Fabrication and welding of Pressure vessel

1) Approval of the Drawing:

Before the start of the manufacturing of the vessel, the manufacturer shall send the proposed final drawing to the purchaser.

It shows all the pressure portion of the vessel and the following details:

a) A statement that the vessel is to be constructed to this standard.

b) Specifications to which the material may conform.

c) Welding process to be adopted for all the parts of the vessel.

d) Large scale dimensional details of the weld preparation for the longitudinal and the circumferential seam.

Detail of the joints for the branch pipes, seatings, etc, and the position of the joint relative to the longitudinal and circumferential seam.

e) Design pressure, temperature, and major structural loadings.

f) Test pressure.

g) The amount and the location of the corrosion allowance.

H) Additional required if any specified by the purchased.

NOTE: No modifications shall be made to the approved drawing except with the prior agreement between the purchaser and the manufacturer.

2) General Consideration for the Welded Joints

The following are the considerations that are taken into account for the welded Joints:

i) All the details of design and construction shall conform to the provisions of this code,

ii) The material shall conform to the requirements of the appropriate Indian Standards or shall be any approved material.

iii) The welder should be qualified for the type of welding he is performing Which can be checked with the **Welder's Performance Qualification.**

Iv) Nozzel, pads, branches, pipes, tubes, etc and other non-pressure parts may be welded to pressure parts provided that the strength and the characteristics of the material of the pressure parts are not affected adversely.

v) The manufacturer of the pressure vessel forming the vessel under the code shall be responsible for the welding process performed under the code.

It is the responsibility of the manufacturer to conduct the test required in the code to qualify the welding procedure employed and judge the performance of the welder.

Vi) The manufacturer shall maintain a record of the welding procedure qualification tests.

These records give an idea about the usage of the proper material and the procedure as the code used and shall be asked anytime by the inspection authority if he so desires.

3) DESIGN OF THE WELDED JOINTS:

Now, we shall see the design of the welded joints in detail before that let's see the important precautionary measures we need to take:

a) Single fillet lap joint shall not be used without the previous consent of the inspection authority.

b) In Design, all the aim should be there to avoid disturbance in the flow of lines of force, in particular in constructions subjected to fatigue stress.

- Holes and the openings shall not be placed in the heat-affected zones of the welded joints.
- When such openings are unavoidable, such holes can be located on circumferential joints provided that the weld is radiographically sound for a length of 3 times the diameter of the hole on either side.C) The welded joint should be positioned in such a manner that the joints are subjected to the lowest possible bending stress is produced.d) Attachment of the parts by welding which cross or which are near existing main welds in pressure parts should be avoided as far as possible.

- If such weld cannot be avoided, they should cross the main weld completely rather than stop abruptly near the main weld where the stress concentration in these areas can be avoided.
- Further, such a section ought to be exposed to neighborhood radiographic assessment or other affirmed non-destructive tests.
- **The concentration of the welded joint** should be avoided and the design should be made in such a way that no two main seams together under acute angle or cross each other.
- The cases where it is not possible to comply with this requirement, the intersection of the welds should be radiographed, 100 mm on each side of the intersection.

Circumferential joint

- The longitudinal joints should be staggered when assembling a cylindrical shell from two parts by mean of a

Circumferential joint.

- The distance shall be at the last five times the thickness of the thicker plate.

C) BUTT joint

- The butt joint is required between plates which differ in thickness by more than $1/4^{th}$ the thickness of the thinner plate or more than 3mm.
- The thicker plate will have a tapered transition.
- The transition section will have a minimum length of four-time the offset between the abutting plate edges.
- The progress area might be framed by any procedure that will give a uniform shape. The weld may be entirely or partially in the tapered section or adjacent to it.

- It is recommended that the width of the parallel portion may not be less than 32mm when the butt weld is to be radiographically examined.

PREPARATION OF THE PARENT METAL

A) Laying out and cutting the plate

i) **Plate Identification**

- In laying out and cutting the plates, the manufacturer's brand should be so located as to be visible when the vessel is completed.

- When the cast number, quality of the plate, tensile strength, and the manufacturer's name are unavoidably cutout then they shall be transferred by the vessel manufacturer.
- The form of transferred markings shall be readily distinguishable from the plate manufacturer's stamping.
- The arrangement for the transferred marking should be agreed with the inspection authorities.

ii) CUTTING THE PLATE

- The plate shall be cut to size and shape by machining and or flame cutting.
- Where the plate thickness does not exceed 25mm cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of one-quarter of the plate thickness.

iii) Preparation of Plate Edges and Opening:

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- Welding preparations and openings of the required shapes may be formed by the following methods:

Step-1

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a) **Machining**, **chipping** or **grinding**, chip surfaces which are not covered with weld metal shall be ground smooth after chipping.

b) **Flame cutting** which includes plasma arc, oxy-gas with or without flux injection or equivalent fusion cutting process.

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STEP-2

- After the edges of the plate have been prepared for welding, they are thoroughly visually examined for cracks, laminations, slag inclusion, or other defects.
- Edges that have been flame cut by hand shall be cut back by machining or chipping for a distance of one-quarter of the plate thickness, but in no case, it should be less than 3mm.

STEP-3

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- Edge surface discoloration which may remain on' flame-cut edges shall not be regarded as detrimental, but burnt metal, slag, and scale shall be removed.

- Brushing of stainless steel edges shall be done with **stainless steel brushes**

STEP-4

- Rust, scale, painting, oil, slag, etc, from the flame-cutting or other contaminations of the fusion faces, shall be removed before welding is commenced.

- In the case of stainless steel, it is usually achieved by decreasing or pickling or both.

STEP-5

- The surfaces to be welded shall be free from foreign materials.
- Grease, oil, or marking paints for a distance of at least 25 mm from the welding edge should be removed.

STEP-6

- Plates for shell sections and endplates shall be formed to the required shape by any process that does not impair the quality of the material.

- Carbon and low alloy steel plates may be formed by blows at a forging temperature provided the blows do not objectionably deform the plate.

- It is subsequently normalized or suitably heat-treated as may be agreed to between the manufacturer and the inspecting authority.

STEP-7

- **Plates Welded Before Forming** –

Seams in plates may be welded before forming provided they meet the specified mechanical test requirements.

- They are examined radiographically throughout the entire length after forming.

- After forming, the surfaces of such seams; in alloy steel parts, also in carbon steel parts over 25 mm in thickness, shall be ground smooth and inspected for cracks by **'magnetic crack detection, dye penetrants or other agreed means.**

We will discuss these tests in detail in my other article.

STEP-8

- **Butt Welds Between Plates of Unequal Thickness**-

Where two plates at a welded joint differ in thickness by more than 3 mm the thicker plate shall be trimmed to a smooth taper.

SR. No.	Joint Detail	Application
1	Double-Welded Butt Joint with Single 'V'.	Longitudinal and Circumferential Butt weld in plates less than 5mm thick and not more than 20 mm thick
2	Double-Welded Butt Joint with double'V'.	Longitudinal and Circumferential Butt weld in plates with thickness greater than 5mm
3	Double-Welded Butt Joint with Single 'U'	Longitudinal and Circumferential Butt weld in plates with thickness greater than 20mm.
4	Double-Welded Butt Joint with double'U'.	Longitudinal and Circumferential Butt weld where the thickness greater than 20mm.
5	Single welded butt joint with the backing strip.	Welding with baking bars in several layers. Device essential t prevent slag or powder running through welding.
6	Single welded butt joint with 'V' groove without backing strip.	Buttweld in plates not exceeding 10mm Thickness
7	Single welded butt joint with 'V' groove without backing strip.	Buttweld in plates not exceeding 10mm Thickness

iv) **ASSEMBLY OF THE PLATES AND FIT-UP**

a) TACK WELDING

- Tack welding is the initial stage of a welding process.
- The main purpose of the Tack weld is to hold the two pieces of material in place while you start your actual welding process.
- Various benefits of tack welding are-

--- It helps to maintain the joint gap.

---It helps in ensuring the strength.

---It holds the material in place.

---It ensures everything is aligned properly.

--- It controls the metal from moving while the actual welding is being carried out.

IMPORTANT POINT

-Tack welds in plates below 7.mm thick need not be removed, if it can be demonstrated to the satisfaction of the inspecting authority, that they are of sufficient length and have proper penetration to form part of the subsequent weld.

B) **TACKING BARS**

- When the plates are kept its position by tacking bars welded to the plates, such bars shall be properly removed, after the welding.
- They should be removed in such a manner that no grooves or notches are left in the plate surface.

c) **ROOT GAP:**

- If two pieces of metal are being welded and if we butt the flat edges completely together without a gap, you most likely will not be able to penetrate your weld through to the other side and your join will be weak.
- To get the complete penetration you need to leave a gap to allow the weld to go all the way to the bottom of the joint.

- Where a root gap is specified, the edges of the butt joint shall be held so that the correct gap is maintained during welding.

- The increase or decrease in root gap at any point in a seam, after tacking, **shall not vary by more than 1.0 mm**.

V) **Alignment and the Tolerances**

- **GENERAL**: Measurements shall be made to the surface of the parent metal and not to a weld, fitting, or other raised part.

- **Shell Section:**

i) Shell sections may be measured for out-of-roundness either when laid flat on their sides or when set up on end.

ii) When the shell sections are checked whilst lying on their side, each measurement for diameter shall be repeated after turning the shell through 90 degrees about its longitudinal axis.

iii) The two measurements for each diameter shall be averaged and the amount of out-of-roundness calculated from the average values so determined.

VI) **BEFORE WELDING**

Before any welding is commenced, it shall be ascertained that the chamfered edges are in alignment and that the defects in alignment at the surface of the plates are less than:

a**) For plates of thickness 5 mm or less** –

- t/6 for a longitudinal seam and t/4 for a circumferential seam subject to a maximum of 1 mm.

- **For plates over 5 mm in thickness** - Before any welding is commenced it shall be ascertained that the prepared edges are in alignment to meet the requirements of the welding process and that the defects in alignment at the surface of the plates are not more than:

b) **10 percent of the nominal plate thick**ness with a maximum of 3 mm for the longitudinal joint.

- However, for plates up to and including, 10 mm thick a misalignment of 1 mm is permitted.

c) **10 percent of the maximum nominal plate** thickness plus 1 mm with a maximum of 4 mm for circumferential joints.

vii) **Circumference:**

- The external circumference of the completed shell shall not depart from the calculated circumference.
- Based upon nominal inside diameter and the actual plate thickness by more than the following amounts:

Outside Diameter (Nominal Inside Diameter Plus twice Actual Plate Thickness)	**Circumferential Tolerance**

3oomm and up to and including 600mm	±5mm
Over 600mm	**±0.25 percent**

VIII) Out Of Roundness Of Vessels

- The difference between the maximum and minimum diameter at any cross-section of a drum or shell welded longitudinally shall not exceed 1 percent of the nominal internal diameter.

IX) **Tolerances:**

- The inner surface of a head shall not deviate from the specified shape by more than 1.25 percent of the inside diameter of the head skirt.

- Such deviations shall not be abrupt, shall be outside of the theoretical shape, and shall be measured perpendicular to the specified shape.

X) Attachments and Fittings –

- All saddle-type nozzles, manhole frames, reinforcement around openings, and different connections will adjust sensibly to the shape of the shell or surface to which they are appended.

XI) ***WELDING PROCEDURES:***

- All welding shall be carried out using a suitable welding sequence and in such a manner that harmful secondary effects are avoided.
- Wherever possible welding should be carried out in a down-hand position.

- During the execution of welding, the working side shall be suitably sheltered against the influence of weather (wind, rain, and snow).

- No welding of any kind shall be done when the temperature of the base metal is lower than 0°C in the vicinity of the welds.

- When the base metal temperature is below O degree Celcius, the surfaces of all areas within 200 mm of the joint, where a weld is to be deposited, should be heated to a temperature at least warm to the hand (15 degrees -20°C).

- Every run of weld metal will be altogether cleaned and all slag expelled before the following run is kept.

- The use of a filler material that will deposit weld metal with a composition and structure as near as that of the material being welded is recommended.

- In making fillet welds, the weld metal shall be deposited in such a way that adequate penetration into the base metal at the root of the weld is ensured,

- Double butt -welded joints shall be welded from both sides of the plate.

- the second side of the plate is welded, the metal at the bottom of the first side shall be removed to sound metal by grinding, chipping, machining or other approved methods.

- When butt joints are to be welded from one side only, care shall be taken in aligning and separating the edges to be joined.

To ensure proper fusion and penetration at the bottom of the joint.

- **REINFORCEMENT**

Additional weld metal may be deposited as reinforcement on each side of the plate to ensure that the weld grooves are filled.

The thickness of the reinforcement on each side of the plate shall not exceed the following thickness in case of severe and medium-duty vessels:

Plate Thickness (mm)	**Max. Thickness Of Reinforcement**
Up to 12mm	1.5 mm
Above 12 and up to 25mm	2.5 mm
Over 25 and up to and including 52	3.0 mm
Over 52	4.0 mm

XII) WELDING OF NON-FERROUS METALS

The commonly used gas process for welding:

a) **Aluminum Base Metal**

Welding Aluminum-based materials employ oxy-hydrogen or oxy-acetylene flames.

b) **Aluminium-nickel and cupro-nickel alloys**

- A neutral to slightly reducing flame should be used.
- whereas for copper-base materials, the flame should be neutral to slightly oxidizing.

c) **FLUX:**

- A suitable flux, applied to the welding rod and the work, shall be used except that no flux is required for a nickel.
- Boron-free and phosphorus-free fluxes are required for nickel-copper alloys and nickel-chromium-iron alloys.
- Residual deposits of flux shall be removed.

XIII) RECTIFICATION

a) Visual Defects:

- Visible defects, such **as cracks, pinholes,** and **incomplete** fusion and defects detected by the pressure test or by the other examinations, shall be repaired:

1) By removing the defective material by grinding, chipping, machining, flame gouging or other approved methods to sound metal, and re-welding.

2) Care is taken to ensure proper penetration and complete fusion of the fresh weld deposit with the plates and the previously deposited weld metal.

b) Repair of Drilled Holes –

- Holes drilled through the vessel wall for measuring thickness should be closed by welding with penetration for the full depth of the hole.

C) Repair of Cracks: -

Cracks or grooving in plates on which forming operations have been carried out may be removed to sound metal and welded subject to prior agreement between the purchaser and the inspecting authority.

ix) POST WELD HEAT TREATMENT

- Post weld heat treatment shall be carried out as the last operation before the pressure test.
- In the case of a carbon and low alloy ferritic steels, it is done either by **normalizing** or **by stress- relieving**.

- Special heat treatment in the case of high alloy steels and in the case of non-ferrous metals where necessary shall be subject to agreement between the manufacturer and the in purchaser authority.

- Stress-relieving, when required, shall be done before the hydrostatic test and after any repairs to welding.
- A preliminary hydrostatic test at a pressure not exceeding 0.5 times the design pressure to reveal leaks before the stress-relieving operation is permissible.

x) Normalizing :

- Normalizing is desirable when a structural improvement is necessary as with pressure vessels that are subjected to blows and knocks.
- When welding pressure vessels that are to be normalized, the filler metal used shall be of the type, that the weld deposit will, after normalizing, meet the same requirements regarding the yield point as the parent metal.

In the next article, we will read in detail about WPS(welding process specification) and WQR(welder Qualification Record).

If you have any doubts or you want more detail about any specific topic, then kindly mention it in the comment section.