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MODEL ANSWER

SUMMER– 17 EXAMINATION

Subject Title: Processes Equipments Subject Code: 17457

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. NO.	ANSWER	Marking scheme
1	**Attempt any Five of the following**	**5 x 4**
a)	A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. Pressure vessels are leak proof containers. They may be of any size, shape and range. Pressure vessels are classified as; Function: Storage tank, Process vessel, Reactor, Heat Exchanger, etc. Geometry: Cylindrical, Spherical, Conical, Non circular, Horizontal, Vertical, etc. Construction: Monowall, Intersecting, Multishell, Cast, Forged, etc. Service: Cryogenic, Steam, Vacuum, Fired/Unfired, Stationery/Mobile, etc.	**02 marks** **02 mark for any two classification with 01 eg. each**

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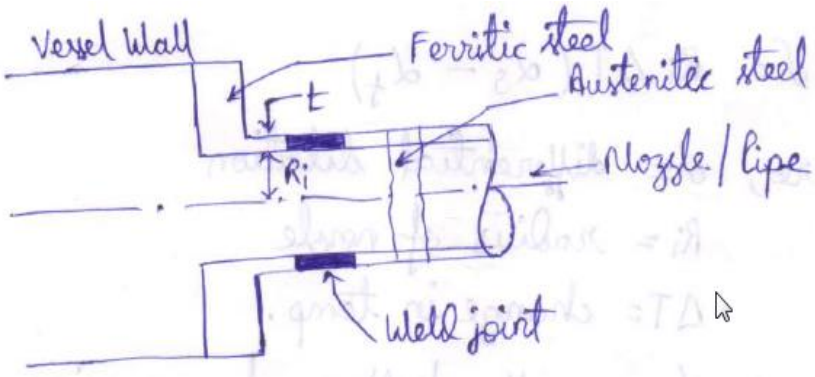
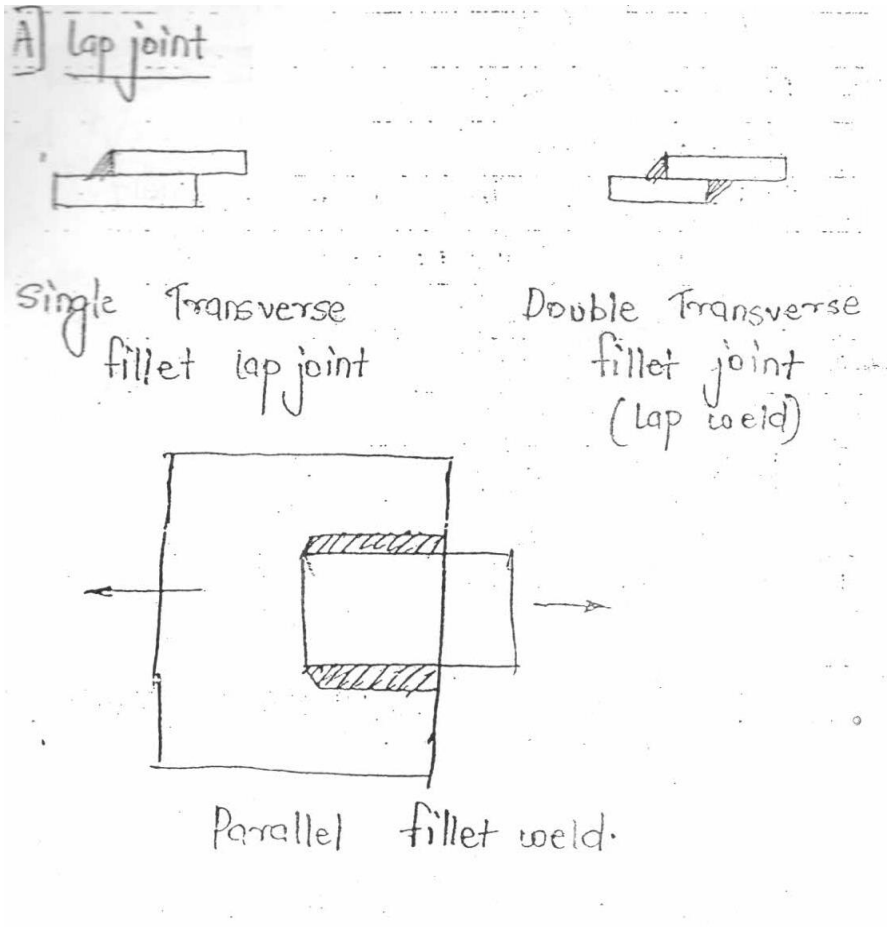
b)	Given data, $P = 1.5\ N/mm^2$ $t = 20\ mm$ $D = 3m = 3000\ mm$ $R_i = \frac{D}{2} = \frac{3000}{2} = 1500\ mm$ $\mu = 0.3$ $E = 2 \times 10^5\ N/mm^2$ Type of vessel = Cylindrical. For dilation of cylindrical vessel. $\delta = \frac{P.R_i^2}{2tE}(2-\mu)$ $\delta = \frac{1.5 \times 1500^2}{2 \times 20 \times 2 \times 10^5}(2-0.3)$ $\boxed{\delta = 0.717\ mm}$ Therefore dilation of cylindrical vessel is 0.717 mm	**04 marks**
c)	Methods of attaching protective coatings: 1. Integral cladding Low carbon steels or low alloy steels (base plates) also called as backing plates and corrosion resistant steel (liners) are welded at the edges. This is then passed through steel mills for hot rolling	**Any one method** **04 marks**

	operations. The high temperature and high pressure creates a solid bond between the plates. Thickness of the liners is about 2mm to 4mm or 8% to 20% thickness of base metals. 2. Sheet lining The corrosion resistant layer is attached to a vessel shell by welding. Thickness of sheet is 2mm to 4mm. Types are; i) Strip type lining of 3' to 5' X 3" to 6" wide strips are welded on base material by spot welding. ii) Sheet type lining of several feet in length and width are welded on base materials by spot, plug or seam welding. The linings are attached to the vessel after the vessel is entirely completed. Sometimes sheets are attached to the base plates before rolling or forming. Carbon steel surfaces (base plates) are ground to provide suitable surface for application of the liner. 3. Protective coatings: Coatings should be applied only on clean surfaces free from grease, oil, dirt, scale, etc. i) Metallic coatings – Common methods are electroplating, mechanical cladding (most important), metal spraying, cementation, hot dipping, and condensation of metal vapors. ii) Inorganic coatings – Chemical dipped methods are used to create protective oxide films on iron, steel, stainless steel, copper, aluminum and some of their alloys. Such films are very thin and colored. e.g. Electrolytic coating. iii) Organic coating – Different synthetic resins, pigments, oils and solvents are used in coating formulations. A continuous adherent inert film is formed between the metal and environment. They change the appearance of the metal e.g. paint enamel, lacquer.	
d)	General design criteria for pressure vessel: For cylinders under internal pressure, three principal stresses are generated, a) Hoop stress, b) Radial stress and c) Longitudinal stress The latter is due to the thrust of pressure on the heads of the cylinder. The value of the Hoop and Radial stresses are not constant through the cylinder walls, whereas longitudinal stresses are in fact constant. In the design phase it is therefore necessary to consider the stresses of the tri-axial state and to derive the ideal stress via. one of the theories of failure. Assuming that the ideal stress is equal to the basic allowable stress, we	**04 marks**

	can then obtain an equation to compute the minimal required thickness for the pressure vessel.	
e)	Many high temperature petroleum refining processes are carried out under high partial pressures of hydrogen. Therefore steps for material selection in vessel construction for such service so as to withstand hydrogen which causes deterioration of the material and subsequent failure depends upon identifying some factors like; • Temperature • Hydrogen pressure • Time, • Composition of materials, • etc. Examples: i) Plain carbon steel or low alloy steels are the materials used for hydrogen service at low temperature & high pressure and vice-versa. ii) Austenitic stainless steel resists hydrogen service	**03 marks for explanation** **01 mark for any one example**
f)	Discontinuity Stresses in Pressure Vessel Bimetallic Joint:  Pressure vessels usually contain regions where abrupt changes in geometry, material, or loading occur. These regions are known as discontinuity areas, and the stresses associated with them are called discontinuity stresses. Because of dissimilar characteristics, each of the adjacent parts joining at a discontinuity area behaves differently to an applied load, such as internal pressure or temperature. The deformations of the disconnected free bodies are different from each other. Because these parts are joined together, they share a common displacement that is different from their free displacements. The difference between the free displacement and the actual joint displacement is a forced displacement, which produces forces and stresses. These additional	**02 marks for diagram** **02 marks for explanation**

	stresses are referred to as discontinuity stresses. Calculation of discontinuity stresses is generally based on the behavior of the longitudinal strip of the cylindrical shell. Local discontinuity stresses are produced in the region where these dissimilar materials are welded together, due to the fact that the coefficient of thermal expansion of the austenitic steels is 50% greater than that of the ferritic steels.	
g)	Welded joints used in in pressure vessel 	**02 marks for any two joints**

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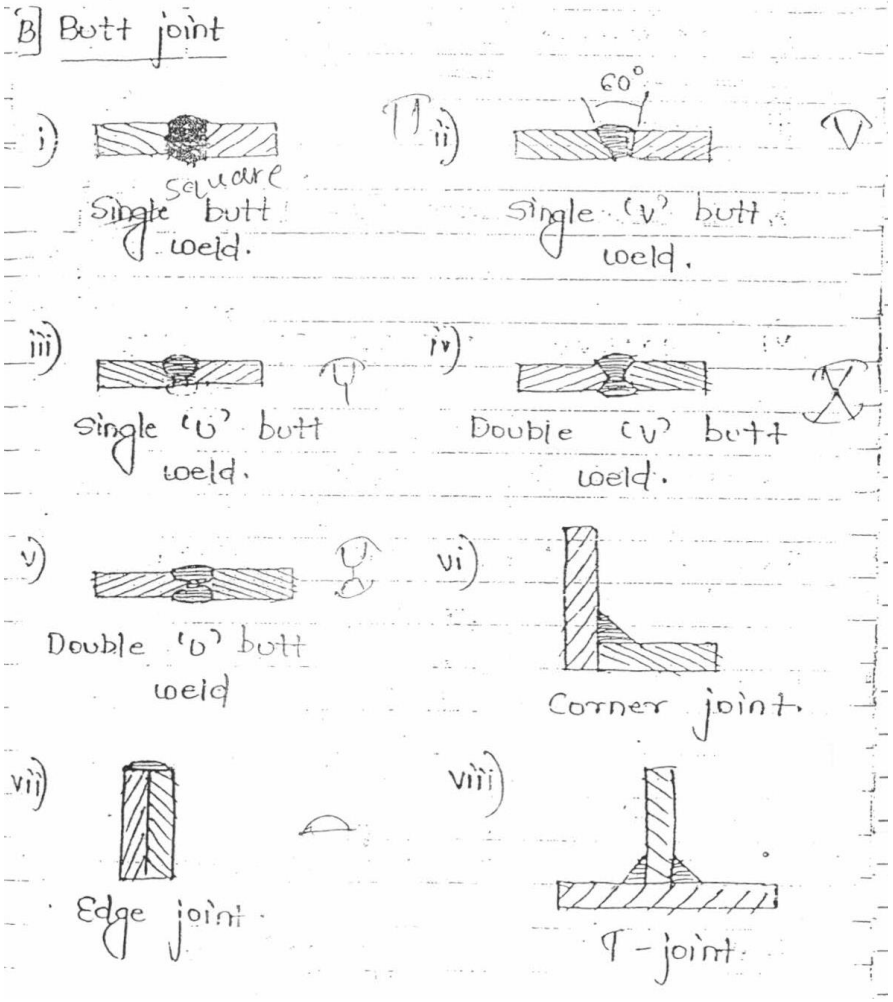

Advantages of Welded Joints:

1) Welded structures are lighter than riveted structure, since other connecting components like gussetes are not used
2) Max.efficency up to 100%
3) Alteration and addition can be easily made
4) Good strength
5) Good appearance
6) Any complicated shape can be welded
7) Rigid joint
8) It is possible to weld any part of structure at any point
9) It take less time
10) Leak proof joints are possible

02 marks for any two advantages

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	11) Dissimilar material can be joined 12) High thickness can be joined	
2	**Attempt any Two of the following**	**8 x 2**
a)	Given data, $P = 0.40\ MPa = 0.40\ N/mm^2$ $S_{ult} = 390\ N/mm^2$ $E = 85\% = \frac{85}{100} = 0.85$ $F.O.S. = 3$ $\therefore S = \frac{S_{ult}}{F.O.S} = \frac{390}{3} = 130\ N/mm^2$ $D_i = 1.2\ m = 1200\ mm$ $\therefore R_i = \frac{D_i}{2} = \frac{1200}{2} = 600\ mm$ $C.A. = 2\ mm$ $W = 35\ kN = 35000\ N$ $f_c = 56\ MPa = 56\ N/mm^2$ $D_{in} = 150\ mm,\ R_{in} = \frac{150}{2} = 75\ mm$ i) Thickness of Cylindrical Shell:- $t = \frac{P.R_i}{SE - 0.6P} + C.A.$ $t = \frac{(0.40 \times 600)}{(130 \times 0.85) - (0.6 \times 0.40)} + 2$ $t = 4.17\ mm$	**02 marks**

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Consider the chart:-

VESSEL DIAMETER (m)	MINIMUM SHELL THICKNESS (mm)
Upto 1.0	5
Above 1.0 to 2.0	7
Above 2.0 to 2.5	9
Above 2.5 to 3.0	10
Above 3.0 to 3.5	12

01 mark for table

So shell thickness as per chart is suggested as 7mm

But designed value is obtained as 4.17mm

Consider the largest value of 7mm

Now, consider the even value 8mm as thickness of shell for further calculations.

ii) Thickness of Head:-

[Since type of head is not mentioned in question students can assume any of the following head (hemispherical heads, semi ellipsoidal heads, torispherical head, Conical heads).

Thus, assuming hemispherical heads

01 mark

ii) For thickness of hemispherical heads:

$$t = \frac{P \cdot R_i}{2SE}$$

$$t = \frac{0.4 \times 600}{2 \times 130 \times 0.85}$$

$$\therefore t = 1.085 \text{ mm}$$

Consider the rounded off even value 2mm as thickness of hemispherical head.

iii) Design of Skirt:- **01 mark**

$$t_s = \frac{W}{D_{is} \pi S \cdot E} + C.A.$$

Here $D_{is} = 2(R_i + t)$

$= 2(600 + 8)$

$= 1216$ mm

$$\therefore t_s = \frac{35000}{1216 \times \pi \times 130 \times 0.85} + 2$$

$\therefore \boxed{t_s = 2.08 \text{ mm}}$ $\therefore \boxed{t_s \approx 4 \text{ mm}}$

iv) Design of Anchor Bolt:- **01 mark**

a) Number of bolts:-

$$n = \frac{D_{os}}{600}$$

Here, $D_{os} = D_{is} + 2t_s$

$= 1216 + (2 \times 4)$

$D_{os} = 1224$ mm

$\therefore n = \frac{1224}{600}$

$n = 2.04$

$\boxed{n \approx 4}$

01 mark

b) Size of bolts:-

$W = \frac{\pi}{4} \times d_c^2 \times f_c \times n$

$\therefore d_c^2 = \frac{W \times 4}{\pi \times f_c \times n}$

$d_c^2 = \frac{35000 \times 4}{\pi \times 56 \times 4}$

$\therefore d_c^2 = 198.94$

$\boxed{d_c = 14.10 \text{ mm}}$

$\therefore$ Dia of bolt $(d) = \frac{d_c}{0.84}$

$\boxed{d = 16.79 \text{ mm}}$

But the minimum size of bolt must be $d = 24$ mm

$\therefore$ Using bolts of M24.

01 mark

v) Design of Nozzle:-

$t_n = \frac{P \cdot R_i}{SE + 0.4P} + C.A.$

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	$t_n = \frac{0.40 \times 75}{(130 \times 0.85) + (0.4 \times 0.4)} + C.A.$ $t_n = 2.27$ $t_n \approx 4mm$ ∴ Thickness of nozzle is 4mm.	
b)	Wind load: A highly turbulent flow of air sweeping over the earth surface with a variable velocity and resisted by an obstacle in this case it is termed as wind load (moment load) on the vessel. The direction of flow is usually horizontal however it may possess a vertical component when passing over a surface obstacle. The wind velocity V_L is affected by the earth surface friction. The effect of wind load on design of pressure vessel are as follows: 1) Wind has a rolling effect on the horizontal vessel, thus creating a twisting force on the vessel. 2) Wind load creates a bending force on the slender vertical vessel. 3) Turbulence of fluid flowing through the pipes creates vibration and affects the joints of the pipes and makes it lose. For this purpose gaskets or bellows can be used to reduce the pipe load. Earthquake load: Intensity and duration of earthquake motion damages the structure of the pressure vessel and hence it is to be taken in to account while designing the pressure vessel. Effects of earthquake on design of pressure vessel: 1) Due to the vibration caused earthquake the supports of the pressure vessel may get weak. 2) The land on which the pressure is placed, it may get lose and may affect the vessel	**02 marks** **02 marks** **02 marks** **02 marks**

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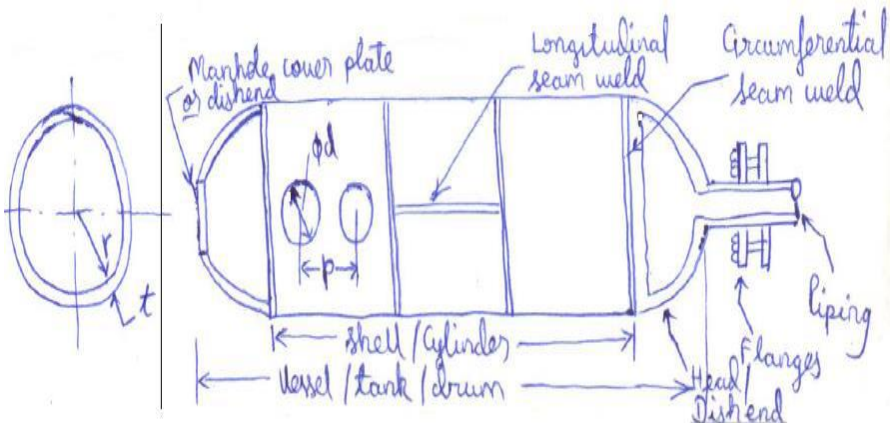
c)	 Pressure vessel consists of basic parts such as; 1) Shell 2) Head 3) Nozzle 4) Baffle Plates 5) Supports (Rings) 6) Piping, etc. Cylinders/shell:- it is the container which holds the fluid under pressure and temperature Rings: - these are used so that leakages at the joints in the pressure vessel are avoided Baffle plates: - these used to increase the pressure in boiler or pressure vessel. The position of these plates varies the pressure in vessel. Curved shape dish ends/ heads/ closure ends:- these are ends which provides closure to the vessel. The shape of the ends varies according to the use. Nozzles: - these are the outlets/inlet hole which is used for the supply of the fluid. Flanges: - these are used to connect the pipes with the vessel so that minimum loses are achieved. Piping: - these are used so that the fluid can be transferred from the vessel	**03 marks diagram** **05 marks explanation**

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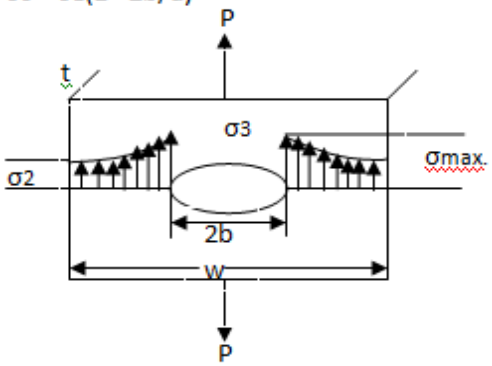
3	**Attempt any two of the following**	**8 X 2**
a)	Stress concentration for circular and elliptical holes: $K_t = \sigma_3 / \sigma_{av}$; where $\sigma_{av} = P/t(w-2b)$ $\sigma_1 = P/tw$ $\sigma_3 = \sigma_1(1+ 2b/a)$  Where, b/a = 1 refers to circular opening b/a = 1/2 refers to vertical ellipse with least stress concentration, K_t Vertical ellipse openings are preferred since, K_t is less. Elliptical openings are used for special purpose such as hand hole openings and is selected so as to allow the insertion of a pressure sealing cover plate through its own opening. It can also be used as a shape of nozzle.	**03 marks for figure** **&** **03 marks for table** **02 marks**
b)	Given data: P= 2 MPa = 2 N/mm^2 Di= 3.5m, Ri= Di/2=1.75m=1750mm E= 85% = 0.85 S= 160MPa = 160N/mm^2 Apex Angle =60^0 Therefore, α= (½) x 60^0 = 30^0 =30^0 X (π/180) =0.5236 radians. To find (i)thickness of shell (ii)Thickness of conical head	

b/a	Kt
1	2.5
2	4.5
3	6.5
1/2	1.5
1/3	2.5
1/4	3.5
1/5	4.5

Calculation:

1) Thickness of shell:

03 marks

$t = (P*R_i) / (S\varepsilon - 0.6P)$

$= (2*1750) / (160*0.85 - 0.6*2)$

$= (3500) / (136 - 1.2)$

$= (3500) / (134.8)$

$= 25.96$ mm

Consider the chart:

VESSEL DIAMETER (m)	MINIMUM SHELL THICKNESS(mm)
Upto 1.0	5
Above 1.0 to 2.0	7
Above 2.0 to 2.5	9
Above 2.5 to 3.0	10
Above 3.0 to 3.5	12

02 marks

So shell thickness as per chart is suggested as 12mm

But designed value is obtained as 25.96 mm

Consider the larger value of 25.96 mm **~ 26 mm**

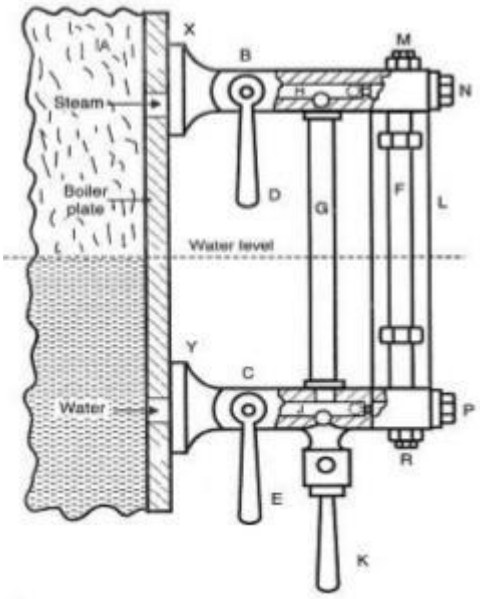
Now, consider the rounded off even value 26mm as thickness of shell for further calculations.

2) Thickness of head(Conical):

	$t = ((P*R_i) / (S\varepsilon - 0.6P))*(1/\cos \alpha)$ $= ((2*3500) / (160*0.85-0.6*2))*(1/\cos 0.5236)$ = 25.96mm **~ 26 mm** Consider the rounded off even value **26mm** as thickness of conical head.	**03 marks**
c)	Weld defects for pressure vessel are as follows <u>Misalignment:</u> Poor weld shape of weld occur due to misalignment of parts being welded. this also reduces the strength of weld <u>Cracks:</u> Cracks in welds occur due to thermal shrinkage after the fused molten metal cools down. <u>Pin Holes:</u> Pin holes on weld surface due insufficient flux covering or dirt on the parent metal. <u>Slag Inclusion:</u> Slag inclusion occurs when slag covering a run is not totally removed after every run before the following run. <u>Porosity:</u> Porosity occurs in the form of voids (cavity) when gases are trapped in the solidifying weld metal. <u>Incomplete fusion:</u> Incomplete fusion between the weld and base metal resulting from too little heat input and / or too rapid traverse of the welding torch (gas or electric). <u>Undercut groove:</u> Undercutting groove adjacent to the weld left unfilled by weld metal due to incorrect settings / procedure may make the weld weak. <u>Insufficient penetration:</u> Insufficient penetration of the weld metal in joints arises from too high heat input and / or too slow traverse of the welding torch (gas or electric).	**Any 02 defects** **02 marks for each**

	NDT Method: i)Visual inspection: Visual-weld-inspection represents the immediate critical observation of the external features visible on all welds. It is the first and most important assessment of quality to be performed as soon as the welding operations are accomplished. Other inspection procedures may be required to detect discontinuities not visible to the eye or present below the external surface. Whatever additional non-destructive inspection methods are applied, they are performed only after visual inspection is successfully completed. -The first is the visual assessment of the external look of the weld. Its appearance has to correspond to engineering drawing requirements and to be evaluated in comparison with that of the best obtainable practice by anyone looking with critical eye at its characteristic features. -The second has to do with the formal documented assessment of the visual Weld Inspector. -Visual inspection is intended to find and mark for repair obvious visual defects such as cracks, surface porosity, dimensional discrepancies, excess concavity or convexity, unfilled areas, undercut, misalignment, craters, unacceptable arc striking spots and any other objectionable visual features ii) Penetrant testing detects only surface breaking defects in smooth and non-porous materials. Penetrant solution is applied to the surface of a precleaned component. The liquid is pulled into surface-breaking defects by capillary action. Excess penetrant material is carefully cleaned from the surface. A developer is applied to pull the trapped penetrant back to the surface where it is spread out and forms an indication. The indication is much easier to see than the actual defect. iii)Magnetic Particle Testing can detect surface and subsurface flaws in ferromagnetic materials. A magnetic field is established in a component made from ferromagnetic material. The magnetic lines of force travel through the material and exit and reenter the material at the poles. Defects such as crack or voids cannot support as much flux and force some of the flux outside of the part. Magnetic particles distributed over the component will be attracted to areas of flux leakage and produce a visible indication.	**04 marks for any one NDT method**

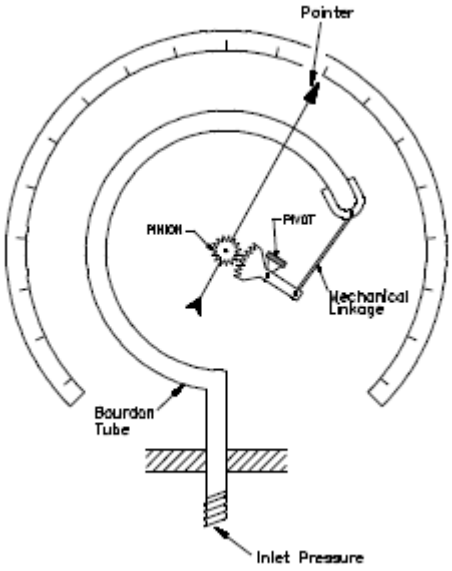
	iv) Ultrasonic Testing is used to locate surface and subsurface defects in many materials including metals, plastics, and wood. It employs high frequency sound waves that are sent into a material by use of a transducer. The sound waves travel through the material and are received by the same transducer or a second transducer. The amount of energy transmitted or received and the time the energy is received are analyzed to determine the presence of flaws. Changes in material thickness and changes in material properties can also be measured. v) Radiographic testing inspects almost any material for surface and subsurface defects. They can also be used to locate and measure internal features, confirm the location of hidden parts in an assembly and to measure thickness of materials. It employs X-rays that are used to produce images of objects using film or other detector that is sensitive to radiation. The test object is placed between the radiation source and detector. The thickness and the density of the material that X-rays must penetrate affect the amount of radiation reaching the detector. This variation in radiation produces an image on the detector that often shows internal features of the test object.	
4	**Attempt any <u>Two</u> of the following**	**8 x 2**
a)	Boiler Mountings: Some of the important mountings are: Pressure Gauge, Safety Valve, Fusible Plug, Blow-Off Cock, etc. Boiler Accessories: Some of the important accessories are: Economizer, Super heater, Air pre heater, Feed water pump, Steam injector, etc. Boiler may operate with/without accessories but should not operate without mountings Explanation of Boiler Mounting: • Water level Indicator Water level indicator is located in front of boiler in such a position that the level of water can easily be seen by attendant. Two water level indicators are used on all boilers.	**01 Mark** **01 Mark** **03 marks for explanation of any one mounting**



• Pressure Gauge

A pressure gauge is fitted in front of boiler in such a position that the operator can conveniently read it. It reads the pressure of steam in the boiler and is connected to steam space by a siphon tube.

Most commonly, the Bourdon pressure gauge is used.

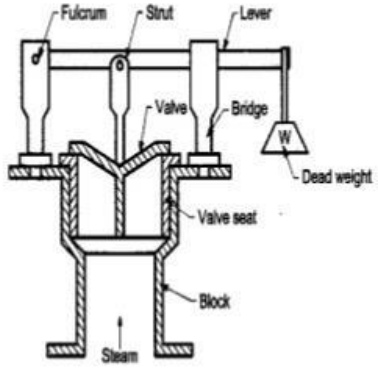


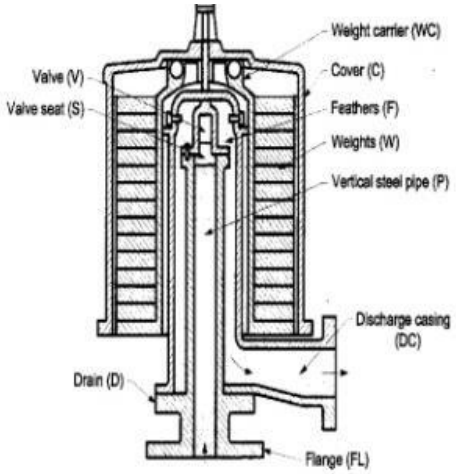
• Safety Valve

Safety valves are located on the top of the boiler. They guard the boiler against the excessive high pressure of steam inside the drum. If the pressure of steam in the boiler drum exceeds the working pressure then the safety valve allows blow-off the excess quantity of steam to atmosphere. Thus the pressure of steam in the drum falls. The escape of steam makes audible noise to warn the boiler attendant.

There are four types of safety valve.

1. Dead weight safety valve.
2. Spring loaded safety valve
3. Lever loaded safety valve
4. High steam and low water safety valve.



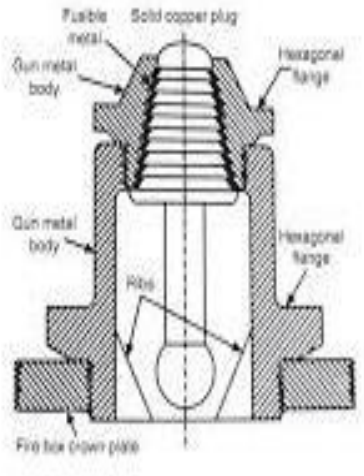


• Fusible Plug

It is very important safety device, which protects the fire tube boiler against overheating. It is located just above the furnace in the boiler. It consists of gun metal plug fixed in a gun metal body with fusible molten metal.

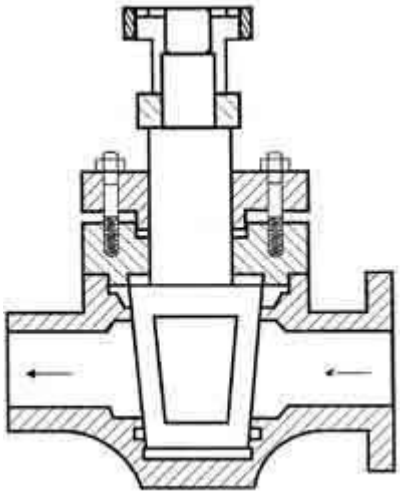
During the normal boiler operation, the fusible plug is covered by water and its temperature does not rise to its melting state. But when the water level falls too low in the boiler, it uncovers the fusible plug. The furnace gases heat up the plug and fusible metal of plug melts, the inner plug falls down. The water and steam then rush through the hole and

extinguish the fire before any major damage occurs to the boiler due to overheating.



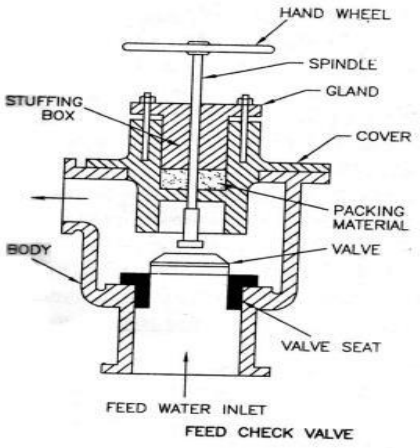
• Blow-Off Cock

The function of blow-off cock is to discharge mud and other sediments deposited in the bottom most part of the water space in the boiler, while boiler is in operation. It can also be used to drain-off boiler water. Hence it is mounted at the lowest part of the boiler. When it is open, water under the pressure rushes out, thus carrying sediments and mud



• Feed Check Valve

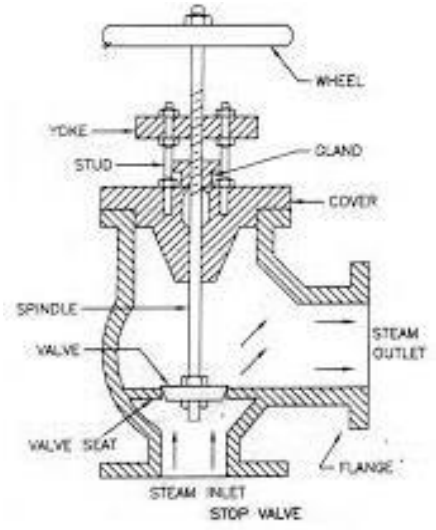
The feed check valve is fitted to the boiler, slightly below the working level in the boiler. It is used to supply high pressure feed water to boiler. It also prevents the returning of feed water from the boiler if feed pump fails to work.



FEED CHECK VALVE

• Steam Stop Valve

The steam stop valve is located on the highest part of the steam space. It regulates the steam supply to use. The steam stop valve can be operated manually or automatically.



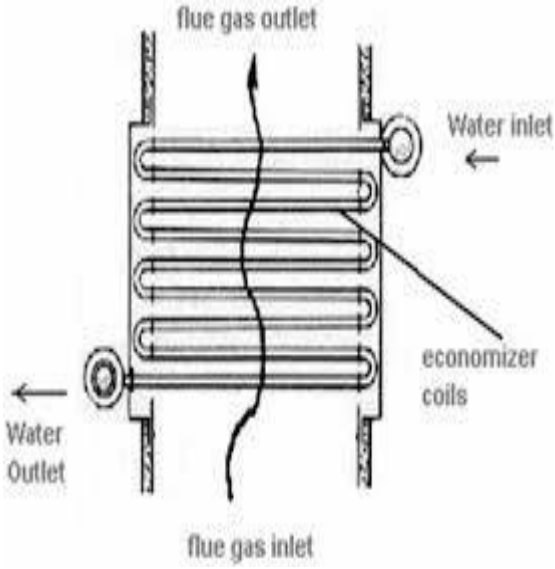
STOP VALVE

Pressure Vessel Accessories:

• Economizer

03 marks for explanation any one accessory

An economizer is a heat exchanger, used for heating the feed water before it enters the boiler. The economizer recovers some of waste heat of hot flue gases going to chimney. It helps in improving the boiler efficiency. It is placed in the path of flue gases at the rear end of the boiler just before air pre-heater.



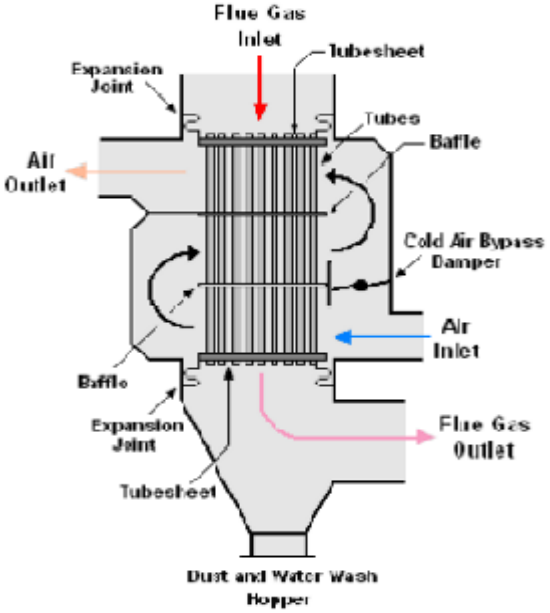
• Super heater

It is a heat exchanger in which heat of combustion products is used to dry the wet steam, pressure remains constant, its volume and temperature increase. Basically, a super heater consists of a set of small diameter U tubes in which steam flows and takes up the heat from hot flue gases.

• Air Pre-heater

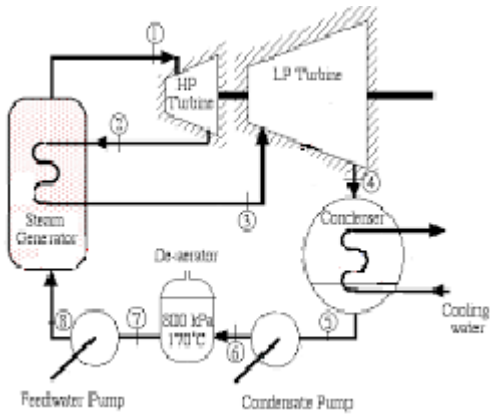
The function of an air pre-heater is similar to that of an economizer. It recovers some portion of the waste heat of hot flue gases going to chimney, and transfers same to the fresh air before it enters the combustion chamber. Due to preheating of air, the furnace

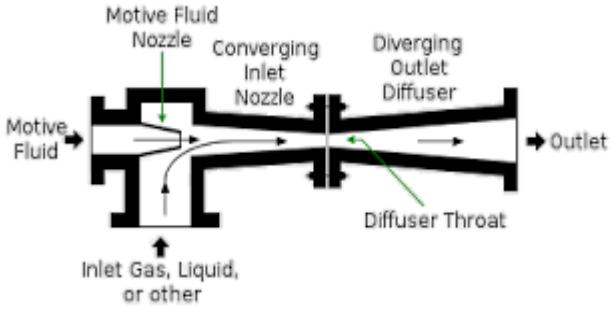
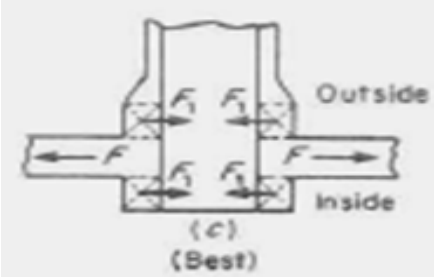
temperature increases. It results in rapid combustion of fuel with less soot, smoke and ash. The high furnace temperature can permit low grade fuel with less atmospheric pollution. The air pre-heater is placed between economizer and chimney.

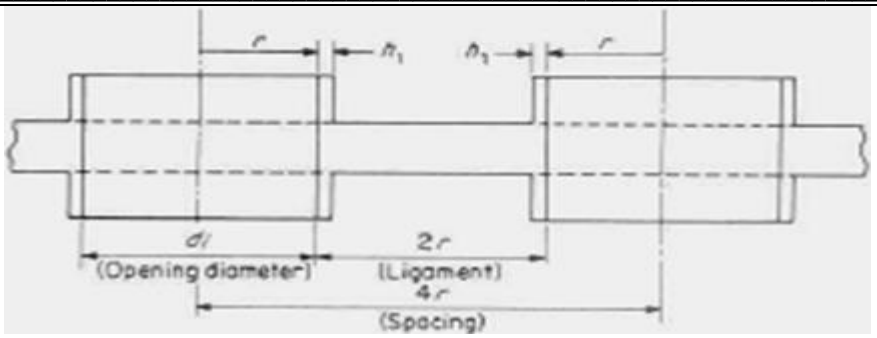


• Feed Water Pump

It is used to feed the water at a high pressure against the high pressure of steam already existing inside the boiler.



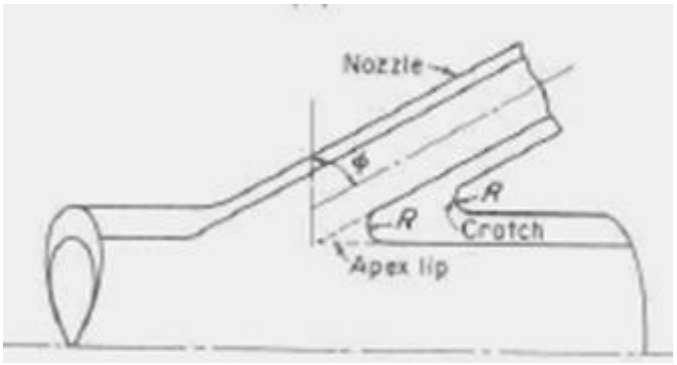
	• Steam Injector A steam injector lifts and forces the feed water into the boiler. It is usually used for vertical and locomotive boilers and can be accommodated in small space. It is less costly. It does not have any moving parts thus operation is salient.  	
b)	Nozzle reinforcement is a means to provide compensation for weakening due to the hole made on the shell by providing sufficient additional materials. The reinforcing material being placed adjacent to the hole such that it should not introduce any stress concentration. Nozzle placement: 1. Single nozzles Minimum stress concentration factor is obtained with balanced reinforcement explainable by the fact that reinforcing material evenly disposed both inside and outside of the vessel surface introduces no eccentricity or unbalance to create local bending moments and stresses.  2. Multiple nozzle arrangements Multiple reinforced nozzle arrangements require special consideration when they are very closely spaced because their individual effects become overlapping and the average membrane stress in the vessel wall are not increased by the presence of reinforced nozzles.	**01 mark** **02 marks** **02 marks**



3. Non radial nozzles

A non-radial nozzle may be installed for a functional purpose and not commonly used. A non-radial circular nozzle makes an elliptical opening in the vessel and just as an elliptical hole in a plate gives rise to a higher stress concentration factor than does a circular hole, so does a non-radial nozzle have higher stress concentration factor than its comparable radial one.

02 marks



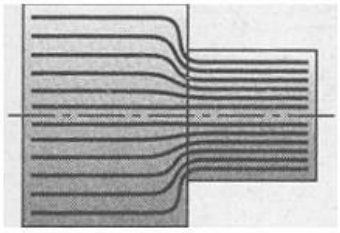
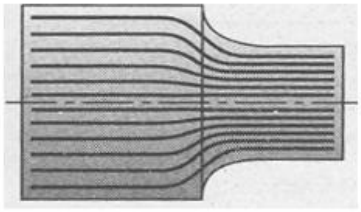
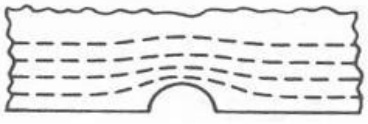
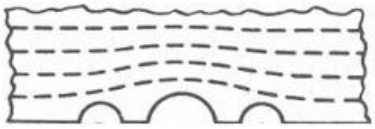
Nozzle shape:

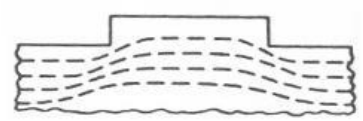
Nozzles may be circular, elliptical or oval in shape

01 mark

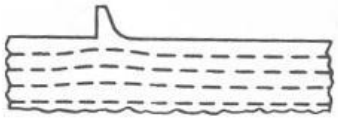
b/a	Kt
1	2.5
2	4.5
3	6.5
1/2	1.5
1/3	2.5
1/4	3.5
1/5	4.5

2b = Major axis and 2a = Minor axis

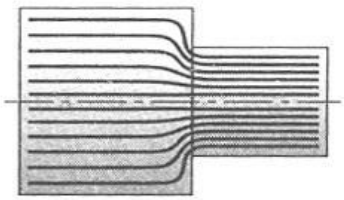
	Where, b/a = 1 refers to circular opening b/a = 1/2 refers to vertical ellipse with least stress concentration, Kt	
c)	Stress Concentration: Mechanical parts and structural elements often have features that cause sudden changes in geometry. Under loads, these changes in geometry increase the local stress fields of the parts quite significantly, and they usually represent locations from which parts start to fail. This localization of high stresses is called stress concentration. Fatigue Concentration: Stress concentrations produced by irregularities are damaging in case of fluctuating stresses. All failures as a result of fatigue are in the areas of high localised stresses. Hence all stresses including localised stresses should be taken into account when designing the pressure vessel. Methods of reducing stress concentration  (a) Force flow around a sharp corner  Force flow around a corner with fillet: Low stress concentration.  (b) Force flow around a large notch  Force flow around a number of small notches: Low stress concentration.	**01 mark** **01 mark** **06 marks for any three methods (02 marks each)**

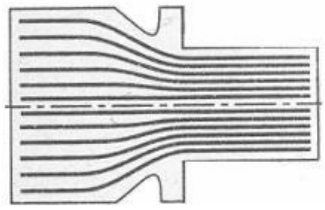


(c) Force flow around a wide projection



Force flow around a narrow projection: Low stress concentration.





(d) Force flow around a sudden change in diameter in a shaft

Force flow around a stress relieving groove.

-Steep and sharp corners be eliminated

-Selecting materials which are tolerant to cyclic loading (ductile /tough materials)

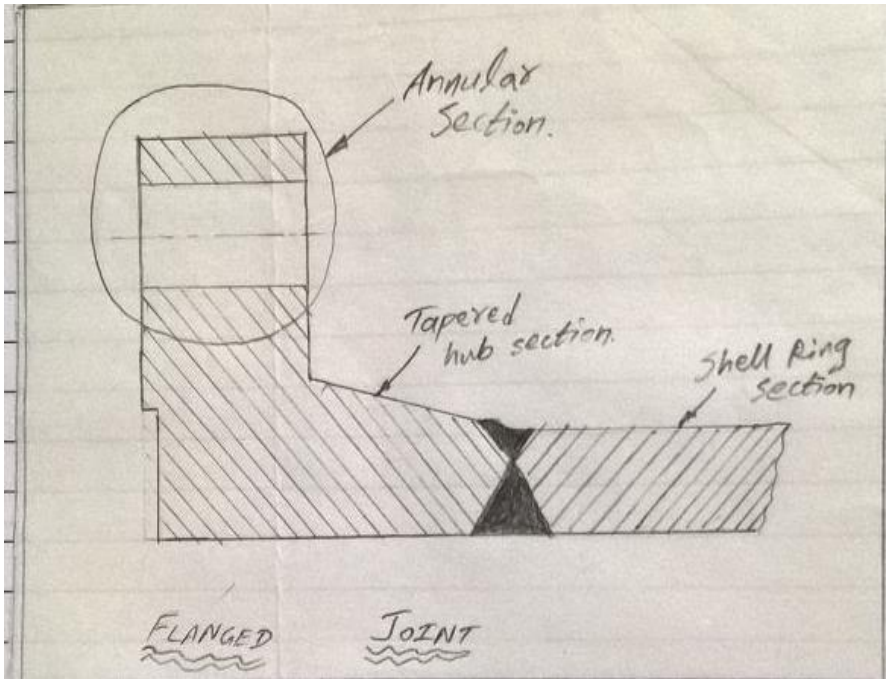
- Specifying manufacturing processes to provide fatigue resistance (Peening /shot blasting/Cold Working)

-Specifying heat treatment to provide fatigue resistance- (Carburising /Nitriding) or Overdesigning part to reduce stress Levels.

MODEL ANSWER

SUMMER– 17 EXAMINATION

Subject Title: Processes Equipments Subject Code: 17457

5	**Attempt any two of the following**	**8 X 2**
a)	 Different stresses acting on flanged joint: Consider the Flange as divided into three sections viz. • Annular ring section: 1. Overturning moment, acting on the ring, due to non-concentricity of the bolt load and gasket reaction load is replaced by two equal and opposite forces. 2. Internal hydrostatic pressure • Tapered hub section 1. Shear force and bending moment 2. Internal hydrostatic pressure • Shell ring section 1. Discontinuity shear force and bending moment	**02 marks for diagram** **02 marks for explanation**

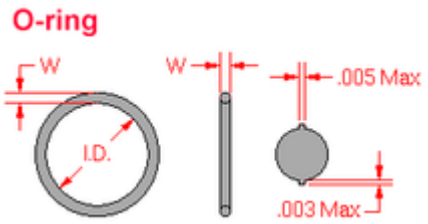
Types of gaskets according to the properties and shapes used in pressure vessels are;

- Flat ring
- Serrated
- Laminated
- Corrugated
- etc.

02 marks for classification

For low temperature services; rubber, plastic, paper, cork, asbestos, fiber, etc. are used as gasket materials e.g. Most common is 'O' ring which is used in flanges, cylindrical end caps, fittings, plugs, etc. Pressures up to 30000 PSI can be sealed by using 'O' rings.

02 marks for application



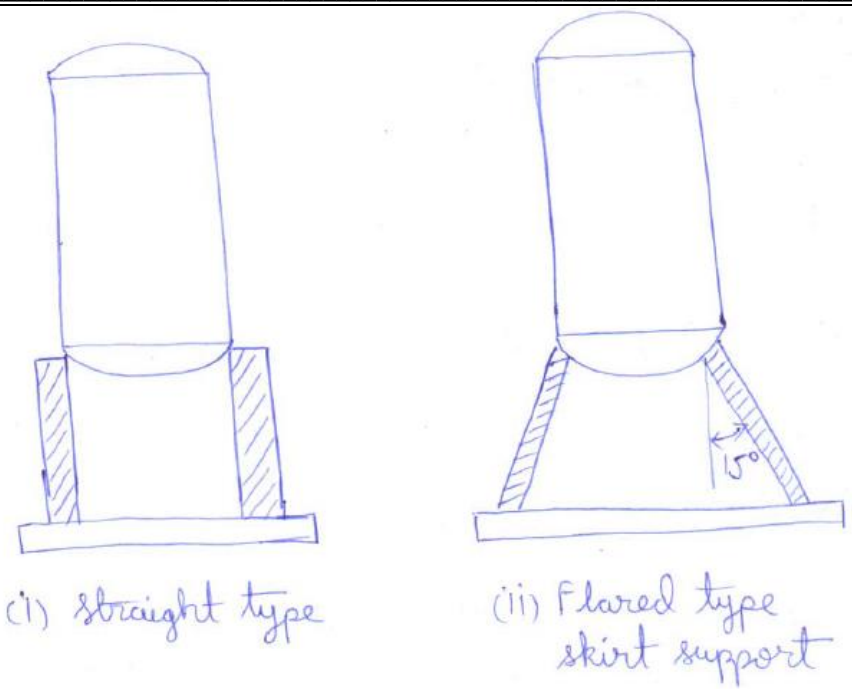
For high temperature service; flat metallic materials like Cu, Ag, Au, etc. are used as gasket materials. They are available in variety of shapes e.g. oval, octagonal, hexagonal, etc.

Corrugated metal gaskets

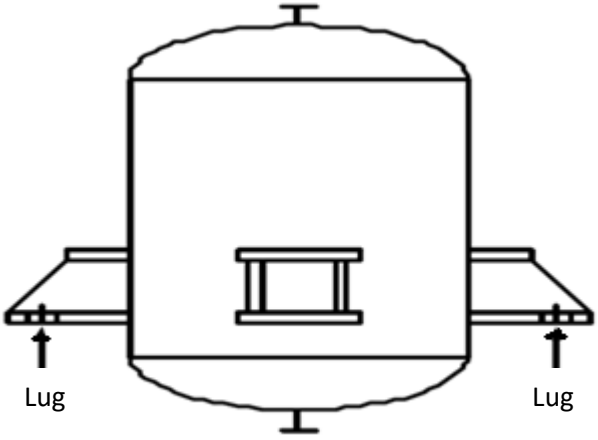
MODEL ANSWER

SUMMER– 17 EXAMINATION

Subject Title: Processes Equipments Subject Code: 17457

b)	 Support skirt: Tall vertical vessels are supported by cylindrical shell called as skirt. The skirt is a suitable supporting structure for tall vessels which are subjected to wind load, seismic load and other load. The skirt is welded to the bottom dish end from the outside of the shell. A bearing plate/ base plate/ support plate is attached to the bottom of the skirt. The plate is made to rest on a concrete foundation and is securely anchored to foundation by means of anchor bolts embedded in concrete to prevent overturning due to wind load or earthquake load. The commonly used materials for skirt supports are carbon steels. 1) Straight type skirt support is used for tall vessels. The centre line of cylindrical skirt and shell are coincident. This type is more difficult to fabricate and is used mainly for high external loads, high design temperatures or cyclic operating temperatures. A good fit between the outside diameter of the shell and inside diameter of skirt is a must. 2) Flared type skirt support is used for very high columns with high external moments. The angle of skirt is maximum 15^{o}.	**01 mark** **01 mark**

Support lug:



01 mark

Brackets are fabricated from plates and are attached to the vessel wall. They are made to rest on small columns or beams of structure depending on the elevation required. They can be easily leveled. Due to the eccentricity of these supports, compressive, tensile and shear stresses are induced in the vessel wall. Bracket supports are suitable for vessels with thick walls.

Diameter of vessel	Number of brackets
Upto 0.6m	2
Upto 3.0m	4
Upto 5.0m	6
Above 5.0m	8

01 mark

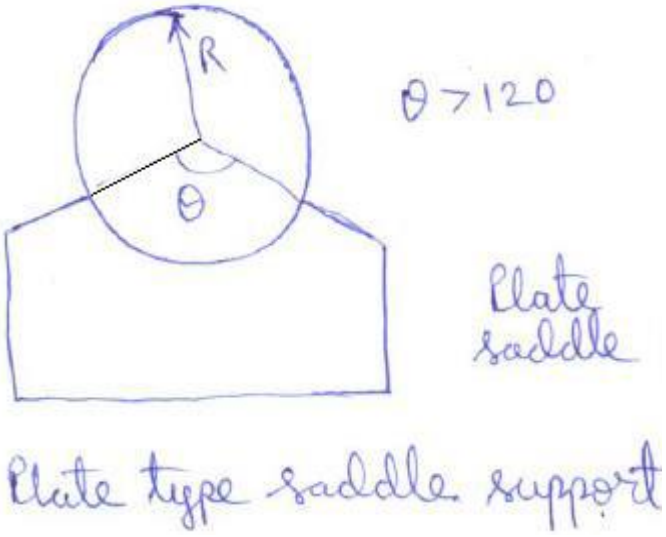
The main loads on the bracket supports are the dead weight of the vessel with its content and the wind load. The wind load tends to overturn the vessel when it is empty. Use of bracket or lug support is limited to vertical pressure vessels with diameter Ø ranging from 1’ to 10’ (0.3m to 3.0m) and a moderate height to diameter ratio as h / d = 5 / 2.

Saddles:
Horizontal cylindrical vessels are supported on saddles. These are placed at minimum two positions. The shell of a vessel is strengthened by stiffeners and supported by using saddle supports. These are used for large thin walled vessels or vessels under vacuum. Supports in the form of rings are preferable for vessels in which supports at more than two

01 mark

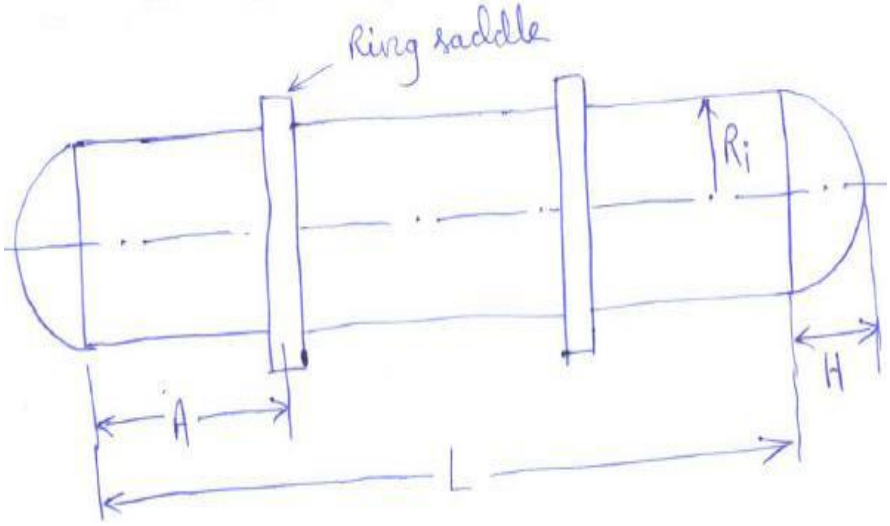
positions are essential. Types are;

1) Plate type saddle support: In this included angle θ should be greater than 1200



1/2 mark

2) Ring type saddle support: In this support, distance A = (0.4 to 0.5) times Ri or A < 0.2L

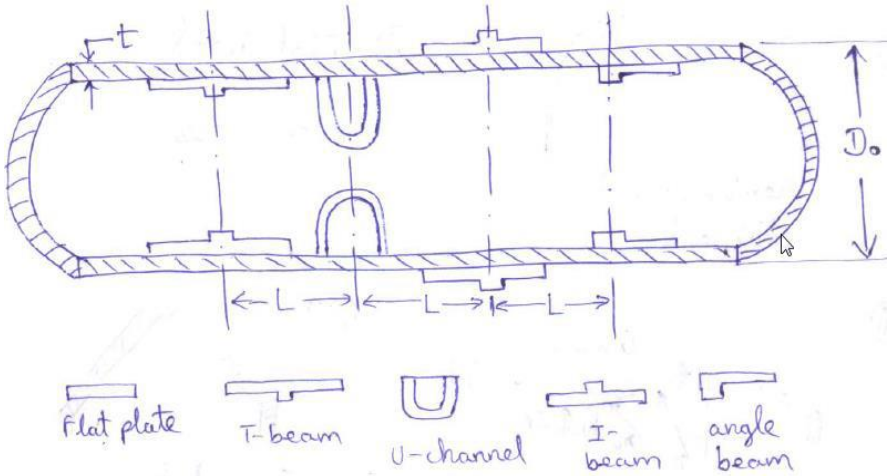


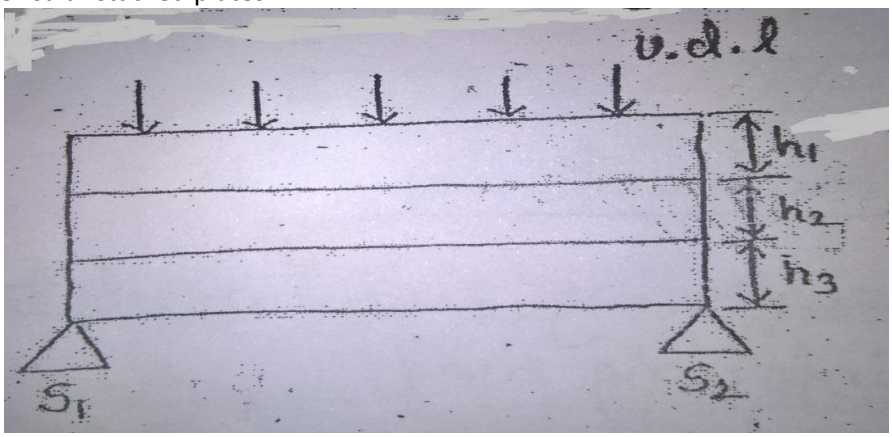
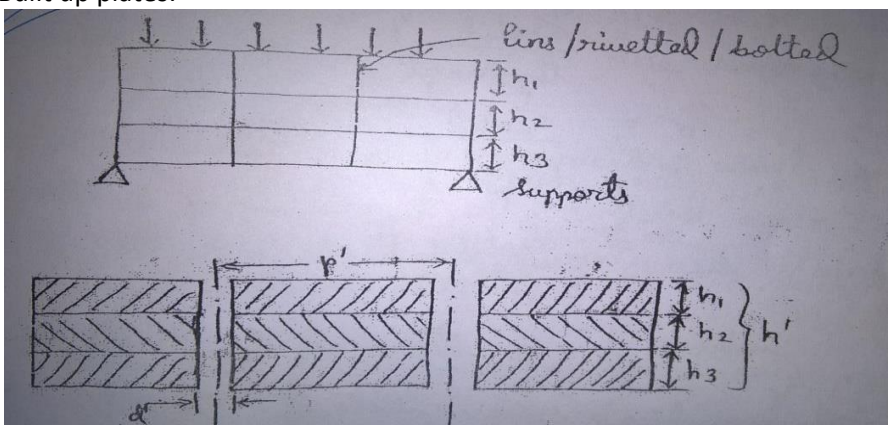
1/2 mark

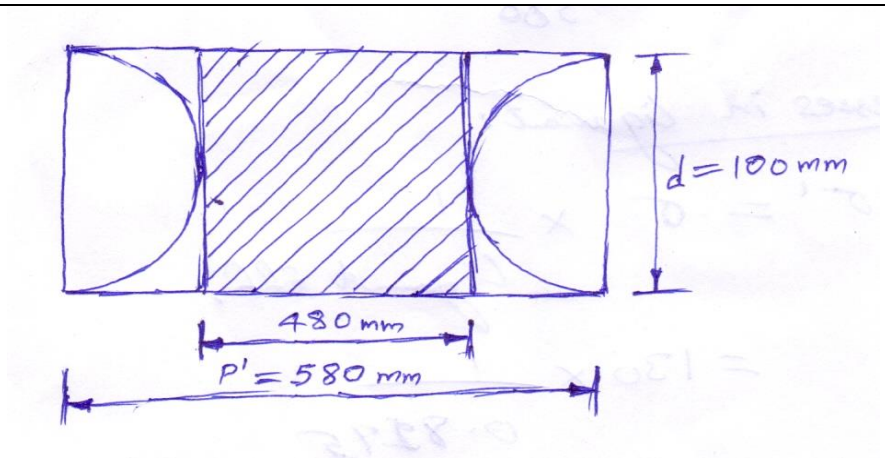
MODEL ANSWER

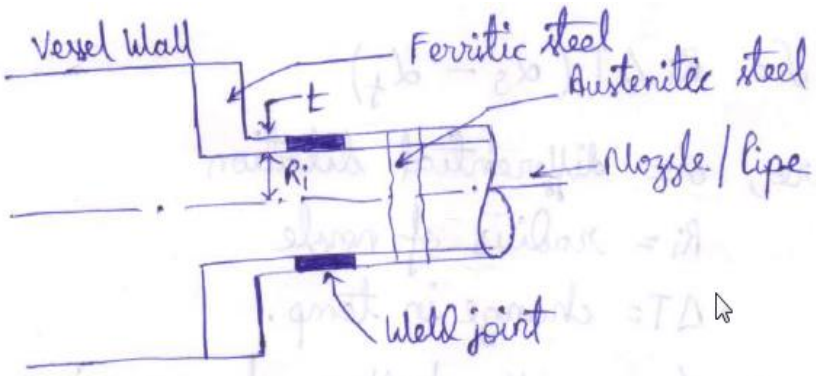
SUMMER– 17 EXAMINATION

Subject Title: Processes Equipments Subject Code: 17457

	Stiffners:  Considerable saving in weight and material can be made by use of stiffening rings (reinforcing rings). Stiffening rings are attached on the inside or outside surface of the shell. These rings extend over the whole circumference and serve the purpose of end supports. T- beams, flat plate rings, I-beam, U-channel, angles, etc. bolted/ riveted/welded to the shell can be used as stiffening rings.	**01 mark** **01 mark**
c) i	Ultra high pressure vessels: Hydraulic and extrusion presses utilize very high fluid pressures to large forces, which in turn required extremely thick walled cylinders. In such cylinders hoop stress at the outside of the inside surface; hence the wall material is not used uniformly to its fullest stress and economic potential. Several design principles that have been successfully used to overcome this situation follow; 1) Wedge principle 2) Segment principle 3) Cascade principle 4) Yoke principle	**02 marks** **02 marks**
ii	Membrane stress The stress calculated by neglecting bending in the membrane is called as membrane stress Membrane stresses determines the required thickness of shell or head/ dishend.	**02 marks**

	Analysis of membrane stress can be applies to find thickness of Cylindrical shell Spherical Shell Elliptical Shell,etc. And various types of heads viz.(Hemispherical, Semi ellipsoidal, Conical, Flat Head, Torispherical, etc.	**02 marks**
6	**Attempt any Two of the following**	**4 x 4**
a)	Circular stacked plates:  Flat pates are stacked one on the other and are frequently used to support loads. This may be done because the construction arrangement does not permit a single plate of equivalent thickness to be used or because a single plate of required thickness is not available. Built up plates:  	**01 Mark** **01 Mark** **01 Mark**

	It sliding of one stacked plate on the other is to be prevented through the use of pins, rivets, bolts or keys to take shear at the plate interfaces, this arrangement is called as built-up plates which is stiffer and stronger than the same stack welded. The shear pins, rivets, bolts or keys used in the built-up plate should have a tight fit in order to prevent high local deformation and initial deflection.	**01 Mark**
b)	 Given, No. of holes=6 D= 100mm P'-d= 480 mm Therefore, p'=480+d =480+100 =580mm S= 130 MPa i)Ligament Efficiency: Ligament Efficiency= ((p'-d)/p')*100 = ((480)/580)*100 = (0.8275)*100) = **82.75 %** ii)Stresses in Ligament (S'): S' =S*(1/Ligament Efficiency) = 130*(1/0.8275) = **157.09 MPa**	**02 marks** **02 marks**

c)	ii) Stresses induced in bi-metallic joints:  Special conditions often require that a pressure vessel be constructed of several materials of different metallurgical and physical properties, whose incompatibility induces stresses when the vessel is subjected to its operating environment. This occurs in the piping (nozzle) of boilers and turbines where austenitic steels such as 18-8 (18%Cr and 8%Ni) are required in the high temperature zones whereas in the cooler zones the more economical ferritic steels are used. Local discontinuity stresses are produced in the region where these dissimilar materials are welded together, due to the fact that the coefficient of thermal expansion of the austenitic steels is 50% greater than that of the ferritic steel.	**02 marks** **02 marks**
d	Design approach for bolted joint: -Bolts are designed for strength and also for tightness at the joint. -In order to prevent leakage of the bolted joint the force exerted by the bolts must exceed the force due to fluid pressure. Bolting materials with applications: -Carbon steel can be used as a bolting material for a design temperature up to 450^0 F. -Austenitic stainless steel bolts are used on pressure joints for low	**02 marks** **02 marks**

	temperature service or for corrosive service. -Steel with Ni-Cr content is used for important joints where additional safety factor is required.	
e	Ferrous metals used for corrosive services in pressure vessel construction: • Wrought iron • Cast iron a. Grey cast iron b. White cast iron c. Alloy cast iron High silicon iron High silicon cast iron with nickel and copper Nickel alloy cast iron • Steel a. Low carbon steel b. Medium carbon steel c. High carbon steel d. Alloy steel Low alloy steel viz. Carbon Molybdenum steels High alloy steels viz. Chromium steels, Chromium nickel steels also called as Stainless steels Commonly used material is Low carbon steels or also called Mild steels: Properties: • Good strength and ductility • Good weldability, machinability and fabricability • Rolled, forged and drawn • Low corrosion resistance • etc.	**04 marks** **(01 mark each)**

Application: Used in normalised condition for;

- Pressure vessel components,
- Pipes and fittings,
- Machine components,
- Structural sections,
- etc.

Non ferrous metals used for corrosive services in pressure vessel construction:

- Aluminium and alloys
- Copper and alloys
- Nickel and alloys
- Chromium and alloys
- Lead
- Titanium
- Beryllium
- Zirconium
- Tantalum

Commonly used materials are Copper and Nickel and their alloys:

Properties:

- Good ductility and malleability
- Good electrical and thermal conductivity
- Good mechanical strength and fabricability
- Good resistance to atmospheric attack, strong alkalies and organic solvents
- etc.
-

Application:

- Copper alloys viz. Brass, Bronze, Aluminium bronze, Cu-Ni alloys for manufacture of process equipments
- Nickel alloys viz. Monel, Inconel, Hastealloy for manufacture of process equipments and cladding purposes etc.

f	Use of Aluminium and alloys in pressure vessel: Properties; • Light in weight • Easy to fabricate • Better mechanical properties comparable to MS • Retains ductility at sub zero temperatures • Resists attack of acids • etc. Applications; • Duralumin is used fabrication of storage vessel, reaction vessels, heat exchangers, absorption columns, etc. • Al-Si alloys is used as castings for pistons and transmission casings for transport • Al-Zn-Mg alloys are used as die casting alloys • etc. Use of Stainless Steel in Pressure Vessel: Stainless steels are any of the various steels alloyed with at least 10 percent chromium and sometimes containing other elements and that are resistant to corrosion or rusting associated with exposure to water and moist air. Types are; • Austenitic stainless steel • Martensitic stainless steel • Ferritic stainless steel • Ferritic Austenitic stainless steel • Nitrogen added stainless steel Resistance to corrosion and staining, low maintenance and familiar lustre are some reasons to being used in pressure vessel construction.	**$^1/_2$ mark each** **(any 2)** **$^1/_2$ mark each** **(any 2)** **$^1/_2$ mark each** **(any 4)**