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**JIS B 8280** : 2003

(KHK/JSA)

**Pressure vessels of noncircular  
cross section**

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## Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Health, Labour and Welfare, and the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee, as the result of proposal for revision of Japanese Industrial Standard submitted by The High Pressure Gas Safety Institute of Japan (KHK) /Japanese Standards Association (JSA), with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently, JIS B 8280 : 1993 is replaced with this Standard.

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## Pressure vessels of noncircular cross section

**1 Scope** This Japanese Industrial Standard specifies the construction of the pressure vessel having a rectangular or obround cross section (hereafter referred to as “noncircular cross section shell”). The method and range of application shall be as follows.

- a) The method of application shall follow the applicable law and provisions in **JIS B 8265** or **JIS B 8266**, if any, or shall be as the agreement between the purchaser and the manufacture if there is no specification.
- b) Noncircular cross section shell in this Standard include shell plate and reinforcing, stiffening and staying members, shell flange and nozzle.

**2 Normative references** The following Standards contain provision which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards(including amendments) shall be applied.

JIS B 0190 *Glossary of terms used in construction of pressure vessels*

JIS B 8265 *Construction of pressure vessel—General principles*

JIS B 8266 *Alternative standard for construction of pressure vessels*

JIS B 8274 *Flat tubesheet for pressure vessels*

**3 Definitions** For the main terms used in this Standard, the definitions in **JIS B 0190** apply.

**4 Materials** The materials used for the construction of noncircular cross section shell shall follow the provisions of the applied law or applied pressure vessel standards.

### 5 Shape of noncircular cross section shell

**5.1 Rectangular cross section shell** Rectangular cross section shell shall be as follows:

- a) **Explanation of figure 1 a)** This figure shows the shell in which the opposite shell plates have the same thickness. Two opposite plates may have a thickness different than that of the other two opposite plates.
- b) **Explanation of figure 1 b)** This figure shows the shell in which the opposite shell plates have the same thickness and the other two plates have two different thicknesses.
- c) **Explanation of figure 1 c)** This figure shows the shell of the cross section as in fig-

ure 1 a) but having two opposite shell plates stayed at midlength by a partition plate or stay bar. The partition plate shall be constructed so as not to be subjected to pressure.

- d) **Explanation of figure 1 d)** This figure shows the shell of the cross section as in figure 1 a) but having two opposite shell plates stayed at the third points by partition plates or stay bars. The partition plate shall be constructed so as not to be subjected to pressure.

Further, the shell of which two opposite shell plates stayed at more than the third points by partition plates or stay bars [except for figure 1 f)], the calculation shall be performed as regarding the shell is stayed at the third points of the maximum span. In this case, the calculation shall be performed as regarding the minimum thickness is applied for all the partition plates or stay bars.

- e) **Explanation of figure 1 e)** This figure shows the shell of the cross section as in figure 1 a) but having two opposite shell plates stayed such that the compartments have different dimensions by partition plates or stay bars. The partition plate shall be constructed so as not to be subjected to pressure.
- f) **Explanation of figure 1 f)** This figure shows the shell of the cross section as in figure 1 a) but having two opposite shell plates stayed such that the compartments of both ends have the same dimensions and the middle compartment has different dimensions by partition plates or stay bars. The partition plate shall be constructed so as not to be subjected to pressure.
- g) **Explanation of figure 1 g)** This figure shows the shell having uniform thickness and corners bent to a radius.
- h) **Explanation of figure 1 h)** This figure shows the shell having the cross section as in figure 1 a) and the both ends of one shell plate bent to a radius.

**5.2 Obround cross section shell** Obround cross section shell shall be as follows:

- a) **Explanation of figure 2 a)** This figure shows the shell of obround form in which the opposite shell plates and semicylindrical parts have the same thickness.
- b) **Explanation of figure 2 b)** This figure shows the shell of obround form as in figure 2 a) but having the flat side plates stayed at midlength by a partition plate or stay bar. The partition plate shall be constructed so as not to be subjected to pressure.

**5.3 Cylindrical shell of circular cross section with a central dividing partition plate**

Figure 3 shows the cylindrical shell of circular cross section with a central dividing partition plate.

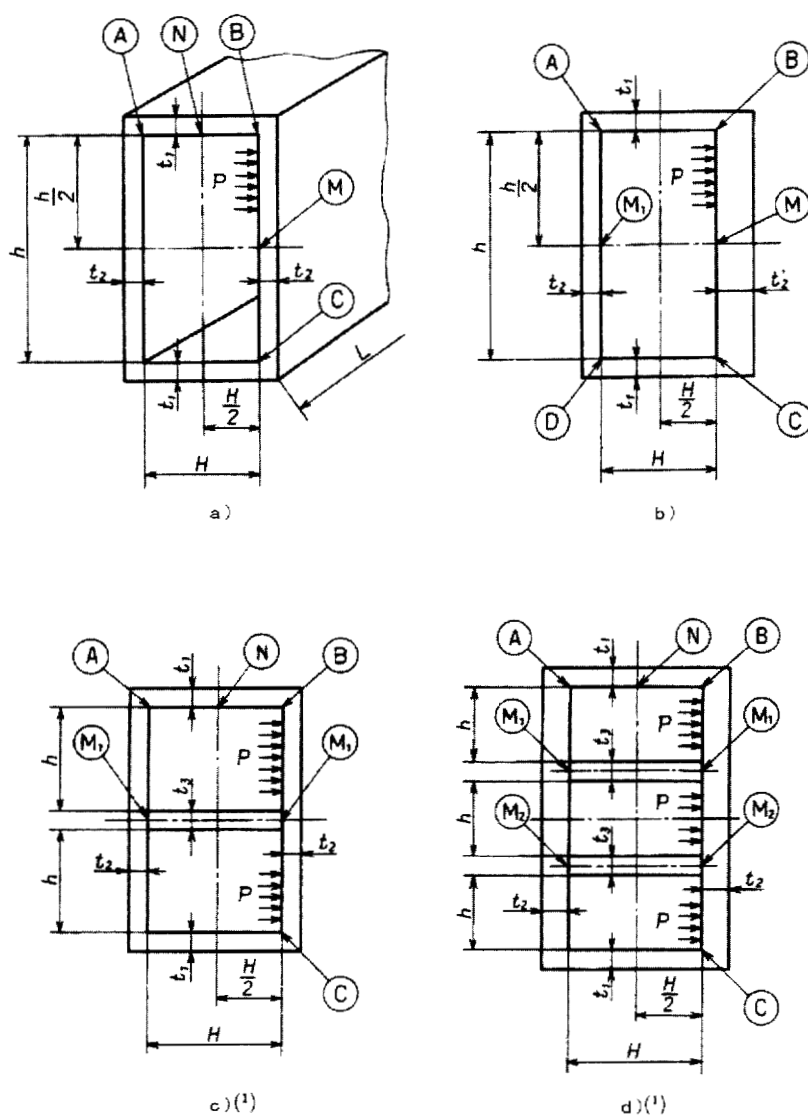
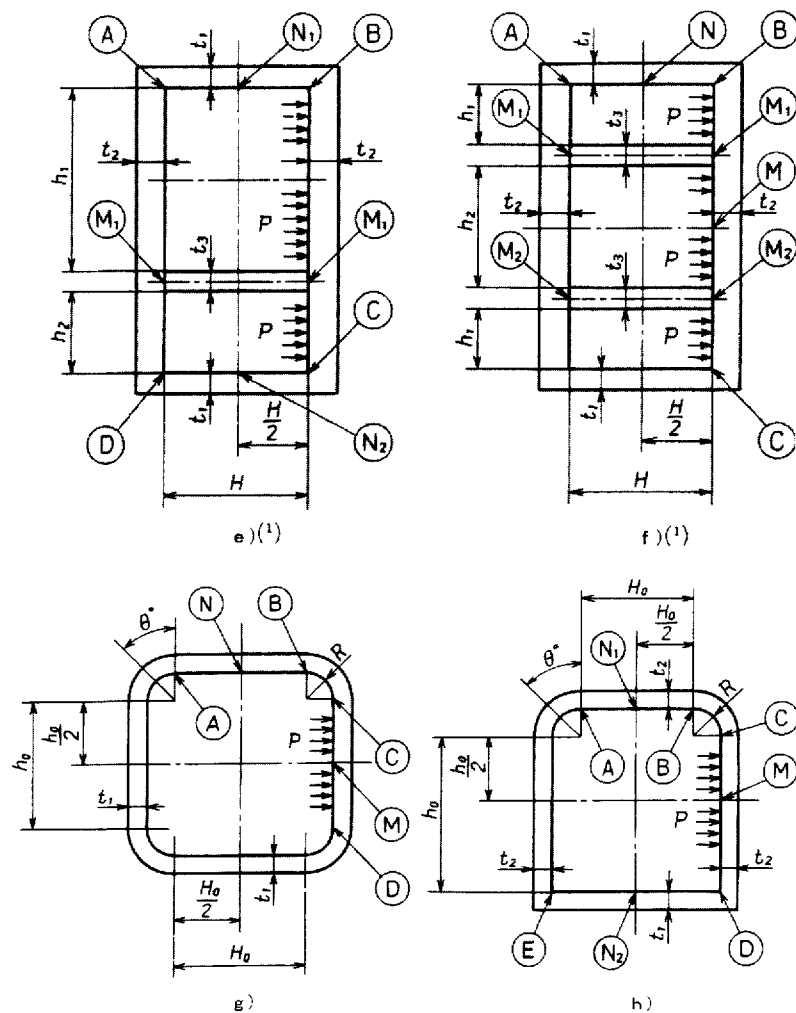
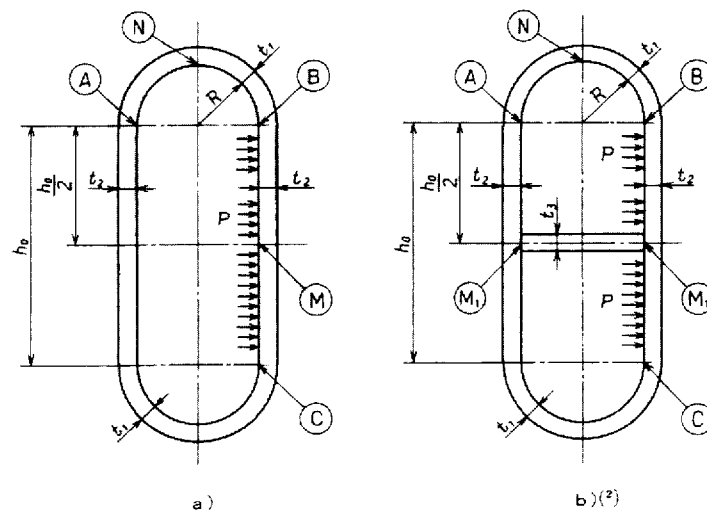


Figure 1 Rectangular cross section shell †



Note (1) :  $t_3$  shall be read as  $d$  for the stay bar.

Figure 1 (concluded)†



Note (2) :  $t_3$  shall be read as  $d$  for the stay bar.

Figure 2 Obround cross section shell†

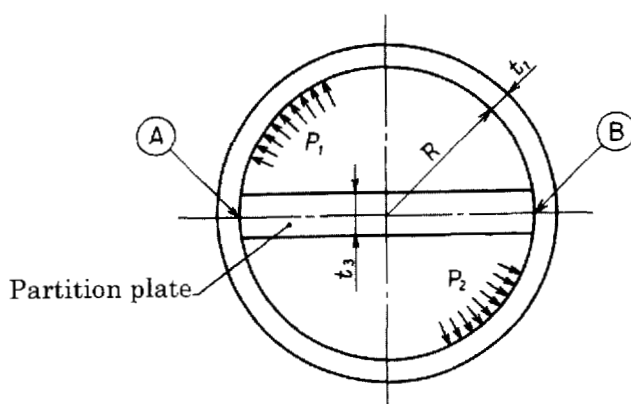


**Figure 3** Cylindrical shell of circular cross section  
with central dividing partition plate†

**6 Meaning of symbols** The meaning of symbols used in this Standard shall be as follows:

- $P$  : internal design pressure (MPa)
- $P_1, P_2$  : internal design pressure in two-compartment vessel (MPa), where  $P_1 > P_2$ .  
(see figure 3)
- $h$  : length of one edge of noncircular cross section shell as shown in figure 1 a) to d) (mm)
- $h_1, h_2$  : length of one edge of noncircular cross section shell as shown in figure 1 e) and f) (mm)
- $h_0$  : length of shell as shown in figure 1 g), h) and figure 2 a), b) (mm)
- $H$  : length of one edge of noncircular cross section shell as shown in figure 1 a) to f) (mm)
- $H_0$  : length of shell as shown in figure 1 g) and h) (mm)
- $R$  : inside radius as shown in figure 1 g), h), figure 2 a), b) and figure 3 (mm)
- Ⓐ to Ⓔ, Ⓝ, Ⓜ and so on: position of the members subjected to stress calculation
- $t$  : thickness of shell plate (mm)
- $t_1, t_2, t_2'$  : thickness of shell plate as shown in figures 1 to 3 (mm)
- $t_3$  : thickness of partition plate as shown in figures 1 to 3 (mm)
- $t_r$  : required minimum thickness <sup>(3)</sup> of shell plate (mm)
- $\theta$  : angle as shown in figure 1 g) and h) (°)
- $\eta$  : joint efficiency of weld or ligament efficiency
- $\sigma_a$  : allowable tensile stress at the design temperature of material (N/mm<sup>2</sup>)
- $\sigma_m$  : membrane stress (N/mm<sup>2</sup>)
- $\sigma_b$  : bending stress (N/mm<sup>2</sup>)

$\sigma_T$  : composite stress (N/mm<sup>2</sup>)

$L$  : length in the longitudinal direction of noncircular cross section shell (mm) (see figure 1 a))

$P_c$  : maximum pitch of round bar stay (mm)

$d$  : diameter of round bar stay (mm)

$C$  : coefficient based on the method to set the stay

$D_E$  : equivalent uniform diameter of multidiameter hole (mm)

$I$  : geometrical moment of inertia (mm<sup>4</sup>)

$T_0$  : length of hole of diameter  $d_0$  excluding corrosion allowance (mm)

$T_1$  : length of hole of diameter  $d_1$  excluding corrosion allowance (mm)

$T_2$  : length of hole of diameter  $d_2$  excluding corrosion allowance (mm)

$T_n$  : length of hole of diameter  $d_n$  excluding corrosion allowance (mm)

$\bar{X}$  : length from base of the plate to neutral axis (mm)

$d_0$  : diameter of hole of length  $T_0$  (pitch diameter for threaded hole) (mm)

$d_1$  : diameter of hole of length  $T_1$  (pitch diameter for threaded hole) (mm)

$d_2$  : diameter of hole of length  $T_2$  (pitch diameter for threaded hole) (mm)

$d_n$  : diameter of hole of length  $T_n$  (pitch diameter for threaded hole) (mm)

$p$  : pitch of hole (mm)

$b_0$  :  $p - d_0$  (mm)

$b_1$  :  $p - d_1$  (mm)

$b_2$  :  $p - d_2$  (mm)

$b_n$  :  $p - d_n$  (mm)

$c$  : length from the neutral plane of cross section to the top surface of member (mm)

$e_b$  : ligament efficiency for bending stress

$e_m$  : ligament efficiency for membrane stress

Note (3) : The required minimum thickness shall be calculated as the minimum thickness in which the membrane stress generated on individual parts such as noncircular shell and partition plate, and the composite stress of membrane stress and bending stress becomes respective allowable values or under in the stress calculating formula for the target noncircular cross section shell.

## 7 Design of noncircular cross section shell

### 7.1 Design : General

a) **Allowable stress** Allowable stress for the stress generated by inner pressure shall

be as follows:

- 1) **Allowable stress for membrane stress** Allowable stress for membrane stress shall be as 4.3.1 of JIS B 8265.
- 2) **Allowable stress for the composite stress of membrane stress and bending stress** Allowable stress for the composite stress of membrane stress and bending stress shall be as 1.5 times the value specified in 1).

Remarks : In the formula of this Standard, the effects of external force other than internal pressure and heat expansion by the temperature difference and so on are not considered.

- b) **Joint efficiency of weld** Joint efficiency of weld of noncircular cross section shell shall be as the value of 6.2 table 6.2 <sup>(4)</sup> in JIS B 8265 according to the joint specified in 6.1.4 of JIS B 8265 with the classification of the position of joint specified in clause 8.

Note <sup>(4)</sup> : Corner joint (FP joint) of noncircular cross section shell jointed by full penetrating weld may be regarded as equivalent to B-1 joint.

- c) **Ligament efficiency** In the case that there are many holes on the shell plate and partition plate of noncircular cross section shell, ligament efficiency shall be as follows:

- 1) **Ligament efficiency of a plate with uniform diameter holes** Ligament efficiency for the membrane stress and bending stress shall be as follows:

$$e_m = e_b = \frac{p - D_0}{p}$$

Where,  $D_0$  : hole diameter (pitch diameter for screw hole) (mm)

- 2) **Ligament efficiency of plate with multidiameter holes** Ligament efficiency of the shell plate and partition plate of noncircular cross section shell with multidiameter holes shall be as follows.

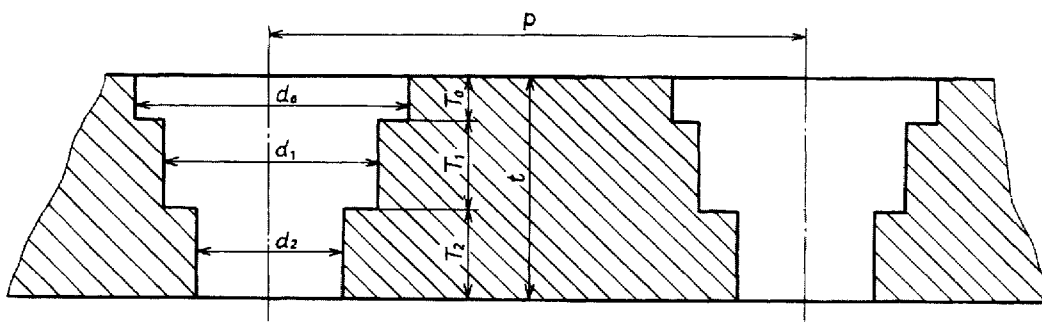


Figure 4 Plate with multidiameter hole pattern†

- 2.1) **Ligament efficiency for the membrane stress** Ligament efficiency for the membrane stress shall be as follows:

$$e_m = \frac{p - D_E}{p}$$

Where,  $D_E = \frac{1}{t}(d_0T_0 + d_1T_1 + d_2T_2 + \dots + d_nT_n)$  (mm)

- 2.2) **Ligament efficiency subject to bending stress** Ligament efficiency subject to the bending stress shall be as follows:

$$e_b = \frac{6I}{t^2cp}$$

Where,  $I = \frac{1}{12}(b_0T_0^3 + b_1T_1^3 + b_2T_2^3 + \dots + b_nT_n^3)$

$$+ b_0T_0\left(\frac{T_0}{2} + T_1 + T_2 + \dots + T_n - \bar{X}\right)^2 + b_1T_1\left(\frac{T_1}{2} + T_2 + \dots + T_n - \bar{X}\right)^2$$

$$+ b_2T_2\left(\frac{T_2}{2} + \dots + T_n - \bar{X}\right)^2 + \dots + b_nT_n\left(\bar{X} - \frac{T_n}{2}\right)^2 \quad (\text{mm}^4)$$

$$\bar{X} = \left[ b_0T_0\left(\frac{T_0}{2} + T_1 + T_2 + \dots + T_n\right) + b_1T_1\left(\frac{T_1}{2} + T_2 + \dots + T_n\right) \right.$$

$$\left. + b_2T_2\left(\frac{T_2}{2} + \dots + T_n\right) + \dots + b_nT_n\left(\frac{T_n}{2}\right) \right]$$

$$\times (b_0T_0 + b_1T_1 + b_2T_2 + \dots + b_nT_n)^{-1}$$

$c = \bar{X}$  or  $(t - \bar{X})$ , whichever is the larger (mm)

- d) **End bonnet plate of noncircular cross section shell** Calculation of end bonnet plate of noncircular cross section shell shall be as in 3.6.1 of JIS B 8265 annex 1. The value of coefficient  $C$  shall be 0.2 or over for any case. End bonnet plates of shell as shown in figure 1 g) and figure 1 h) shall be regarded as rectangular of which the corners are not round for calculation, and end bonnet plates of shell as shown in figure 2 a) and figure 2 b) shall be subjected to calculation using the maximum span measured perpendicular to the minimum span.
- e) **Holes bored on noncircular cross section shell** Holes bored on noncircular cross section shell be as follows:
- 1) For installing nozzles and so on, the round hole corresponding to clause 4 of JIS B 8265 annex 2 needs no reinforcement.
  - 2) If the reinforcement is necessary for holes to install nozzles and so on, it shall be as follows:
    - 2.1) For the hole whose diameter is 1/2 or under of  $H$  or  $2R$  shown in figure 1, figure 2 or figure 3, the reinforcement of hole shall be as in 5.6 a) of JIS B 8265 annex 2. The minimum cross section of reinforcing member  $A$  shall be as  $A = d_N t_r$ . Where,  $d_N$  is hole diameter.
    - 2.2) In case where the hole diameter is greater than 2.1), any one method out of following shall be adopted. And this method may be applied to the hole corresponding to 2.1).

- 2.2.1) Established stress analyzing method or experimental stress analyzing method including the nozzle part.
- 2.2.2) Official approval of hydraulic pressure test specified in annex 2.
- 2.2.3) Following simplified reinforcement calculations
- Reinforcement calculation for membrane stress : Simplified reinforcement calculation for membrane stress shall be as follows:  
  
Procedure 1 : Calculate the required minimum thickness  $t_r$  of the plate having the hole corresponding to the composite stress of membrane stress and bending stress.  
  
Procedure 2 : The necessary reinforcing area for the membrane stress shall be the area of product of the required minimum thickness and the ratio of membrane stress and allowable tensile stress multiplied by the hole diameter.  
  
Procedure 3 : The necessary reinforcing area corresponding membrane stress shall be within the effective range of reinforcement specified in **JIS B 8265** annex 2.
  - Reinforcement calculation for bending stress : Simplified reinforcement calculation for bending stress shall be as follows:  
  
Procedure 1 : Calculate the geometrical moment of inertia relevant to the neutral axis perpendicular to the plate thickness direction for the member consisting of required minimum thickness and hole diameter.  
  
Procedure 2 : Set the reinforcing area within the range of effective reinforcement (part other than the part considered with the reinforcement of membrane stress) specified in **JIS B 8265** annex 2 so that the geometrical moment of inertia relevant to the same neutral axis with the Procedure 1 shall become equal or greater than the required moment of inertia obtained in the Procedure 1.
- 3) Reinforcing plate is not necessary for the holes to be applied to the ligament efficiency
- f) **Tube hole** Tube hole shall be as given in 4.3 and 4.4 of **JIS B 8274** and the following:
- 1) The distance between the centres of adjacent tube holes shall be not less than 1.25 times the outside diameter of the tubes when fitted to the shell plate by expanding.
  - 2) The thickness of fitting part of tube shall be not less than 10 mm in the case of the tube plate of noncircular cross section shell to which tubes are fitted by expanding.

## 7.2 Calculation of rectangular cross section shell

7.2.1 **Shell as shown in figure 1 a)** Membrane stress, bending stress and composite stress of them generated on shell plate as shown in figure 1 a) shall be calculated by following formula.

a) **Stress between the members ① and ②**

1) **Membrane stress ( $\sigma_m$ )**

$$\sigma_m = \frac{Ph}{2t_1\eta} \dots\dots\dots (1)$$

2) **Bending stress ( $\sigma_b$ )**

$$(\sigma_b)_N = \pm \frac{Ph^2c}{2t_1^3\eta} \left[ \frac{2 - (K+3)\alpha^2}{K+1} \right] \dots\dots\dots \text{central point ③} \quad (2)$$

$$(\sigma_b)_B = \pm \frac{Ph^2c}{t_1^3\eta} \left[ \frac{\alpha^2K+1}{K+1} \right] \dots\dots\dots \text{corner sections ①, ②} \quad (3)$$

3) **Composite stress ( $\sigma_T$ )**

$$(\sigma_T)_N = \text{Formula (1) + Formula (2)} \dots\dots\dots \text{central point ③}$$

$$(\sigma_T)_B = \text{Formula (1) + Formula (3)} \dots\dots\dots \text{corner sections ①, ②}$$

b) **Stress between the members ② and ③**

1) **Membrane stress ( $\sigma_m$ )**

$$\sigma_m = \frac{PH}{2t_2\eta} \dots\dots\dots (4)$$

2) **Bending stress ( $\sigma_b$ )**

$$(\sigma_b)_M = \pm \frac{Ph^2c}{2t_2^3\eta} \left[ \frac{(2\alpha^2 - 3)K - 1}{K+1} \right] \dots\dots\dots \text{central point ④} \quad (5)$$

$$(\sigma_b)_B = \pm \frac{Ph^2c}{t_2^3\eta} \left[ \frac{\alpha^2K+1}{K+1} \right] \dots\dots\dots \text{corner sections ②, ③} \quad (6)$$

3) **Composite stress ( $\sigma_T$ )**

$$(\sigma_T)_M = \text{Formula (4) + Formula (5)} \dots\dots\dots \text{central point ④}$$

$$(\sigma_T)_B = \text{Formula (4) + Formula (6)} \dots\dots\dots \text{corner sections ②, ③}$$

$$\text{Where, } \alpha = \frac{H}{h}, \quad K = \alpha \left( \frac{t_2}{t_1} \right)^3$$

$P, H, h, t_1, t_2, \sigma_m, \sigma_b, \sigma_T$  and  $\eta$  shall be as in clause 6 and figure 1 a).

**7.2.2 Shell as shown in figure 1 b)** Membrane stress, bending stress and composite stress of them generated on shell plate as shown in figure 1 b) shall be calculated by following formula.

a) **Stress between the members ① to ③**

1) **Membrane stress ( $\sigma_m$ )**

$$\sigma_m = \frac{Ph}{2t_1\eta} \dots\dots\dots (7)$$

2) **Bending stress ( $\sigma_b$ )**

$$(\sigma_b)_A = \pm \frac{3Ph^2c}{t_1^3\eta} \left[ \frac{(K_1k_1 - k_2) + \alpha^2k_2(K_1 - k_2)}{N} \right] \dots\dots\dots \text{corner section } \textcircled{A} \quad (8)$$

$$(\sigma_b)_B = \pm \frac{3Ph^2c}{t_1^3\eta} \left[ \frac{(K_2 - k_1k_2) + \alpha^2k_2(K_2 - k_2)}{N} \right] \dots\dots\dots \text{corner section } \textcircled{B} \quad (9)$$

3) **Composite stress ( $\sigma_T$ )**

$$(\sigma_T)_A = \text{Formula (7) + Formula (8)} \dots\dots\dots \text{corner section } \textcircled{A}$$

$$(\sigma_T)_B = \text{Formula (7) + Formula (9)} \dots\dots\dots \text{corner section } \textcircled{B}$$

b) **Stress between the members  $\textcircled{B}$  and  $\textcircled{C}$**

1) **Membrane stress ( $\sigma_m$ )**

$$\sigma_m = \frac{Ph}{4t_2'\eta} \left[ \frac{2N\alpha^2 + (K_2 + k_2) - k_1(K_1 + k_2) + \alpha^2k_2(K_2 - K_1)}{N\alpha} \right] \dots\dots\dots (10)$$

2) **Bending stress ( $\sigma_b$ )**

$$(\sigma_b)_M = \pm \frac{3Ph^2c}{2t_2'^3\eta} \left[ \frac{2\{(K_2 - k_1k_2) + \alpha^2k_2(K_2 - k_2)\} - N}{N} \right] \dots\dots\dots \text{central point } \textcircled{M} \quad (11)$$

$$(\sigma_b)_B = \pm \frac{3Ph^2c}{t_2'^3\eta} \left[ \frac{(K_2 - k_1k_2) + \alpha^2k_2(K_2 - k_2)}{N} \right] \dots\dots\dots \text{corner sections } \textcircled{B}, \textcircled{C} \quad (12)$$

3) **Composite stress ( $\sigma_T$ )**

$$(\sigma_T)_M = \text{Formula (10) + Formula (11)} \dots\dots\dots \text{central point } \textcircled{M}$$

$$(\sigma_T)_B = \text{Formula (10) + Formula (12)} \dots\dots\dots \text{corner sections } \textcircled{B}, \textcircled{C}$$

c) **Stress between the members  $\textcircled{D}$  and  $\textcircled{A}$**

1) **Membrane stress ( $\sigma_m$ )**

$$\sigma_m = \frac{Ph}{4t_2\eta} \left[ \frac{2N\alpha^2 - (K_2 + k_2) + k_1(K_1 + k_2) - \alpha^2k_2(K_2 - K_1)}{N\alpha} \right] \dots\dots\dots (13)$$

2) **Bending stress ( $\sigma_b$ )**

$$(\sigma_b)_{M1} = \pm \frac{3Ph^2c}{2t_2^3\eta} \left[ \frac{2\{(K_1k_1 - k_2) + \alpha^2k_2(K_1 - k_2)\} - N}{N} \right] \dots\dots\dots \text{central point } \textcircled{M1} \quad (14)$$

$$(\sigma_b)_A = \pm \frac{3Ph^2c}{t_2^3\eta} \left[ \frac{(K_1k_1 - k_2) + \alpha^2k_2(K_1 - k_2)}{N} \right] \dots\dots\dots \text{corner sections } \textcircled{A}, \textcircled{D} \quad (15)$$