wire brushes used on high alloy materials shall not have been used on ferrous materials.
- 9.2.4.** Tack-welds shall be made with the same type of electrode that is used for the root pass.
- 9.2.5.** Double-welded butt joints shall be used for all pipe 30 inches O.D. and larger where accessible.
- 9.2.6.** Peening is only permitted for cleaning the weld slag.
- 9.2.7.** Before welding, all surfaces to be welded shall be clean and free from paint, oil, dirt, scale, oxides and other foreign material detrimental to welding. If the ends of the pipe joints are damaged (depending on depth and shape of deformation), it shall be repaired or cutted under Employer's inspector supervision.
- 9.2.8.** The cost of all beveling shall be borne by Contractor, who supplied the material. When any defects, such as lamination, split ends, or other defects will be detected on or in the pipe, it shall be repaired or rejected as directed by the Employer's inspector.

- 9.2.9.** Bevels of the stainless steel, low alloy steel and nickel bases pipes which repair shall be inspected before welding by either magnetic particle or dye penetrant method, as recommended by the Employer's inspector.
- 9.2.10.** Flux, weld spatter and slag shall be removed from weld beads before starting to deposit a succeeding pass.
- 9.2.11.** As indicated on spool drawings, the piping systems around compressors require special cleaning. The root pass of these piping systems shall be welded with the gas tungsten arc welding process. The backside of the root pass shall be purged with inert gas.

9.3.Alignment

- 9.3.1.** In socket weld assembly, the pipe shall be inserted into the socket to the maximum depth and withdrawn approximately 2mm away from contact between the end of the pipe and the shoulder of the socket. In sleeve pipe joints without internal shoulder, there shall be a distance of approximately 2mm between the butting ends of the pipes.
- 9.3.2.** The fit between the socket and the pipe shall conform to applicable standards for socket weld fittings and in to case shall the inside diameter of the socket or sleeve exceed the outside diameter of the pipe by more than 2mm.
- 9.3.3.** The space between abutting pipe ends, when aligned for welding, shall be such as to ensure complete penetration without burn-through. For pipes with the same dimensions, the space shall be as specified on WPS. The alignment of the abutting pipe ends shall be such as to minimize the offset between pipe surfaces. For pipe of the same nominal wall thickness the offset shall not exceed 1.5mm.
- 9.3.4.** When flanges are attached to piping system, bolt holes shall be straddled in a manner that establish centerlines (horizontal, vertical, or layout centerlines) but shall meet the orientation of equipment.

9.4.Production Welding Operation

- 9.4.1.** Welders/operators Performance Test documents shall be available before production welding started.
- 9.4.2.** No welding shall be performed if there is undesired weather condition including rain, snow, high wind, blowing sand etc. When it's possible, windshield may be used.
- 9.4.3.** Preheating shall be performed if specified in the relevant WPS and whenever required by ASME B 31.3.
- 9.4.4.** Seal welds: Where seal welding of threaded joints is performed, threads shall be entirely covered by the seal weld. Seal welding shall be done by qualified welders.
- 9.4.5.** All attachments to the piping system shall be continuously welded (skip welding not permitted). Fillet welds shall have a minimum leg length of 4 mm.

10. INSPECTION OF PRODUCTION WELD

10.1. Visual Inspection

10.1.1. Visual inspection before performing production weld

10.1.1.1 Pipe end

Inspect that the form and dimensions of the pipe end are in accordance with the approved WPS, using appropriate measuring devices.

10.1.1.2 Cleaness

Inspect immediately prior to welding to ensure that fusion faces and adjacent material have the cleanliness required. Wire brushing, dry grinding or other mechanical means or solvent as appropriate, may be used for cleaning.

10.1.1.3 Fit-Up

Check that fit-up (gap and alignment) of the parts to be welded including any backing material is in accordance with approved WPS, using appropriate measuring devices.

10.1.1.4 Welding consumables

Check the classification of the welding consumables and trade name(s) against what is cited in welding procedure.

10.1.1.5 Preheating

When preheating is required, the temperature specified in the WPS and satisfactory temperature distribution around the joint shall be checked.

10.1.2. Visual inspection during progress of production weld**10.1.2.1 Back gouging**

When back gouging is mandatory through WPS, the gouging apparatus and the soundness of the first pass shall be checked before starting the next pass. The shape and surface of all passes shall be such as to permit complete fusion of the deposited run.

10.1.2.2 Inter pass

Check that each pass of weld material is cleaned before it is covered by a further pass. Particular attention shall be paid to the junctions between the weld metal and the fusion faces. Visual examination shall be made for any visible defects such as cracks, cavities or other deposition faults so that remedial action shall be taken before further welding (according to article 12).

In the case of multi-pass welds, check that the conditions specified in the welding procedure for interpass temperature are observed.

10.1.3. Visual inspection after completion of production/repair weld:**10.1.3.1 Cleaning and dressing**

All slag shall be removed by manual or mechanical means otherwise flaws may be obscured. When dressing of the weld face is required, it shall be ensured that overheating of the joint due to the grinding action; grinding marks and uneven finish are avoided.

In the case of fillet welds and butt welds that are to be dressed flush, ensure that the joint merges smoothly with the parent metal without under-flushing.

10.1.3.2 Penetration and root examination

In the case of butt welds made from one side only, entire joint shall be inspected to ensure that penetration, root concavity; burn-through and shrinkage grooves are within the acceptable limits. If feasible, appropriate measuring devices shall be used.

In the case of butt welds made from two sides, (partial penetration butt welds and fillet welds) that penetration cannot be checked visually after welding. Alternative inspection methods shall be used if stated by Employer.

10.1.3.3 Contour

The contour of the weld face and the height of the excess weld metal shall be checked, using appropriate measuring devices. Surface of the weld shall be regular and the pattern and pitch of weave marks shall present an even and satisfactory visual appearance.

10.1.3.4 Weld width

The weld width shall be consistent over the whole of the joint and shall be according to dimensional requirements given on the working drawing. In the case of butt welds, the weld preparation shall be at least completely filled.

10.1.3.5 Undercut

Any undercut shall be measured with appropriate measuring devices and shall be checked against the acceptance criteria.

10.1.3.6 Overlap

Toes of the weld where the weld width is excessive shall be carefully inspected for weld fusion.

10.1.3.7 Weld flaws

Weldment and heat-affected zone shall be inspected using optical aids (if necessary).

10.1.3.8 Internal and external weld reinforcement and finish (weld contour) shall be as required by the applicable code.**10.2. Inspection by Non-Destructive Testing****10.2.1. General**

10.2.1.1 All non- destructive testing shall be performed in accordance with the requirements and methods specified in ASME, Section V.

10.2.1.2 When PWHT is mandatory, non-destructive tests shall be done after PWHT.

10.2.1.3 All welds shall be 100% visually inspected before any other NDTs.

10.2.1.4 Non- destructive testing and examination of welds shall be carried out according to detailed written procedures prepared by the Contractor and approved by the Employer.

10.2.1.5 Personnel who assigned for NDT activities shall meet the requirements of ASNT Recommended Practice No.SNT-TC-1 A.

10.2.1.6 Selected welds for N.D.T. shall include representative sample of each welder's work. Selection of welds for N.D.T shall be made by the Inspector.

10.2.1.7 The welds shall be accepted in the undressed condition unless dressing is necessary, in the opinion of the inspector, to effect satisfactory non-destructive testing.

10.2.1.8 The Contractor shall submit to the Inspector certificate of calibration for all NDT equipment to be used for weld inspection.

10.2.1.9 Welds of a size or type preventing conclusive radiograph images (this does not apply to welds in pressure retaining service including nozzle welds), such as some types of branch connections and fillet welds, shall be tested with a magnetic particle examination. For non-magnetic materials and nickel alloys, a liquid penetrant examination shall be used. Internal surfaces shall be examined where accessible.

10.2.1.10 The attachment welds between structural components and pressure parts shall be tested with either dye penetrant or magnetic particle test. For heat-treated components, this shall be done after post weld

10.2.2. Liquid penetrant examination

10.2.2.1 Initial procedure: Liquid penetrant examination shall be performed in accordance with Article 6 of ASME, Section V.

10.2.2.2 Procedure revision

A revised procedure shall be prepared by the Contractor and approved by the Inspector for the following cases:

- a) Whenever a change or substitution is made in the type or family group of penetrant materials (including developers, emulsifiers, etc.) or in the processing techniques;
- b) Whenever a change or substitution is made in the type of pre-cleaning materials or processes;
- c) For any change in part processing that can close surface opening of discontinuities or leave interfering deposits, such as grinding, grit blasting and power brush cleaning or acid treatments.

10.2.2.3 Techniques

Either a color contrast penetrant technique or a fluorescent penetrant technique shall be used. One of the following three types of penetrant systems shall be used:

- a) Post-emulsifying.
- b) Solvent removable.
- c) Water washable (if specified by Employer).

10.2.3. Magnetic particle examination

10.2.3.1 Procedure: Examination procedures shall be prepared in accordance with ASME, Section V, Article 7.

10.2.3.2 Method of examination: Examination shall be done by the continuous method; that is, the magnetizing current remains on while the examination medium is being applied and while excess of the examination medium is being removed.

10.2.3.3 Material of particle: The ferromagnetic particles used as an examination medium shall be either wet or dry, and may be either fluorescent or non-fluorescent. If dry particles are used prior approval of the inspector shall be obtained.

10.2.3.4 Techniques

One or more of the following five magnetization techniques may be used provided that prior approval of the inspector is obtained.

- a) prod technique;
- b) longitudinal magnetization technique;
- c) circular magnetization technique;
- d) yoke technique;
- e) Multidirectional magnetization technique.

When carrying out MP, care shall be taken to avoid spark on the metal surfaces, especially for air hardening steels.

10.2.3.5 Calibration of equipment: Calibration shall be made according to ASME Section V clause T-760.

10.2.3.6 System and sensitivity evaluation: The overall performance and sensitivity of examination system (i.e. combination of the magnetic particle material/magnetic particle equipment. The sequence of operation and the level of magnetizing field) shall be monitored with the test block at regular intervals to assure the system performance is properly maintained: A reference block or fabricated test piece with known discontinuities shall be prepared for above demonstration.

10.2.3.7 Demagnetization: When residual magnetism in the part could harmfully interfere with the

subsequent processing or usage, the part shall be demagnetized after completion of the examination.

10.2.3.8 The final pass of attachment welds to P-4, P-5 and P-6 materials shall be magnetic particle examined after final post weld heat treatment.

10.2.3.9 On completion of MT, all spark spots shall be ground flush to sound metal (care shall be taken not to thin metal thickness). For P-4, P-5 and P-6 materials, grounded locations shall be inspected to detect probable microfissure cracks by dye penetrant method and remedial action shall be taken if necessary (according to article 12).

10.2.4. Ultrasonic examination

10.2.4.1 Conventional Ultrasonic Examination

10.2.4.1.1. General

The ultrasonic testing of the weld shall be carried out by manual scanning using an A-scan and shall be performed with written procedure. The procedure shall include but not limited to the following information:

- a) Type of ultrasonic flaw detector.
- b) Weld type and welding procedure.
- c) Joint design.
- d) Surface condition.
- e) Type of standard block.
- f) Reference block and its relative reflectors.
- g) Type of probes.
- h) Method of sensitivity setting for parent metal testing.
- i) Method of sensitivity setting for weld metal.
- j) Scanning techniques.
- k) Reporting requirements.
- l) Acceptance standard.
- m) Operators qualification.

10.2.4.1.2. Equipment

10.2.4.1.2.1. Frequency

The equipment shall be capable of working frequency within the range 1MHz to 5MHz.

10.2.4.1.2.2. Time base linearity

The linearity of time base shall be within 2% over the whole range.

10.2.4.1.2.3. Amplifier linearity

The amplifier shall be linear to an accuracy of ± 1 dB at any point within the range 20% to 80% of full screen height.

The amplitude control of flaw detector shall be made according to Appendix I, Article 5, ASME, Section V.

10.2.4.1.2.4. Operators

Operators shall be certified by the requirements of ASNT recommended practice SNT-TC-1A Level II or III.

If required, the operator shall demonstrate his ability to perform the test, using the actual equipment and the technique to be employed.

10.2.4.1.3. Scanning**10.2.4.1.3.1. Parent metal**

Parent metal at both sides of welded joints, to the extent necessary for weld examination, shall be scanned using straight beam technique for:

- a) Locating any flaws, such as laminations and tears.
- b) Determining actual material thickness.

10.2.4.1.3.2. Weld metal

The weld examination shall consist of scan from both sides:

- a) of the weld root;
- b) of the side fusion faces;
- c) of the weld body;
- d) In addition to scanning for defects lying transverse of the weld.

10.2.4.1.4. Sensitivity setting Sensitivity setting for straight and angle beam probe shall be made according to ASME SEC V.**10.2.4.2 Phased Array and Time of Flight Diffraction (TOFD) Ultrasonic Testing****10.2.4.2.1. General**

- 1) The ultrasonic examinations shall be conducted using automated or semi-automated techniques with computer-based data acquisition and analysis abilities.
- 2) The examinations shall be performed in accordance with a written procedure approved by Employer which shall, as a minimum, contain the requirements listed in Tables T-421 of ASME BPV Code Section V, Article 4 and:
 - a) For phased array—ASME Section V, Article 4, Mandatory Appendix IV
 - b) For time of flight diffraction (TOFD) —ASME Section V, Article 4, Mandatory Appendix III
- 3) Procedure qualification shall meet the requirements of ASME Section V Article 4 Mandatory Appendix VIII.

10.2.4.2.2. Equipment

- 1) Equipment using for TOFD examination shall provide the requirements of part III-430 and III-432 of ASME Section V Article 4 Mandatory Appendix III.
- 2) The examination for transverse reflectors may be performed manually.

10.2.4.2.3. Personnel

- 1) Setup and scanning of welds shall be performed by personnel certified as Level II or III (or by Level I personnel under the direct supervision of Level II personnel).
- 2) Interpretation and evaluation of data shall be performed by Level II or III personnel.
- 3) Examination personnel shall be qualified and certified following a procedure or program as described in ASME Section V, Article 1, T-120(e), (f), (h), and (i).
- 4) Personnel demonstration requirements shall be as stated in ASME Section V Article 4 Mandatory Appendix VII.

10.2.4.2.4. Scan Plan

A scan plan (documented examination strategy) shall be provided showing search unit placement and movement that provides a standardized and repeatable methodology for the examination.

10.2.4.2.5. Calibration

10.2.4.2.5.1. Amplitude Control Linearity: The ultrasonic instrument's amplitude control linearity shall be evaluated in accordance with ASME Section V Article 4 Mandatory Appendix II for each pulser-receiver circuit.

10.2.4.2.5.2. Focal Law: The focal law to be used during the examination shall be used for calibration.

10.2.4.2.5.3. Beam Calibration: All individual beams used in the examination shall be calibrated to provide measurement of distance and amplitude correction over the sound path employed in the examination.

10.2.4.2.5.4. Calibration for TOFD examination shall provide the requirements of part III-460 of ASME Section V Article 4 Mandatory Appendix III.

10.2.4.2.6. Scanner block: A block shall be fabricated meeting the requirements of T-434.1 and Fig. T-434.2.1 of ASME Section V, Article 4, except that its thickness, T, shall be within the lesser of 1/4 in. (6 mm) or 25% of the material thickness to be examined and the number and position of the side-drilled holes shall be adequate to confirm the sensitivity setting of each probe, or probe pair in the case of a TOFD setup, as positioned per the scan plan in the scanner. The scanner block is in addition to the calibration block required per Article 4, unless the scanner block also has all the specified reference reflectors required per Fig. T-434.2.1. of ASME Section V, Article 4.

10.2.4.2.7. System Confirmation Scan: The scanner block shall be scanned and the reference reflector indications recorded to confirm system calibration prior to and at the completion of each examination or series of similar examinations, when examination personnel (except for automated equipment) are changed, and if the scan plan is required to be modified.

10.2.4.2.8. Examination

10.2.4.2.8.1. The initial straight beam scan for reflectors that could interfere with the angle beam examination shall be performed

- a) Manually
- b) As part of a previous manufacturing process or
- c) During the weld examination

10.2.4.2.8.2. The examination area shall include the volume of the weld, plus the lesser of 25 mm (1.0 in.) or t of adjacent base metal. Alternatively, the examination volume may be reduced to include the actual heat affected zone (HAZ) plus 6mm (0.25 in.) of base material beyond the heat affected zone on each side of the weld, provided the extent of the weld HAZ is measured and documented.

10.2.4.2.9. Data Recording: Data shall be recorded in the unprocessed form with no thresholding. The data record shall include the complete examination area as specified in 10.2.4.2.8.2 above.

10.2.5. Radiographic examination

10.2.5.1. General

Production welds shall be inspected by radiographic examination according to approved procedure, and carried out after post weld heat treatment when required. Contractor may prefer to carry out radiography examination to detect defective weldment prior to heat treatment to avoid undue heat treatment operation. However the acceptance judgment is based on radiography examination after heat treatment.

10.2.5.2. Procedure

Radiographic procedure shall include but not limited to the following:

- a) material and thickness range;
- b) type of X-ray tube or isotope;
- c) strength of isotope used or X-ray voltage;
- d) radiography technique;
- e) film type;
- f) intensifying screens used;
- g) type of image quality indicator, place and numbers;
- h) sensitivity;
- i) density;
- j) processing time and temperature;
- k) reporting requirements

10.2.5.3. Techniques

A single wall exposure technique shall be used for radiography whenever practical. When it is not practical to use single wall technique, a double wall single image technique (DWSI) and for pipes with DN less than 90 (NPS 3½) double wall double image (DWDI) technique may be used, upon approved by Employer.

10.2.5.4. Film type

Radiography shall be made using industrial radiography film type Class II ASTM, equivalent to D7 normally and D4, if required in the opinion of the Inspector, in special cases. Fluorescent and fluorometallic screens are not acceptable.

10.2.5.5. Image quality indicators (IQI)

Wire type penetrometer shall be used to measure radiographic sensitivity. In special cases other type of penetrameters may be used. Max. Sensitivity shall not exceed 2% where:

$$\text{Sensitivity} = \frac{\text{size of thinnest wire}}{\text{thickness of specimen}} \times 100$$

Number of penetrameters and placement shall be as per ASME sec V.

10.2.5.6. Selection of radiation sources shall be accordance with T-272 ARTICLE 2 ASME SEC V.**10.2.5.7. Darkroom**

Processing shall be carried out in a darkroom with the following facilities as minimum requirement:

- a) Automatic or manual processing devices with temperature indicating controller (T.I.C).
- b) Loading bench.
- c) Red light (subdued light).
- d) Adequate ventilation.
- e) Drying bench.
- f) Clean and washable floor.

10.2.5.8. Processing

Processing shall follow a standard technique with five separate stages; Development, stop bath, fixing, washing and drying. Development time and temperature shall be controlled according to standard (4 min. at 20°C) or film manufacturer's recommendations.

Excess density due to additional developing time or higher temperature shall not be allowed.

The Employer engineer is allowed to visit processing condition to evaluate the quality and density of radiographs.

10.2.5.9. Personnel: The personnel are tasked for radiography activities, shall be certified in accordance with the recommendations of ASNT Recommended Practice No.SNT-TC-1A. Assigned personnel shall obtain the certificate of competence for working with radiation sources from authorized organization.

10.2.5.10. Quality of radiographs

All radiographs shall be free from mechanical, chemical and other blemishes to the extent that they do not mask and are not confused with the image of any discontinuity in the area of interest of the object being radiographed. Such blemishes include, but are not limited to:

- a) Fogging;
- b) Processing defects such as streaks, watermarks or chemical stains;
- c) Scratches, fingermarks, crimps, dirtiness, staticmarks, smudges, or tears;
- d) False indications due to defective screens;
- e) Film shall be exposed so that the H & D density through the weld metal shall not be less than 1.8 not greater than 3.0 for transparent based film.

10.2.5.11. Identification

- a) A system shall be used to produce permanent identification on the radiograph of weld. Consecutive / number series and the date of the radiograph shall be plainly and permanently included on the radiograph.
- b) Markers, usually in the form of lead arrows or other symbols, shall be placed alongside but clear of the outer edges of the weld to identify its position.
- c) In general, permanent marking of the work piece shall be used to provide reference points for the accurate relocation of the position of each radiograph.

10.2.5.12. Interpretation

Only level II or III NDT personnel in accordance with SNT-TC-1A for radiography shall interpret images. The radiographer shall examine each radiograph and shall determine the acceptability of each weld based on Chapter VI ASME B 31.3. The radiographer shall describe to the Inspector those weld defects that he considers cause for rejection of the weld. The Inspector will make final interpretation on all welds. However this will not relieve the Contractor/Construction Contractor from his responsibilities as outlined in the contract.

10.2.5.13. Radiation safety

Whenever X-ray equipment or radioactive sources are in use, adequate precautions shall be taken to protect the radiographer and others in the vicinity. Radiation hazards shall be minimized by adherence to requirements cited in IPS-G-SF-110.

10.2.5.14. Random radiography

Where 10 percent radiography is specified the following rules shall be applied:

- a) At least 10 percent of the number of welds within the specified line class shall be radiographed around their total circumference.
- b) At least 10 percent of the number of welds made by each welder shall be radiographed around their total circumference. If a welder makes less than 10 welds, one of these shall be fully radiographed.
- c) Radiographs shall sample the entire range of pipe sizes that have been welded, where practicable.
- d) Since the intent of 10 percent examination is to evaluate the quality of welder performance, radiographs shall be made as soon after weld completion as practicable.

10.2.6. Brinell hardness test

10.2.6.1. Submerged arc welding procedure qualifications for P-1, -P-3 and P-4 group materials shall have a hardness not exceeding 225 Brinell in the weld deposit.

10.2.6.2. On production welds for P-4,P-5 and P-6 group material a Brinell hardness test shall be taken on the butt-welds in each P-groups material for all air hardening filler metal. Brinell hardness shall not exceed 225 BHN.

10.2.6.3. The Brinell hardness testing shall be limited to piping and tubing greater than DN 100 (NPS 4) and a wall thickness over 6.35mm.

10.2.6.4. Hardness test results and locations shall be recorded. The Employer shall be permitted to witness hardness testing and shall have access to test results.

10.3. Field Inspection and Test Plans (FIPS)

The contractor shall record the results of examinations and tests on NIOEC quality control forms which named FIPs (Field Inspection and Test Plans). FIPs for piping system which after mentioned are given in APPENDIX B:

MATERIAL RECEIVING (PIPING)

MATERIAL STORAGE PIPING

SPOOL CHECK

WELDING ACTIVITY REPORT

HEAT TREATMENT AND BRINELL TEST REPORT

PENETRANT TEST REPORT

RADIOGRAPHIC TEST REPORT

ULTRASONIC TEST REPORT

MAGNETIC TEST REPORT

MECHANICAL LINE CHECK UNDERGROUND

MECHANICAL LINE CHECK

HYDROSTATIC TEST

WELDER PERFORMANCE QUALIFICATION (WPQ)

FIT-UP INSPECTION
RADIOGRAPHY REQUEST FOR PIPING
PAD TEST REPORT
GENERAL INSPECTION REPORT
INSPECTION OF ORIFICE FLANGE

11. WELD DEFECTS AND ACCEPTANCE CRITERIA

- 11.1.** Welds which are deposited by procedures differing from those properly qualified approved shall be rejected and completely removed from the piping.
- 11.2.** Weld metal shall be properly fused with the parent metal without significant undercutting or overlapping at the toes of the weld; slight intermittent undercut shall be permitted provided that it does not form a sharp notch and it meets the following requirements.
- The stop and start of each run of weld shall merge smoothly and shall show no pronounced hump or crater in the weld surface.
- 11.3.** Acceptance criteria shall be as stated in the engineering design and shall at least meet the limits stated in Table 341-3.2 of ASME B.31.3.
- 11.4.** For ultrasonic examination of welds supplementary acceptance criteria cited in Clause 344.6.2 of ASME B.31.3 shall be considered.

12. WELD REPAIR

- 12.1.** When a defective weld is detected either visually or by any other method in accordance with Section 10 of this Standard, it shall be removed to sound metal and repaired. Repair weld shall be made using qualified welding procedure as well as qualified welders/welding operators. Preheating and heat treatment shall be as required for the original welding.
- 12.2.** External undercut shall be repaired by grinding off the weld cap in the undercut location and recapping the location.
- 12.3.** No weld containing cracks, regardless of size or location, is acceptable. Cracked welds shall be cut, removed and re-welded.
- 12.4.** Arc strikes on the surface of the weld bevel, shall be removed by grinding and inspected by magnetic particle examination or liquid penetrant examination to ensure freedom from cracks.
- 12.5.** As a completion test, the repaired area shall be radiographed (if not possible, it shall be evaluated using MT) whether the defect in the original weld was detected with NDT done or not.
- 12.6.** When a required examination reveals that weld examined fails to meet applicable quality requirements, the weld shall be repaired or replaced to meet requirements of the applicable Code. Also, two additional examinations of the same type shall be made of the same kind of weld by the same welder or welding operator that was deficient in quality. If the second group of welds examined meets applicable quality requirements, all welds represented by these additional examinations shall be accepted. For each of the second groups of welds which fail to meet applicable quality requirements, two additional welds shall be examined. If all of the third groups of welds examined meet applicable quality requirements, the items which were deficient shall be repaired or replaced to meet the requirements of the applicable

Code and all items represented by the examined welds shall be accepted. . If any of the third group of welds examined fails to meet applicable quality requirements, all comparable welds may be replaced or they shall be fully examined and repaired as necessary to meet applicable quality requirements, at Contractor 's expense.

13. PRE-AND POST-WELD HEAT TREATMENT

13.1. General Requirements

13.1.1. Heat treatments may be carried out either full body or locally, depending on:

- Type of heat treatment
- Material composition of pipe.
- Number and sizes of pipe.
- Availability and cost of energy.
- Required accuracy of heat treatment.
- Welding process and welding consumable.
- Code requirement.

13.1.2. Heat treatment shall be carried out in accordance with a qualified heat treatment procedure specification which is submitted by the Contractor for approval of the Employer.

13.1.3. During heating up and cooling down, no temperature gradient shall exceed:

100°C/m in axial direction, nor
40°C/m in tangential direction,
to be checked by temperature recorder.

13.1.4. For wall thicknesses of pipe up to and including 20 mm the rate of heating shall not exceed 200-250°C/h.

13.1.5. For wall thicknesses of pipe over 20 mm the rate of heating shall not exceed:

$5500/t$ °C/h (t = maximum pipe wall thickness)

or

55°C/h

Whichever is greater?

13.1.6. The work piece shall be cooled to 300°C whereby the cooling rate is limited as follows:

- For wall thickness of pipe < 20mm
275°C/h
- For wall thicknesses ≥ 20 mm
 $6875/t$ °C/h (t = maximum pipe wall thickness)
or
55°C/h, whichever is the greater.

13.2. Preheat Requirements

13.2.1. Preheating of the parent metal is necessary prior to any welding, tack welding and thermal cutting where specified by approved WPS, to avoid cold cracking of certain ferritic steels in the weld and HAZ. Preheating could also be required for welding of non-ferrous materials to remove moisture or to prevent hot cracking.

13.2.2. Temperature control may be carried out with temple stick, digital pyrometers or contact thermometer.

13.2.3. Where preheating is necessary to be carried out by electrical resistance method, automatic

temperature control facilities shall be utilized and the specified preheat temperature shall be maintained throughout the welding course.

13.2.4. When required for field welds of piping, the following methods of preheating shall be applied, except for heavy wall thickness alloy steel piping which electrical resistance elements shall be used.

- a) For $DN < 250$ ($NPS < 10$) heating by appropriate torches is allowed
- b) For $DN \geq 250$ ($NPS \geq 10$) electrical resistance heating element or heating by means of infrared or ring burners is required.

13.2.5. The following requirements shall be adhered to for the preheating zone:

- a) Width of the heated zone is $2t$ (t = wall thickness) with a minimum of 100 mm on each side of the weld.
Width of the insulated zone = width of zone heated + 150mm.
- b) For pipe butt welds, the width of the heated band on each side of the weld is $2.5t$, with a minimum of 75mm.
- c) Special attention shall be paid to the extent of heated bands in order not to aggravate the problems related to residual stress distribution, such as cracking, buckling and distortion.

13.2.6. Specified preheat temperature shall be maintained throughout the whole welding course. Also the specified maximum interpass temperature shall be considered.

13.2.7. For Cr-Mo steel with a wall thickness of 25mm the above preheat shall always be applied.

13.2.8. For other ferritic steels, intermediate lowering of preheat temperature is permitted only when at least 50% of the weld is completed. The joint shall be cooled under insulation. Preheating shall be restored to the specified temperature and maintained for 30 minutes. Before the welding is recommenced.

13.2.9. Preheat temperature required shall be as specified in the approved WPS.

13.3. Post-Weld Heat Treatments (PWHT)

This section covers basic practices which are suitable for most welding operations, but not necessarily appropriate for all service conditions.

13.3.1. Methods of heating

Heat treatment shall be carried out by one of the following methods, ensuring that the minimum stipulated temperature is achieved through the thickness of the pipes.

- a) Heating in a stationary industrial furnace.
- b) Local heating:
 - 1) Portable muffle furnace.
 - 2) Induction coils.
 - 3) Resistance heaters. The method of securing resistance heating elements around the joint shall be capable of holding the elements securely in contact with the pipe work throughout the heat treatment cycle. Any fixing, e.g., galvanized wire; likely to be injurious to the joint shall not be used.
Selection of the method for heat treatment is subject to prior approval of the Employer. Manually-operated gas torches shall not be used.