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Piping Engineer's Handbook

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I. INTRODUCTION

1.1 Purpose

Thisbookisintendedtobrieflydescribesequenceofeventsduringvariousprocesses involved in Piping Fabrication, Erection &Testing.

1.2 Scope

This Book is used to conduct the lecture for the students who all are registered with the Ibis academy for the Oil & Gas courses

II. DEFINITIONS & ABBREVIATION

Quality Control Plan	:	The term Quality Control Plan (Inspection Test Plan), is used to identify activities that are to be controlled, the controlling specification and the control mechanisms site and source inspection control.
Procedure	:	Specified way to carry out an activity or a process
Audit	:	Systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled.
Shall	:	This shall mean contractual requirement
Should	:	This should mean desired requirement
May	:	This word 'may' is to be understood as indicating a possible course of action.
Abbreviations		
AFC	:	Approved for Construction
ASTM	:	American Society for Testing & Materials
ASME	:	American Society of Mechanical Engineers
CAR	:	Corrective Action Request
CQP	:	Contract Quality Plan
CS	:	Carbon Steel
EPC	:	Engineering, Procurement & Construction
IMTE	:	Inspection, Measuring & test Equipment
ISO	:	International Organization for Standardization
ITP	:	Inspection & Test Plan
LTCS	:	Low temperature Carbon Steel
MS	:	Method Statement
MTC	:	Material Test Certificate
NCR	:	Non-Conformance Report
PO	:	Purchase Order
PQR	:	Procedure Qualification Record
QA/QC	:	Quality Assurance / Quality Control
QCP	:	Quality Control Plan
QMS	:	Quality Management System
RFI	:	Request For Inspection
TBA	:	To be addressed / advised
WPQT	:	Welder Performance Qualification Test

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WPS	:	Welding Procedure Specification
SS		Stainless Steel
DSS		Duplex Stainless Steel
SDSS		Super Duplex Stainless Steel
CRA		Corrosion Resistant Alloys (Inconel 625 and 825)
AS		Alloy Steel
PAM Unit		Portable Arc Monitor

III. REFERENCES

ASME B 31.3	:	Process Piping
SP 1173	:	Specification of welding on plot piping
SP1176	:	NDT Examinations
ASME Sec IX	:	Welding Procedure and Welder Qualification
DEP 30.10.60.18	:	Welding of Materials
DEP 31.38.01.31	:	Shop and Field Fabrication of Piping

IV. INTRODUCTION TO PIPING

Piping is a system of pipes used to convey fluids (liquids and gases) from one location to another. Piping includes pipe, flanges, fittings, bolting, gaskets, valves, and the pressurecontainingportions of other piping components. It also includes pipe hangers andsupports and other items necessary to prevent overpressurization and overstressingof the pressure-containing components. It is evident that pipe is one element or apart of piping.

Pipe

Pipe is a tube with round cross section conforming to the dimensional requirementsof

- ASME B36.10M Welded and Seamless Wrought Steel Pipe
- ASME B36.19M Stainless Steel Pipe

Normally the pipes are generally differentiated on the basis of its Size and Wall thickness

Pipe Size

Nominal pipe size (NPS) is a dimensionless designator of pipe size. It indicatesstandard pipe size when followed by the specific size designation number withoutan inch symbol. For example, NPS 2 indicates a pipe whose outside diameter is2.375 in. The NPS 12 and smaller pipe has outside diameter greater than the sizedesignator (say, 2, 4, 6). However, the outside diameter of NPS 14 and largerpipe is the same as the size designator in inches. For example, NPS 14 pipe has anoutside diameter equal to 14 in. The inside diameter will depend upon the pipewall thickness specified by the schedule number. Refer to ASME B36.10M orASME B36.19M.

NPS	DN	NPS	DN	NPS	DN	NPS	DN
⅛	6	3½	90	22	550	44	1100
¼	8	4	100	24	600	48	1200
⅜	10	5	125	26	650	52	1300
½	15	6	150	28	700	56	1400
¾	20	8	200	30	750	60	1500
1	25	10	250	32	800	64	1600
1¼	32	12	300	34	850	68	1700
1½	40	14	350	36	900	72	1800
2	50	16	400	38	950	76	1900
2½	65	18	450	40	1000	80	2000
3	80	20	500	42	1050	—	—

Diameter nominal (DN) is also a dimensionless designator of pipe size in themetric unit system, developed by the International Standards Organization (ISO).It indicates standard pipe size when followed by the specific size designation numberwithout a millimeter symbol. For example, DN 50 is the equivalent designation ofNPS 2. Refer to Table above for NPS and DN pipe size equivalents.

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Pipe Wall Thickness

Schedule is expressed in numbers (5, 5S, 10, 10S, 20, 20S, 30, 40, 40S, 60, 80, 80S,100, 120, 140, 160). A schedule number indicates the approximate value of theexpression 1000 P/S, where P is the service pressure and S is the allowable stress, both expressed in pounds per square inch (psi). The higher the schedule number, the thicker the pipe is. The outside diameter of each pipe size is standardized.

Therefore, a particular nominal pipe size will have a different inside diameterdepending upon the schedule number specified.

Pipe Components

The commonly used piping fittings in the industries are Elbows (90˚ & 45˚,Long& Short),Tee (Equal, Reducer) ,Reducers (Concentric and Eccentric),Cross, Lateral Tee, Flange ,Blinds.

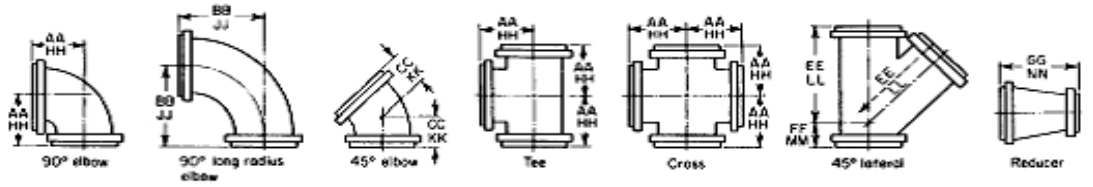
Elbows

They are used to divert the flow from one direction to another intended to join a piece of pipe and another fitting at an angle . They are available in different angles and in sizes.

Long Radius Elbow -In a long radius elbow the radius of curvature is 1.5 times the nominal diameter. Long radius elbows give less frictional resistance to the fluid than the short elbows

Short Radius Elbow-In a standard elbow the radius of curvature is 1.0 times the nominal diameter of the pipe.

TABLE A2.7 Dimensions of Typical Commercial Cast-Steel Flanged Fittings (from ASME B16.5-1996)



Nominal pipe size	⅛-in raised-face						Ring joint							
	AA	*BB*	*CC*	*EK*	*FF*	*GG*	*HH*	*JJ*	*KK*	*LL*	*MM*	*NN*	*L**	*D1*
							Class 150							
1	3½	5	1⅝	5¾	1⅛	4⅛	3⅜	5⅛	2	6	2		⅜	⅝
1¼	3⅝	5½	2	6¼	1⅛	4⅛	4	5⅝	2⅛	6½	2		⅜	⅝
1½	4	6	2¼	7	2	4⅛	4⅛	6⅛	2⅛	7¼	2⅛		⅜	⅝
2	4⅝	6½	2½	8	2⅛	5	4⅝	6⅝	2⅜	8¼	2⅜		⅜	⅝
2½	5	7	3	9¼	2⅛	5⅛	5⅛	7⅛	3¼	9¼	2⅜		⅜	⅝
3	5½	7¾	3	10	3	6	5⅝	8	3¼	10¼	3¼		⅜	⅝
3½	6	8½	3½	11½	3	6⅛	6⅛	8⅝	3¾	11¾	3¼		⅜	⅝
4	6⅝	9	4	12	3	7	6⅝	9⅛	4¼	12¼	3¼		⅜	⅝
5	7⅝	10¾	4½	13½	3⅛	8	7⅛	10⅛	4¾	13¾	3⅜		⅜	⅝
6	8	11½	5	14½	3⅛	9	8⅛	11⅛	5¼	14¾	3⅜	See note‖	⅜	⅝
8	9	14	5½	17½	4⅛	11	9⅝	14⅛	5⅝	17¾	4⅜		⅜	⅝
10	11	16½	6½	20½	5	12	11⅛	16⅛	6⅝	20¾	5⅛		⅜	⅝
12	12	19	7½	24½	5⅛	14	12⅝	19⅛	7¾	24¾	5⅜		⅜	⅝
14	14	21½	7½	27	6	16	14⅛	21⅛	7⅝	27¼	6⅛		⅜	⅜
16	15	24	8	30	6⅛	18	15⅛	24⅛	8¼	30¼	6⅜		⅜	⅜
18	16½	26½	8½	32	7	19	16⅝	26⅝	8⅝	32¼	7¼		⅜	⅜
20	18	29	9½	35	8	20	18⅝	29⅛	9⅜	35¼	8⅛		⅜	⅜
24	22	34	11	40½	9	24	22⅛	34⅛	11¼	40¾	9⅛		⅜	⅜

V. SEQUENCE OF EVENTS DURING FABRICATION

Prefabrication for Carbon Steel and Stainless Steel and other DSS, SDSS,CRAshall take place at separate location to avoid any mix up and contamination on stainless steel ,DSS,SDSS,CRA..Toolsfor DSS,SDSS,CRA Stainless steelshall be separatedfromother workstools and shall be colourcoded with different colour.

5.1 Welding Procedures & Welders Qualification

5.1.1 Welding Procedure and Welding Qualification activities shall be controlled though the document "Weldingcode -ASME Sec IX"

5.1.2 Welding Consumable handling shall be done as the manufacturer's recommendation or as per the customer requirements

5.2 Receipt of materials from Supplier's stores and storage.

5.2.1 The Piping materials (Pipes, Fittings, Flanges, etc) received at site, shall be stored in the storage area. Material shall be kept on stands with wedges or on saddles. Materials of different specifications / grades shall not be mixed.

5.2.2 Piping supervisor shall draw required material from the stores as per the priority of the

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progress schedule. Prior to shifting of piping materials to fabrication area, piping supervisor shall ensure the identification of the materials e.g. Material grades, Colour code and schedule of the items.

5.2.3 While transporting and storing the Stainless Steel material, care shall be taken to avoid contact with ferritic steels and galvanized components to prevent contamination of SS,DSS,SDSS,CRA... Separate area shall be assigned for the storage of DSS,SDSS,CRA, stainless steel piping.

5.3 Marking and cutting

5.3.1 Pipes shall be marked and cut as per dimensions specified in the isometric drawing. Carbon Steel, Low and Intermediate alloy steels may be cut using thermal cutting. The cut surface shall be ground to a smooth, bright uniform finish by removing approximately 3 mm of metal. Thermally cut edges of low and intermediate alloy steels shall be dressed back at least 2 mm by machining or grinding. Plasma cutting with mechanically guided torch may be used for stainless steels,DSS,SDSS,CRA in which surface shall be ground to bright metal. Alternatively cutting may be carried out by grinding machine using cutting disc, where appropriate.

5.3.2 After grinding, the weld edges and surrounding material shall be cleaned with Acetone for CRA,DSS,SDSS,Stainless steel materials and visually examined to ensure freedom from cracks, notches or other defects which may affect weld quality. Any bevel edge that has been damaged shall be restored by machining or grinding within the tolerances required by the welding procedure to be applied. Restoration involving welding shall not be permitted.

5.3.3 Hole in the pipe for branch connection shall be made by drilling on to 1 inch and small size pipe.

5.3.4 Identification details such as Heat No, Iso. / Dwg. number, Line size and line number shall be transferred by means of paint markers(choloride and floride free for CRA,DSS,SDSS,SS) or hard punching, prior to cutting pipe lengths. Pipes will be supported on stands or saddles with wedges. Care shall be taken to prevent contamination on stainless steels DSS,SDSS,CRA..

5.3.5 Support items (plates, columns, beams, channel, angles, flats etc) shall be marked as per the dimension & profile mentioned in the support standard drawings. Cutting shall be done as per markings manually or by pug cutting m/c by gas cutting and edges shall be trimmed by grinding.

5.3.6 Tag or punching for support type, shall be made for identification as per drawing.

5.4 Weld beveled edge preparation

5.4.1 Weld preparation on Pipes, fittings, flanges & valves shall be in accordance with the code ASME B 31.3 and as specified in the applicable WPS(Welding Procedure Qualification).

5.4.2 All new weld bevels shall be visually inspected. If any indication is observed then the entire bevel shall be removed and the pipe shall be ultrasonically examined for laminations over a zone of 50 mm back from the new bevel edge. The acceptance criteria shall be that the maximum dimension of the minor axis of the lamination shall not exceed 6.3 mm and the maximum product of the major and minor axes shall not exceed 50 mm^2.

5.4.3 All the surfaces to be welded shall be thoroughly cleaned from oxide, scale, oil or other foreign material with Acetone for SS,DSS,SDSS,CRA and shall be dry. The cleaned surface shall extend at least 50 mm beyond the substrate surface touched by the arc

5.4.4 The root opening, root face and bevel angle shall be within the tolerances specified in the WPS

5.4.5 Shop beveling of field welds is not required if a makeup length (extra length for field cutting to size) is provided. In these cases, bevels shall be prepared after cutting the relevant pipe spool to the required length.

5.4.6 Pipe for socket weld joints shall be cut square and burrs removed.

5.5 Fit up and tack welding of the assembly

5.5.1 The fit up of the assembly shall be as per WPS & Drawing requirements. The piping department shall not make any assumptions where inadequate fabrication data exists like horizontal or vertical slope notations and orientations in the isometric drawings. The same shall be discussed between Contractor and Customer and shall be resolved if it is not specified in the code .

5.5.2 Fit – up shall be carried out by using either Bridge techniques or direct tacking on root. Where root tack welding is specified in the WPS, the welding parameters shall be those for the root pass of the approved WPS, including any minimum preheat or ambient temperature requirements, and shall be performed by qualified welders.

5.5.3 For root tacks in pipe upto 4 inch diameter, a minimum of three tack welds shall be deposited at equal spaces around the joint. For root tacks in pipe exceeding 4 inch diameter, a minimum of four tack welds around the joint shall be made. Tack weld shall be minimum of 25 mm long wherever practical. When direct tacking on root, tack weld shall be fused with the root pass

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weld, except for those having crack which shall be removed prior to root pass welding.

5.5.4 Where bridge or bar tacks are used, these shall be welded using the electrode and parameters shown in the approved WPS for the fill passes. In Bridge technique small metallic bullets shall be cut from same piping material or the same consumable going to be used, and tacked in the groove at as many places as necessary depending on the diameter of the pipe. Ensure no damage in the groove, or root gap or root face and tack welds shall not touch the root gap or the root face. Welding shall not encroach on the root area

5.5.5 Misalignment due to unequal internal diameter is permitted to a maximum of 1 mm provided it is distributed equally around the circumference. If the misalignment exceeds the above value, provided it is caused by dimensional variations within the specified tolerance or the use of two piping component of different nominal thickness and the same outside diameter, tapering of the internal diameter of the thicker member to a taper of 1:4 should be carried out.

If the external surfaces of the two components are not aligned, the weld shall be tapered between them.

5.5.6 Non-welded fit up clamps are preferred for alignment of all pipe, however temporary attachment may also be used for alignment purposes. Temporary attachments used during fit up shall be of the same or similar material to that of the parent material and shall be welded using the appropriate qualified WPS. Carbon steel attachments shall not be used on stainless steel or copper nickel materials. Temporary attachments shall be removed by grinding without reducing the wall thickness of the pipe and shall be liquid penetrant examined if required.

5.5.7 In order to avoid excessive shrinkage stresses during weld solidification, a gap of 1.6 mm shall be left between the end of the pipe and the stop of the socket welding component.

5.5.8 In Butt welded joint diameter 3 inch and above before start of the welding Joint numbers, Line number shall be identified near the joint as per isometric drawing shown below. The piping department shall ensure that all the branches, tapping and pads are finished at prefab stage. The isometric drawing number, spool number shall be marked on each fabricated pipe spool, by paint marker (choloride and floride free markers for SS,DSS,SDSS,CRA)(as shown in sketch).

5.5.9 Inspection of fit up assemblies shall be done by QC inspectors, as per ITP for piping fabrication, and the relevant reports shall be duly filled out.

5.6 Weld Separation

5.6.1 The toes of adjacent circumferential welds shall be separated by a minimum distance equal to the nominal outside diameter of the pipe. Where the above requirement cannot be met, the minimum distance between the toes of adjacent circumferential welds shall not be less than five times the nominal wall thickness or 50 mm whichever is greater. Both joints shall be subjected to radiographic and penetrant test.

5.6.2 For circumferential welds on longitudinally welded pipes, the longitudinal welds shall be so positioned that

- The weld is at the upper segment of 120^{O} of the pipe.
- Any two adjacent longitudinal welds shall be at least either 45^{O} apart or 200 mm apart whichever is less .

When it is not possible to meet the above separation requirements between two longitudinal welded joints, the minimum separation shall be greater than five times the nominal wall thickness or 50 mm provided that the weld joint is fully radiographed and accepted

5.6.3 When longitudinal welded pipe is used in horizontal line, the pipe should be laid so that the longitudinal weld lines comes to upper part of the pipe. In no case the weld shall be located at the bottom of the pipe after installation; it should be located at least 45^{O} or 200 mm from the bottom of the pipe.

5.6.4 The minimum distance between the edges of pressure containing welds and a non-pressure attachment welds shall be twice the wall thickness of the thicker pressure part in order to allow non-destructive inspection of the pressure containing weld.

5.7 Shielding / Purging

5.7.1 Gases

Shielding gas shall be made traceable with identification numbers to their material test certificates. All material shall be visually inspected prior to welding to confirm compliance with specification. All bottles containing shielding gases shall have clear identification labels. The shielding gas for GTAW shall be high purity Argon per AWS 5.32. The oxygen content in the shielding (and backing) gas shall be less than 50 ppm. GTAW shall be used with a hydrogen free shielding gas to avoid possible cracking and

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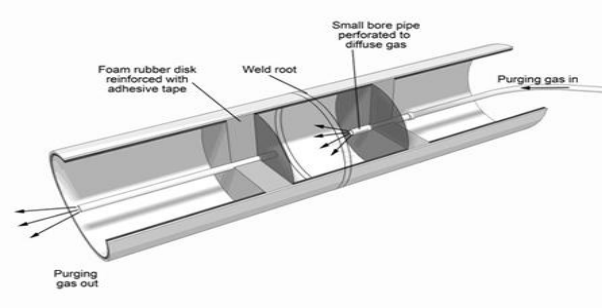
embrittlement of the weld. The shielding gas shall be pure argon (99.998 per cent vol.) for GTAW process.

5.7.2 Purging Equipment

- A purging unit.
- Aluminum tape
- An oxygen indicator

A purging unit should reduce the purge volume, provide a well-sealed chamber and introduce no contaminants. The purging gas must be distributed at a slow enough speed within the purge chamber so that argon and oxygen mixing is reduced and excess turbulence is minimized-a key to high-quality purging. At the same time, the purging chamber should be sealed against further oxygen penetration. To speed up the purge time, the loss of argon should be reduced and fresh oxygen prevented from entering the weld area.



The pipe's joints should be sealed from the outside with a halogen-free, temperature-resistant aluminum tape. Regular tape should not be used for sealing pipe gaps Contractoruse these adhesives generally contain halogens, specifically chlorine. Chlorine, like hydrogen and oxygen, is absorbed by reactive metals at high temperatures, causing embrittlement in the weld surface.

5.7.3 Use of Soluble Dams

The use of soluble dams for minimizing back purge requirement during piping fabrication shall be approved by the Welding Technical Authority Team of the customer. When dams are to be used on site, working procedures shall ensure removal after welding. The effectiveness the procedure shall be demonstrated.

5.7.4 Purging Techniques

The welder should strive for enough flow to force the oxygen gently out and maintain a slightly higher pressure inside than outside the purge chamber. This action prevents fresh oxygen from re-entering the purged area through the weld seam when welding and, at the same time, minimizes excess turbulence, which can cause instability in the welding arc

Besides using practical experience to determine purge time, welders can use many formulas that have been calculated to find the exact moment to weld. However, weld quality depends on many factors, including humidity, volume and material.

The correct length of time to typically purge is until the oxygen sensor indicates a value below 70 PPM or otherwise specified in the Approved WPS for stainless steel,DSS,SDSS,CRA or below 50 PPM for titanium. This can take between two and four minutes when using a purging unit.

The welding parameters should be set by the welding engineer and enforced by quality control. Also, purging should continue until the weld seam has cooled sufficiently so that oxidation can no longer occur. When making multiple root-pass welds, purge gas flow should be maintained until the weld seam is 3/8 to 1/2 inch thick, depending on the specific welding procedure and the material's elasticity.

5.8 Welding Condition

5.8.1 The material temperature shall be above 5^0 C. If material temperature below 5^OC preheating up to 50^0 C or as per the relevant WPS whichever is higher shall be carried out before start of the welding.

2. No welding shall be done if there is impingement of rain or high wind in the weld area except that weld area is protected against strong wind to keep welding arc and shielding gas in proper weldable condition. Welding shelters shall be provided at all the times to the weld area. In windy conditions the pipe ends shall be sealed to prevent through draughts.

3. Weld surfaces shall be thoroughly cleaned and dried before welding. Moisture shall be removed to a bandwidth of at least 75 mm either side of the joint by means of blowers, or in exceptional cases a gas burner may be used to produce a controlled preheat of 50^OC.Welding and cutting torches shall not be used.

10. Welding of joints

5.9.1 Welding shall be done as per the approved WPS by qualified welders. All the requirements of WPS, project specification and HSE practices shall be strictly adhered to. Welder identification number shall be marked near the joint except less than 3 inch dia joint.

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5.9.2 Arc strikes struck only on the fusion path. Root pass shall be made without interruption other than for changing the electrodes or to allow the welder to reposition himself. Welds shall not be allowed to cool until at least half the thickness is welded.

If Arc Strike is struck outside the fusion path then it shall be removed and PT or MT to be conducted

5.9.3 Thorough inter-run cleaning and slag removal shall be carried out by grinding or chipping by mechanical tool before deposition of subsequent layers. Cleaning of stainless steel metal alloy or nonferrous metal shall be done only with the uncontaminated stainless steel tools and the welds shall not be peened.

5.9.4 No welding shall be done if there is impingement of rain, snow or high wind in the weld area except that weld area will be protected against strong wind to keep welding arc and shielding gas in popper weldable condition.

5.9.5 When the surface of the parts to be welded are wet, the base metal shall be dried and completely clean just prior to welding. If necessary drying shall be performed using Propane torch except oxy acetylene flame.

5.9.6 After purging operation is completed the purge gas flow rate shall be reduced to that shown on the applicable WPS. Welding shall be started only after reducing the gas flow rate.

5.9.7 Masking Tape shall be fixed all around the joint externally to make an inert enclosure. Under no circumstances shall the low chloride masking tape be used on the internal bore of the pipe. This masking tape shall be removed in advance by the welder just 10 mm to 15 mm in the same direction as the welding arc progress beginning at approximately the 6 O'clock position and progressing in uphill direction, alternately for branch connection in a horizontal or uphill direction depending on joint orientation.

5.9.8 The purging shall be maintained until the completion of the hot pass (2nd Pass). The purge will be dropped only when the interpass temperature has fallen below 150° C.

5.9.9 Prior to Preparation / fabrication / Cutting of vessel wall or process piping branch connection, it shall be UT tested to confirm freedom from lamination discontinuities, i.e. no recordable indications .The weld foot print and 75mm minimum about the weld shall be examined.

Care shall be taken to prevent distortion of header pipe while cutting the branch holes and welding the branch connection. Temporary strong backs where necessary; may be provided prior to welding the branch connection. Other suitable measures such as holding the header pipe in camber prior to welding may also be considered.

Supplementary to the requirements for visual examination in ASME B31.3, branch-to-run pipe welds of branch fittings or outlets of pipe-to-pipe connections shall be visually examined for proper geometry, branch fit-up and weld penetration.

The examinations shall be recorded for each branch connection.

For the purpose of internal examination of the weld penetration, the branch-to-run pipe weld should be made before the first butt weld in the branch pipe next to where the branch connection is made.

5.9.10 When longitudinal welded pipe is used in horizontal line, the pipe should be laid so that the longitudinal weld lines comes to upper part of the pipe.

5.9.11 Removal of the assembly jig shall be made by means of grinding or gas cutting, never be struck down by hammer or plucked off.

In case of removal by gas cutting, cutting shall be carried out at upper part of the weld toe and the remaining weld metal shall be finished by grinder. And after removing the jigs, the finished parts by grinding shall be inspected by means of visual examination followed by NDT(PT).

5.9.12 Interruption of Welding

Interruption of welding should be avoided .When interruption is unavoidable a minimum of three passes or 1/3 of the joint thickness whichever is greater should be deposited

The weld shall be wrapped in a dry thermal insulating blanket for a slower cooling Upon resumption of welding ,preheat in accordance with the approved WPS shall be applied .In case of extreme situation when the above condition cannot be made the welding Engineer shall be consulted ,who will decide further in consultation with the Customer

5.9.13 Welding Reinforcement Pads

Each segments of reinforcement pads for pressure openings shall be provided with two 6 mm holes drilled and tapped for testing and venting. These two holes shall be located 1soo apart.

All reinforcing pads for structure attachments shall be provided with an untapped 6 mm hole for venting. One of the holes in each pad or pad section shall be located at the lower most point of the pad in the erected position of the piping. Reinforcement pads shall be formed that no gap larger than 3 mm shall exist between the pad and the pipe. No gap larger than 1.8 mm measured before welding, shall exists between the periphery of the reinforcement pad and the pipe to which it is attached.

10. Repair of Weld Joints

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All repairs shall be executed by welders qualified in accordance with General repair procedure

5.10.1 A Separate WPS will be used for repair activities which should be qualified as per the specification requirements.

5.10.2 Cracks shall not be repaired. When cracking is observed in the completed weld, the weld shall be cut out entirely. For partial penetration repairs, the total length of excavation shall not exceed 30% of the weld length. For full penetration repairs, the total length of excavation shall not exceed 20% of the weld length.

5.10.3 Excavation shall be by machining or grinding. After excavation, visual and PT inspection shall be performed to confirm defect removal. At the ends and the sides of the excavation there shall be a gradual taper from the base of the excavation to the surface of the weld metal. The profile shall be such that adequate access for welding is achieved.

5.10.4 After completion of repair welding, the full extent of the repair shall be inspected by the method prescribed for the original weld to a length extending 50 mm beyond each end of the repair.

5.10.5 If again unacceptable defects be found on re-inspection then the weld shall be cut-out entirely.

5.11 Dimensional Tolerances

Length	<1.5m	≥1.5m
Distance of any two parallel or crossing center lines	±1.5mm	±3 mm
Center to flange face		
Flange face to flange face		

5.11.1Flange face alignment

Generally, the free insertion of the bolts in flange sets is sufficient to demonstrate acceptable lateral alignment.

DN	Maximum Misalignment
≤ 100	2mm
≥ 100	3mm

5.11.2 Flange Parallelism

Flange face alignment shall be checked by measuring the distance between the mating flanges of the pre-assembled joint. Measurement shall be taken around the circumference at equal distances from the center line the outside rim of the flange will normally be the most convenient position.

5.11.3Nozzle faces on Static Equipment.

Alignment of nozzle flange face with the indicated plane shall be within 0.5 degree in any direction.

5.11.4 Flanges connecting to rotating Equipment (pumps, compressors etc)

The flange face alignment check shall be performed with bolting inserted loosely, and the acceptance criteria shall be as follows

Flange Diameter (DN)	Max. misalignment at OD of flange
<300	0.2mm
300 to 600	0.3mm
≥600	0.5mm

5.11.5 Straightening of Pipe Spools

The straightening of the spools shall not be allowed. Any repair work shall be as per an approved procedure and with prior customer approval.

5.12 Preheating

5.12.1 Preheating of the parent metal prior to welding, where specified in the applicable WPS, shall be carried out using gas heating torches or

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electrical resistance heating or induction heating. An even temperature distribution shall be ensured.

5.12.2 Welding and cutting torches shall not used for the pre heating

5.12.3 Preheating, by means of gas heating torches, shall be carried out up to 19 mm thickness for Carbon steel and for alloy steel where preheating temperature required is below 200°c

5.12.4 When pipe must be threaded before heat treatment and such threaded parts would be affected by heat treatment, all exposed threaded surfaces shall be protected during heat treatment with high temperature silicon paint of 10µ dry film thickness.

5.12.5 Heating width of preheating shall be more than three times of the pipe thickness to each side from the bevel end, but it is not necessary to exceed 100 mm. The preheat zone shall extend at least 25 mm beyond each edge of the weld.

5.12.6 The preheat temperature shall be checked by thermo stick to assure that the required preheat temperature is obtained prior, and is maintained during the welding operation, and the thermo stick shall be free of lead and Sulphur (less than 1 ppm) as per the SP 1173 Para 8 also for the Olets welding the minimum preheat is 50 deg C above that indicated by the code .

5.12.7 If the interruption is inevitable, means to avoid sudden cooling shall be taken and preheating shall be done before re starting of welding.

5.12.8 When WPS specifies the Pre heating temperature >200 then electric resistance heating shall be used

5.12.9 Above 19mm thickness electric resistance heating shall be used

5.12.10 Above 6" OD or attachment weld above 300mm, resistance heating using heating pad to be used

5.13 Post weld heat Treatment

Post weld heat treatment temperature ranges and holding times shall be in accordance with the code ASME B 31.3, and applicable WPS. Localized PWHT of pipe welds shall be carried out using the electric resistance heating and the temperature control shall be with the thermocouples.

5.13.1 Thermocouple attachments should preferably be by either capacitance discharge method or by nut and bolt construction attached by two tack welds. The number and position of thermocouples shall be in accordance with the Document *"Procedure for Post Weld Heat Treatment"*.

5.13.2 When welding two different P. No material the PWHT should be that specified for the material requires the higher tempt.

5.13.3 PWHT shall be done after completion of all activities, repairs and any nondestructive examination, unless otherwise specified.

5.13.4 Before starting PWHT confirm that there should be no deformation of piping by heating, nor adverse affection by heating to the parts such as valve, gasket, instrument, etc

If necessary, additional temporary supports or other suitable protection shall be provided.

5.13.5 Hardness test of production weld after PWHT shall be performed in accordance with "Specification for Piping.

No welding or heating shall be carried out after final PWHT.

5.14 Identification of joints & execution of NDT

5.14.1 The QC Inspector shall identify the joints to be offered for NDT in Daily Weld Inspection Report Doc as per the NDT percentages specified. In case of weld repair all control measures shall be applied and the same or appropriate NDT shall be carried out.

5.14.2 ASNT RT LEVEL II approved by Customer shall perform interpretation of radiographs. The NDT Contractor shall prepare the evaluations and submit to CONTRACTOR for review. CONTRACTOR shall review the reports and interpret the radiography films and shall submit to CUSTOMER for review and interpretation, where required as per ITP.

5.14.3 Welds identified to contain unacceptable defects shall be repaired using the following applicable WPS and penalty radiography for welds found defective in RT should be in accordance with design code.

5.14.4 The requirement for examination of 10% of the welds shall mean that 10% of the production welds shall be randomly and independently selected throughout the fabrication period and fully examined. The random selection should be equally distributed over all welders and all type of welds, which includes welding procedure, pipe size, thickness, welding position, etc.

The first 10 production welds made by each welder shall be examined before that welder performs any further welding as per the respective codes and standards.

5.14.5 The extent of other examination such as radiography, ultrasonic, penetrant testing etc shall be identified with each pipe class during execution

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of the project and shall be followed according to that. NDT shall be carried out according to respective NDT procedures.

5.14.6 5% of the branch –to-run pipe welds of branch connections with a size of the run pipe equal or less than DN 150 (NPS 6") shall be examined for this purpose by radiography

5.15 Pneumatic Testing of Reinforcement Pad

- Prior to testing air shall be blown through the vent holes (only where two holes are available) so that any presence of dust shall be removed and weld shall be checked for cleanliness.
- A foot pumps/hand pump or nitrogen cylinder controlled by a regulator and pressure gauges shall be connected to the vent hole by a threaded adaptor.
- The system shall be pressurized to 15 psi (1 bar) then bubble forming leak detection solution shall be applied to pad welds for detection of any discontinuities.
- The pressure shall be kept for a period of 10 min or the observation time whichever more.
- The pressure gauges used shall be duly calibrated and valid calibration certificate shall be available.
- If any leakage is observed, the pad shall be depressurized and the leak points to be attended or repaired. The pad shall be re pressurized and tested in the same manner as above.
- The pneumatic test results shall be recorded on "RF pad leak test certificate".

5.16 Spool Release

5.16.1 The piping department shall identify the spool which are completed with respect to welding and shall inform the spool coordinator for QC release. QC inspector shall ensure that all NDT, PWHT and reinforcement pad testing (if any) are completed and release the same to CUSTOMER QC for review. The spools that are released by CONTRACTOR & CUSTOMER (Piping & QC) including straight lengths (if any) shall be sent for painting. The release of spools for paint shall be recorded in "Spool Release Note" Form .

5.16.2 Particular attention shall be given to maintain Weld identification during grid blasting and painting as per the customer Requirements.

All the painted spools shall be collected and stacked according to material, area and isometric. All spools shall be protected from corrosion ingress of foreign material and mechanical damage by the provision of end covers and flange protection. Spools shall be shifted to site as per the schedule and program of the site requirement. Spool coordinator shall check such spools for internal cleanliness and shall record the same in the register or in electronic file, prior to shifting the spools at site.

6. Sequence of events during Erection of Piping

6.1 Inspection of Pipe Rack / Tracks / Equipment

6.1.1 Pipe racks / tracks / equipment and routing shall be checked with respect to piping GA Drawing, isometric drawing and equipment drawings prior to erection of piping components. Erection of piping on pipe rack and around equipment shall be commenced after respective structures; pipe rack and equipment have been installed and aligned.

6.1.2 Checking shall be made about cleaning the inside of the pipes, flange seat surface, condition and availability of pipe supports and foundation etc.

6.1.3 Scaffolding and temporary platform shall be arranged to carry out fit up and welding of joints at elevated positions**.**

6.1.4 A close coordination to the other work shall be made so that the pipe assembly work shall not interfere with other works

6.2 Assembly & Erection of Piping

Prior to releasing the fabricated piping for erection checks the following:

- Where possible, supports to be welded on to the pipe shall be completed prior to erection work at the fabrication location.
- All necessary Material identification, NDT and PWHT shall be completed as per the specification and records shall be available for customer review.
- If supports are to be welded after installation, for the purpose of any in-situ adjustments, the supports may be tack welded at the fabrication location and forwarded to the erection location.

6.2.1 Piping components shall be lifted and placed in a safe way to avoid any undue strain on the piping components during erection and installation works. Before installing the pipe spools it shall be ensured that there is no foreign material (debris, dust, etc.) inside the pipe material.

6.2.2 When making up connections to equipment and machinery, protection shall be provided to prevent from getting foreign substances into them

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6.2.4 When piping is connected to equipment and machinery, no load shall be allowed to the equipment or machinery. Making up connection to rotating machines shall be done with the consultation of Customer's Engineer. Excessive misalignment between rotating machines and piping shall be basically adjusted by piping.

6.2.5 All necessary measures shall be taken to prevent stainless steel piping components getting into contact with carbon steel and galvanized material.

6.3 Support Installation

6.3.1 Shoe or pads for shoes shall be welded to the piping with careful way avoiding any welding defects. Special care must be taken to the anchor points, as they are to be heavily loaded. Shoes pads for low alloy steel piping shall be of the same material as the pipes.

6.3.2 In case of lines having shoe or saddle support, site measurement between distances of supports may be taken and marked on the assembly. The supports are then welded on the spool assembly on the ground. In case of lines having guide or anchor the supports are to be welded in position.

6.3.3 Supports shall not be welded to the equipment unless otherwise specified.

6.4 Valve Installation

Following Preparations shall be carried out prior to the installation of Valves

- The flushing / blasting of the piping should be completed as per the code and customer requirements.
- The permanent label / tag is fixed and matching with the drawing
- Inspect valves for any damage. (Dent, Corrosion, Defects)
- The maintenance access to the valve, flow meter(if possible)
- Flow arrows: Install each valve in the line with the arrow pointing in the direction of the flow. To verify proper installation, make sure each valve opens in the direction of desired flow.
- Valve support: Valves must be adequately supported with pipe hangers, etc. to prevent additional loading on the valve body
- Surface of the flanges shall be free from the defects (if applicable)
- Alignment of the Pipe.
- Handle threads on valves carefully to avoid damage.
- Safe connection: Valves must be adequately connected (threaded, welded, etc.) to surrounding piping to prevent unsafe discharge during filling and/or operation
- Cleaning: Care should be exercised when cleaning valves (with steam, chemicals, etc.) to protect them against excessive pressure, temperature, and/or corrosion
- Conform whether the pipe is supported properly
- The valve from full open to close to assure operability.
- Cutting and Beveling inspection followed by NDT (if applicable)
- Approved rigging plan is available for the erection
- Welding /Installation should be done as per the Vendor manual

After the Welding / Installation activities a thorough Visual inspection should be done in order to confirm that there is no damage for the Valve and its accessories.

6.5 Final Corrections of Fabricated Piping

6.5.1 Modifications of the dimensions of a fabricated pipe spools can be carried out by cutting and re welding. Maximum temperature during the final corrections shall not be more than 600°C and the duration of heating shall be kept as minimum as possible. Temperature control shall be done by using temperature sensitive crayons or contacting type temperature measuring instruments. Hardness after heat correction for low and intermediate alloys, stainless steels shall be in accordance with the design code and project specification. Heat application method shall not be done on PWHT joints and lines containing those welds

For carbon steel which does not require a PWHT, the maximum temperature during alignment corrections shall be 600 °C (1110 °F). Temperature-indicating crayons or contact thermometers shall be used to measure the maximum temperature. If temperature-indicating crayons are used, a margin of 50 °C (90 °F) shall be taken to allow for measurement inaccuracy, i.e., the reading with the crayon shall not exceed 550 °C (1020 °F). Forcing may be applied if necessary. Cooling in still air shall be applied.

6.6 Line Check before Testing

6.6.1 Line checking shall be conducted, as given below, prior to pressure tests in order to confirm the installed condition that it is exactly in accordance with the AFC drawings without any defects

6.6.2 All fusion joints are visually inspected

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6.6.3 Pipe size, fittings are as per drawings and routed as per isometric
6.6.4 All valves are installed as indicated in the Piping flow sheet
6.6.5 All vents and drains are installed according to drawings.
6.6.6 All Pipe Support, anchors, guides are installed as detailed on the Construction drawings
6.6.7 All additional supports, if required are provided
6.6.8 All isometrics as per drawing index are available in hydro test packages and test lines & Limit are properly marked.

6.7 Submission of Hydro / Pneumatic test package

6.7.1 Test pack consisting of Weld joint history sheet, marked up isometric sketch & P&IDs, will be submitted to customer for verification, for the piping that is ready for testing. Line inspection shall be carried out with Customer piping and Quality Control Team.
6.7.2 Punch list shall be prepared for outstanding items and rectification if any. The punch items categorized as those to be completed before testing shall be verified and confirmed. The signed off line inspection report and punch list shall be enclosed to the test pack. On acceptance of the piping system for testing by customer, requisition for hydro / pneumatic test shall be submitted in advance for to witness the test.

7. Inspection prior to the Integrity Testing

- Before starting the job, the drawings shall be checked for the latest revision.
- All piping material shall be checked for conformity to specifications, construction drawings
- Welding surveillance shall be carried out by QC inspector daily at least once a day at fabrication shop area and once a day at site installation area.
- All measuring Instruments shall be checked for valid Calibration.
- Area to be joined shall be checked for the cleanliness, free from paint, grease, dirt etc.
- List of Inspections that are applicable
- Visual Inspection
- Radiography Testing Butt joints as per requirement
- Dye penetrant Testing on fillet or lap joint as per requirement
- Ensure the test valves and gauges are calibrated prior to testing

8. Integrity Testing of Piping Systems

8.1 Safety Requirements

- All area needs to be barricaded to keep away the unauthorized personal entry and warning boards to be place prior to the testing activity
- All lie shall be examined before the test, to check the positioning of the line from moving to withstand the test medium load.
- One person needs to there at the manifold area to monitor and release the pressure
- No rework repair after the pressurization of the line
- All the persons involved, shall wear the PPEs
- To the possible extent, movement of men and equipment will be avoided

8.2 Preparation for the Testing

- All weld joints and flange joints have to kept exposed without painting /Insulation
- Pressure test will be conducted as per the process piping code requirements ASME B31.3
- Installation of the temporary gaskets for the blind flanges
- The vent should be identified and opened, to confirm there is no air entrapment.

8.3 Pressure Gauges and Relief Valve Installation

- Unique numbering needs to be provided to identify the gauges and the relief valve units
- Need to assure the devices are properly calibrated
- Diameter requirement for the pressure gauge dial is min 125mm
- Gauge Ranging up to max 1.5 to 2 times of the test pressure
- Relief valve should be set at a pressure not higher than 10% of the test pressure

8.4 Procedure for the Integrity Test

- Method of testing, acceptance, Completions shall be performed in accordance with ASME B 31.3 Process Piping Code

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