



# HEAT EXCHANGER AND PRESSURE VESSEL DESIGN AND MANUFACTURING AS PER ASME SEC VIII/DIV-I


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## Agenda- Reference to Ammonia refrigeration industry

- ▶ An introduction to Codes and Standards
- ▶ Objectives of Codes/ Standards.
- ▶ ASME Code System.
- ▶ Introduction To ASME Sec. VIII-1
- ▶ Equivalent code in India
- ▶ Material selection
- ▶ Operating, design set pressure requirements

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## Agenda (cont.)

- ▶ Thickness calculation dish end size calculation
- ▶ Welding requirement
- ▶ Testing method and requirements
- ▶ Radiography stress relieving requirement
- ▶ Painting requirement
- ▶ Quality plan preparation
- ▶ How to prepare for requirements of external international agencies

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## WHY ADOPT CODES ?

```

    graph LR
      CODE --> 2C[2 C]
      CODE --> 2S[2 S]
      2C --> CK[Collective Knowledge and Experience]
      2C --> Cred[Credibility]
      2S --> Safety["Safety (Plant, Personnel, People)"]
      2S --> Std[Standardization]
    
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## Common pressure vessel codes

- ASME Sec VIII Div 1 and Div 2
- BS 5500
- IS 2825-1969 with latest amendment

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## ASME codes


Issued by: American society of mechanical Engineers, New York.  
Issue freq.: New edition every 3 years, on 1<sup>st</sup> July latest edition was on 1<sup>st</sup> July 23

Addenda: In-between revisions, issued yearly also on 1<sup>st</sup> July  
2024 Edn. & '24 add. --- 1<sup>st</sup> July '24  
2025 Addenda --- 1<sup>st</sup> July '25  
2026 Addenda --- 1<sup>st</sup> July '26  
Again new edition - 2027 (1<sup>st</sup> July)

Applicability :Edition & Addendas effective 6 months from date of issue (i.e. 1<sup>st</sup> Jan of next year)

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**ASME SEC. VIII DIV. 1**

**Pressure vessels within scope:**


Vessels designed for pressures above 15 psig (1.05 kg/cm<sup>2</sup>) and not exceeding 3000 psi (211 kg/cm<sup>2</sup>)

Vessels having inside diameter **above 6 in. (150mm)**

Evaporators, Heat exchangers

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**ASME Sec. VIII div.1--Excluded from scope**

Vessels covered by other sections


Pressure containers which are integral part of rotating machinery.

Piping system & components beyond battery limits.

Vessels for human occupancy

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**CODE SYSTEM**

**In its present from the ASME Code System is a follows**

- Section II Material specifications.
  - Part A Ferrous materials,
  - Part B Non Ferrous Materials
  - Part C Welding rods, electrodes, filler metals.
  - Part D Material properties.

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**CODE SYSTEM**

- Section III Nuclear Power Plant Components.
- Section IV Heating Boilers.
- Section V Non destructive Examinations.
- Section VI Care and operation of Heating Boilers.
- Section VII Rules for care of Power Boilers.
- Section VIII Division 1 - Pressure Vessels
  - Division 2 - Alternative Rules ( Pr. Vessel)
  - Division 3 - Rules for constructive of High Pressure vessel.
- Section IX Welding and Brazing Qualifications.

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**CODE SYSTEM, cont'd**

Section X Fiber glass reinforced Plastic Pressure Vessels.

Section XI Rules for in service inspection of Nuclear Power Plant Components.

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**ASME Sec. VIII Div. 1 has five different parts**

Part 1 : UG – General requirements (Design requirements)

Part 2 : Material Specific Requirements
 

- UCS – Carbon steel & low alloy steel UHA – High alloy steels
- UNF – Non ferrous metallurgy

Part 3 : Fabrication method specific requirements UW – Welded construction
 

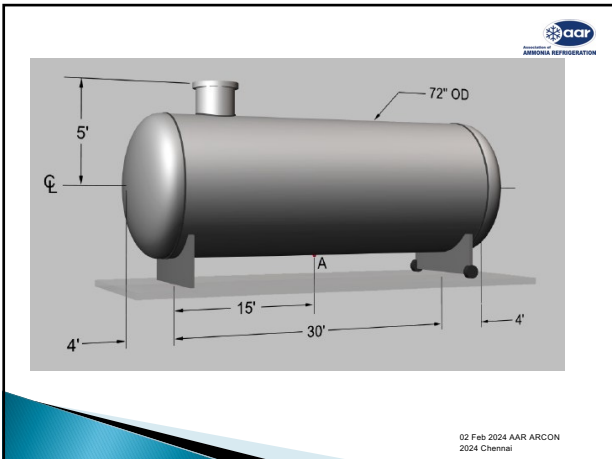
- UF – Forging construction

Part 4 : Mandatory Appendices &

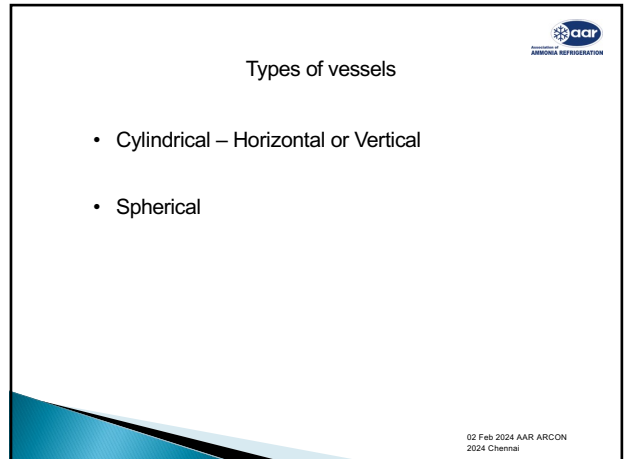
Part 5 : Non mandatory Appendices

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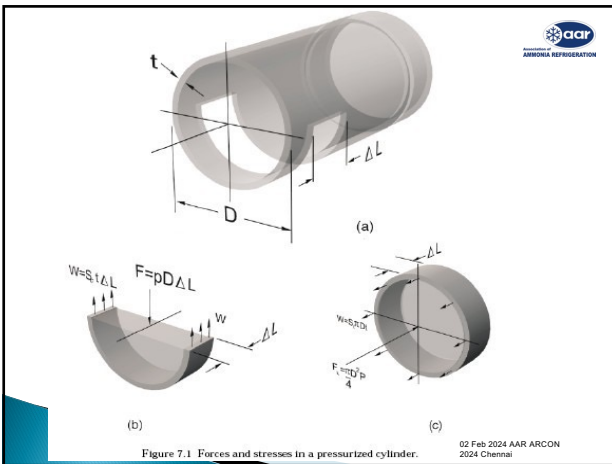
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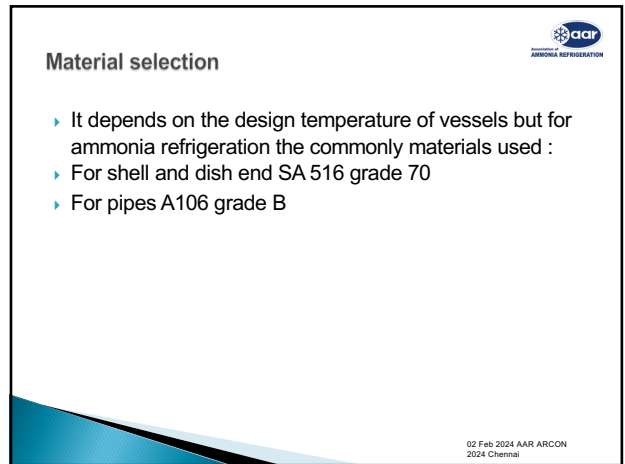
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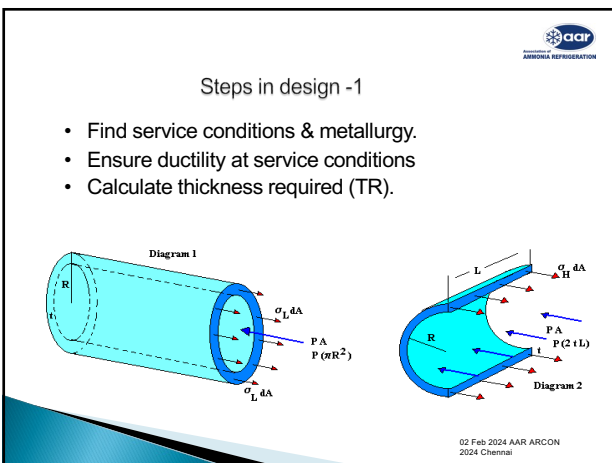
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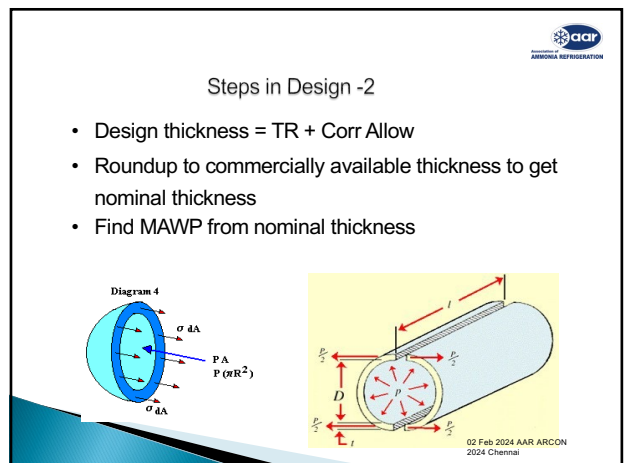
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### Design requirement of refrigeration system

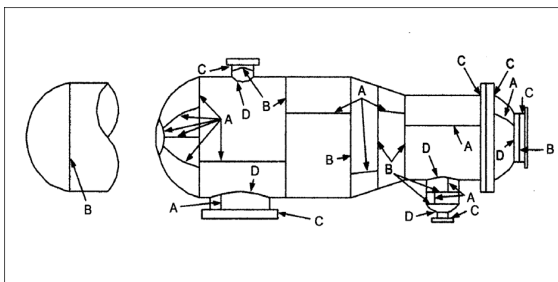
- ▶ As per standard IS 17773 design requirement :
- ▶ Vapour pressure at +40 °C , the design pressure will be 211.6 psi (14.88 kg/cm<sup>2</sup>)

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### UW – 3 : WELD JOINTS CATEGORIES.



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### UW – 3 : WELD JOINTS CATEGORIES.

**Category A :**

- 1 Longitudinal weld joints in main shell or nozzles.
- 2 Any welded joints in spherical shell.
3. Any welded joints in Dished Head.
4. Circumferential Seam , Hemisph. head to shell.

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### UW – 3 : WELD JOINTS CATEGORIES.

▶ **Category B :**

- 1 Circumferential seam in main shell, or nozzle
- 2 Circumferential seam connecting formed head (other than hemi-spherical head) to shell.

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### UW – 3 : WELD JOINTS CATEGORIES. Contd.

**Category C :**


- Weld joints connecting flanges, tube sheets, flat head to main shell or Nozzles (Flange Welds)

**Category D:**

- Welds joining communicating chamber or nozzle to the main shell / heads. (Attachment Welds).

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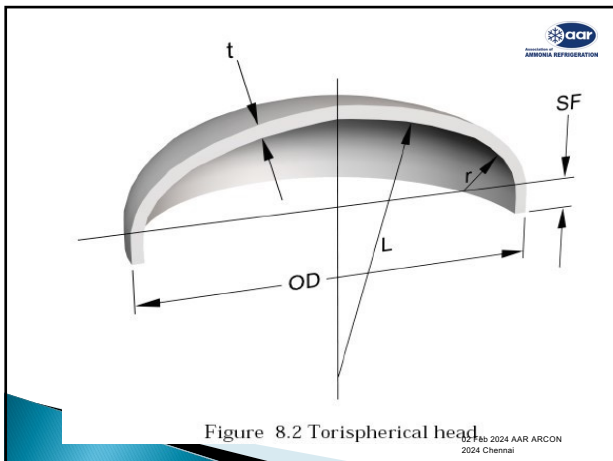
  
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### Types of ends

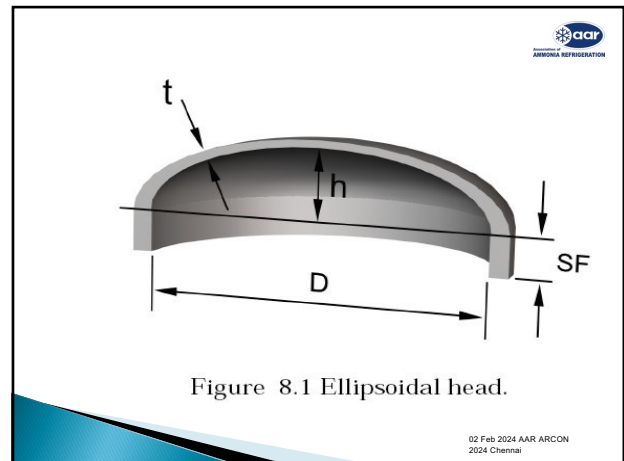
- ▶ **FLAT HEADS :**
  - For low pressures up to 5 kg/sqcm
- ▶ **FORMED HEADS :**
  - Torispherical
    - Generally used up to 15 kg/sqcm
  - Ellipsoidal
    - Generally used between 15 to 25 kg/sqcm
  - Hemispherical
    - Generally used above 25 kg/sqcm.
- ▶ **CONICAL HEADS :** for Special purposes.

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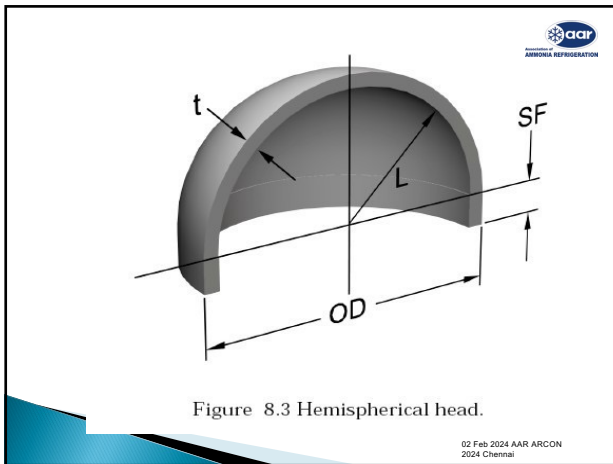
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**FORMED HEADS**

- ▶ For spherical shells / head :
  - ▶  $t = P \times R / (2SE - 0.2P)$  ....for Thickness
  - ▶  $P = 2SEt / (R + 0.2t)$ ....for MAWP
- ▶ For Ellipsoidal Heads : ( 2 : 1 type)
  - ▶  $t = P \times D / (2SE - 0.2P)$  ....for Thickness
  - ▶  $P = 2SEt / (D + 0.2t)$  ....for MAWP
- ▶ For Torisph. Heads : (L = Crown Rad.,  $r = 0.06 \times L$ )
  - ▶  $t, = 0.885 \times P \times L / (SE - 0.1P)$ ... for Thickness
  - ▶  $P = SEt / ( 0.885L + 0.1 t )$  ... for MAWP

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**UW-11 :RT and UT EXAMINATIONS**

**Full Radiography is required in following cases :**

- All butt welds of vessels for lethal substances
- If thickness exceeds given in table UCS-57, UHA-33,
- Butt welds of unfired boilers, with design pr. > 50 psi.
- For all other vessels, All cat. A welds full radiography . Cat. B & C welds which intersect the Cat. A welds shall be spot radiographed.
- Radiography is not required of category B and C butt welds in nozzles less than NPS 10 or 1 1/8 in. thick.

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**UW-11: RT and UT EXAMINATIONS...contd.**

- 1 Spot Radiography :** Spot RT of Butt joints if design efficiency is selected for spot radiography.
- 2 No Radiography :** No RT of weld joints if design efficiency is selected for no radiography or vessel is designed for external pressure
- 3 Ultrasonic examination :** May be substituted for RT only for the final closure seam of a pressure vessel.

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**UW - 12 : WELDED JOINT TYPES**

Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surface. Backing strip, if used, shall be removed after completion of weld.

Single-welded butt joint with backing strip which remains in place after welding.

For circumferential joint only

Single-welded butt joint without backing strip.

Double-full fillet lap joint.

Single-full fillet lap joint with plug welds.

Single-full fillet lap joint without plug welds.

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**UW - 12 : WELDED JOINT EFFICIENCY**

RT – Full Radiography ( E=1) :

1 : Full length radiography of all butt welds

RT – Full Radiography ( E=1):

2 : Cat – A: Full length radiography  
Cat – B: Spot RT per [UW – 11 (a) 5 (b)]

RT – Spot radiography ( E= 0.85) No

3 :

RT – radiography ( E= 0.7)

4 :

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crevice

Figure 4.6 Typical Type 2 weld joint.

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**Out of roundness of Shell**

- ▶ Difference between the maximum and minimum inside diameter measured at any cross section of the vessel shall not exceed 1% of the nominal diameter at that cross section under consideration.
- ▶ The diameter can be measured from either inside or outside. If measured from outside shall be corrected for the thickness at that cross section.

FIG. UC-80.2 EXAMPLE OF DIFFERENCES BETWEEN MAXIMUM AND MINIMUM INSIDE DIAMETERS IN CYLINDRICAL, CONICAL, AND SPHERICAL SHELLS

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**NOZZLE REINFORCEMENT**

- ▶ **Required area of Reinforcement = d X t<sub>r</sub>**
  - ▶ d= Diameter of finished opening
  - ▶ t<sub>r</sub> = Required thickness of shell or head.
- ▶ **Reinforcement is waived off for single openings if:**
  - ▶ 1. finished opening size is 3 1/2" or less diameter in shell or head of thickness 3/8" or less; or
  - ▶ 2. finished opening size 2 3/8" or less diameter in shell or head of thickness over 3/8";

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**UCS-66: IMPACT TESTING**

- 1 MDMT - Thickness point falls on or above the relevant curve. Impact test is not required (Curve UCS – 66 )
- 2 Impact test is must, if MDMT < 120 deg F, and:  
Thickness Of welded part > 4"  
Thickness for Non-welded part > 6"
- 3 Test normally required for MDMT < -55 deg. F

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**IMPACT TESTING EXEMPTION -- UG-20 (f) :**

- ▶ **Impact test exempt for if,**
- ▶ **Materials are P No 1, Gr. No. 1 and 2**

1. Materials of curve A : thickness  $\leq 0.5$  inch
2. Materials curve B, C, D : thickness  $\leq 1.0$  inch
3. Hydrostatic test performed as required
4. Design temp = -20 deg F to 650deg.F
5. No cyclic or thermal shock loading

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**IMPACT TESTING EXEMPTION.....contd.**

- 1 UCS-68 (c) : If PWHT is performed when not a Code requirement, reduction of 30 deg. F (17 °C) in impact testing exemption temp.(from Fig UCS-66) may be given for

P No. 1 materials

- 1 If coincident ratio is  $< 1$ , Reduction to exemption temperature may be given as per UCS-66.1

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**UW-40 : POST-WELD HEAT TREATMENT**

Figure 7.1 Forces and stresses in a pressurized cylinder.

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**UW-40 : POST-WELD HEAT TREATMENT**

- PWHT is Code Requirement if thickness exceeds those given in tables for respective materials .
- Furnace PWHT method is preferred .
- Min. Overlap for PWHT in multiple heats = 5 ft.
- Local PWHT : Min Soak Band = weld width + Lesser of 2" or t. and it shall extend full 360 deg for circ. Joint
- PWHT temperature is higher of the two for dissimilar metal joints

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**UCS-56: POST-WELD HEAT TREATMENT**

- Max. Loading temp in furnace = 800 deg .F
- Max. heating rate 400 deg F/hr/inch of thickness.
- Soaking period as per UCS-56 tables.
- Temp difference between hottest and coldest parts of vessel shall not exceed 150 deg .F
  - Max. cooling rate = 500 deg .F /hr/inch of thk.
- Max. offloading temp = 800 deg. F
- Still air cooling permitted below 800 deg .F.

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**NDE OF PRESSURE VESSELS**

▶ **Selection of a particular NDT technique :**

Discontinuities	Applicable NDT Methods					
	RT	T	PT	MT	VT	ET
Porosity	√	*	√	√	√	*
Slag Inclusion	√	√	NA	√	NA	*
Incomplete fusion	*	√	NA	*	NA	*
Incomplete Penetration	√	√	NA	*	NA	*
Undercut	√	*	*	*	√	*
Overlap	NA	*	√	√	*	*
Cracks	*	√	√	√	√	√
Laminations	NA	√	√	√	√	NA

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**Applicable NDT methods for Weld joint types**

NDT Methods

NDT Methods	RT	UT	PT	MT	VT	ET
<b>Joints</b>						
Butt	√	√	√	√	√	√
Corner	*	√	√	√	√	*
T	*	√	√	√	√	*
Lap	*	*	√	√	√	*

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**Note to NDT Table**

- a. Surface
- b. Surface and slightly subsurface
- c. Weld preparation or edge of base metal

□ Applicable method

\* Marginal applicability depending on other factors.

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**UG-99: HYDROSTATIC TEST**

- Hydrostatic Test pr. = 1.3 X MAWP X stress ratio  
Stress ratio = Stress at test temp./Stress at design temp.
- Min. Inspection pressure = Test pressure / 1.3
- Any non-hazardous liquid may be used for the test.
- Min. Test temp = MDMT + 30 deg. F ( 17 °C) Inspection temperature <= 120 deg. F. The MAWP may be same as Design pr.
- Test gauge range = 1.5 to 4 times test pr.  
Duration: approx. 60 mins

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**UG-100: PNEUMATIC TESTS**

- Pneumatic test is used instead of hydro when:
  - Vessels cannot be safely filled with water
  - Vessels in service in which traces of testing liquid cannot be tolerated
- Test pr = 1.1 X MAWP X stress ratio.
- Test temp shall exceed MDMT by 30 deg F.
- Pr. Gauge range = 1.5 to 4 times test pressure
- Duration

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**Safety precautions for Pneumatic Test**

- All welds around openings and attachment welds with throat >= 6mm ( 0.25") to be MT or PT tested
- The pr. shall be first raised to 50% of the test pr.
- Then the pressure shall be raised in steps of 10% of test pr. To reach full test pressure
- The pressure then shall be reduced to a value of test pressure /1.1 , to permit inspection.

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**CODE STAMPING**

**Each pressure vessel shall be marked with the following :**

- 1) The official Code U Symbol or the official UM Symbol.
- 2) Name of the Manufacturer of the pressure vessel preceded by the words "certified by";
- 3) Max. allowable working pressure ----psi at ---- °F.
- 4) Minimum design metal temperature ---- °F ----psi
- 5) Manufacturer's serial number;
- 6) Year built.

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### Surface preparation and painting

- ▶ Painting is not specified in code but manufacturer and purchaser can mutually decide the painting quality as per tropical condition
- ▶ But as per good engineering practice it has to be sand blasted and painted with epoxy paint with proper painting procedure.

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### Engage the external inspection agency

- ▶ It is mandatory to appoint the third party inspection agency for the vessel covers under the PESO rule
- ▶ International agency in India:
  1. Bureau Veritas
  2. TUV- Nord
  3. DNV
  4. LRIS
  5. IRS
 and many more...

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### Quality assurance plan

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SR NO.	COMPONENT/ACTIVITY	CHARACTERISTICS TO BE CHECKED	QUANT. OF CHECK	REF. DOCUMENT	RECORDING FORMAT	CONTROLLED BY REC	ALSL
1	GENERAL REQUIREMENTS						
1.1	GAP	VERIFICATION	100%	AS PER P.O. & ASS.SPEC.	APPROVED-GAP	P	A
1.2	APPROVAL OF FABRICATION DRAWING	VERIFICATION	100%	AS PER P.O. & ASS.SPEC.	APPROVED-FAB DRAWING	P	A
2	MATERIAL INSPECTION						
2.1	RAW MATERIAL IDENTIFICATION	IDENTIFICATION		ALL SPEC.&APPROVED DRAWING, MTC	MATERIAL-HEAT COVER	P	B
3	STAGE INSPECTION & TESTING DURING FABRICATION						
3.1	EDGED END	VISUAL, DIMENSIONAL, EDGE PREP PROFILE AS PER TEMPLATES & IPT	100%	APPROVED DRAWING	EDGED END REPORT	P	B
3.2	SHELL	LONGITUDINAL CRACK, ROOT GAP & TACK EDGE (PT/LOCAL DIMENSIONS)	100%	APPROVED DRAWING	LONG SCAM SET UP REPORT	P	B
3.3	DISHS END TO SHELL	DISHS END BY GAP, EDGE TRIP, ROOT GAP & TACK EDGE, IPT, VISUAL, DIMENSIONS	100%	APPROVED DRAWING	DISHS END FIT UP REPORT	P	B
3.4	NOZZLE	NOZZLE SET UP TO VESSEL, DIMENSIONAL	100%	APPROVED DRAWING	NOZZLE SET UP REPORT	P	B
3.5	ALL PARTS/VISUAL INSPECTION	SPATTERS, PIN HOLES, BUCK CORROSION ETC.	100%	APPROVED DRAWING	-	P	B
3.6	EQUIPMENT/FU	FINAL DIMENSIONS FOR ALL SHELL, NOZZLE, NOZZLES & OTHER PARTS	100%	APPROVED DRAWING	FIN REPORT	P	W
3.7	TEST: HYDROTEST	AS PER P.O. DRAWING, PRESSURE DROP, CAL. CRT.	100%	APPROVED DRAWING	HYDROSTATIC TEST REPORT	P	W
	TEST: CLEANING	AS PER P.O. DRAWING, CLEANING PROC. CAL. CRT.	100%	APPROVED DRAWING	CLEANING REPORT	P	B
	PAINTWORK & PAINTING	FABRICATION (DIP IN / PAINT BRUSHING OR BLASTING & 2 COAT RECOAT (FOR MS))	100%	APPROVED DRAWING	PAINTING REPORT	P	B

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SR NO.	COMPONENT/ACTIVITY	CHARACTERISTICS TO BE CHECKED	QUANT. OF CHECK	REF. DOCUMENT	RECORDING FORMAT	CONTROLLED BY REC	ALSL
4	QC DOCUMENTATION & IPR	DOCUMENT REVIEW	100%	P.O. REQD. REQD.	QC DOSSIER	H	H

FOR JEC

PREPARED BY: INSP. ENGG. (Signature)

CHECKED BY: QC INCHARGE (Signature)

QC REPT./JEC SURVEYOR

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# THANK YOU

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