

TOWERS**JGS 210-120-1-21E**

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1. SCOPE

- (1) This standard practice provides the guidelines for the design of towers and their internals provided in refineries, petrochemical plant and similar plants.
The following items are not included herein :
- (a) Materials of towers and internals
 - (b) Tray and packing detailed design procedure
- (2) Specific instructions given in the Project Specifications take precedence over the requirements given in this standard practice.

2. WORK PROCEDURE

2.1 Input to the Design

2.1.1 Process Condition

The data to be used for tower design should be clarified as follows.

- (1) Source of the data
The design data will be obtained from, but not limited to the following documents.
- Process Simulation Output (PRO - II, ASPEN, HYSYS, HYSIM, DESIGN II, Chemtran, C338, #AMINE etc.)
 - Process Flow Diagram (PFD)
 - Basic Engineering Design Data (BEDD)
 - Piping & Instrument Diagram (P&ID)
 - Plot Plan
- (2) Design base
Maximum, normal and minimum feed rate and corresponding physical properties should be used for designing towers.

2.1.2 Input Data

- (1) Operating Conditions
The following is a summary of operating condition data to be specified before the tower design.
- Service for identification
 - Fluid name for identification
 - Fluid character (Foaming tendency, Fouling, Corrosion etc.)
 - Feed flow rate of liquid and / or vapor (maximum, normal and minimum)
 - Each theoretical stage operation data ; Temperature, Pressure
 - Liquid ; Load (kg/hr), Density (kg/m³), Viscosity (cp), Surface Tension (dyne/cm)
 - Vapor ; Load (kg/hr), Density (kg/m³), Viscosity (cp), Molecular Weight
 - Stripping steam flow rate, pressure, temperature
- (2) Performance Requirement
Following requirements should be clarified before the tower design.
- Holding time for liquid draw off
 - Allowable pressure drop
 - Overall tower efficiency
 - De - rating factors
- (3) Mechanical Design Data
Following item should be specified before the tower design.
- Code to be applied
 - Design temperature
 - Design pressure
 - Corrosion allowance
 - Material of construction
 - Condenser Type
 - Reboiler Type

2.2 Output from the Design

- (1) Data sheet of the tower (Skeleton, Internal type, Vapor / Liquid load)
- (2) Data sheet of tray, packing
- (3) Vender data sheet (tray, packing, distributor etc.)

2.3 Work Steps

The design of tower will be conducted according to be the following work steps, as a guideline.

- (1) Prepare input data as listed in section 2.1.
- (2) Selection of tray or packing.
- (3) Design of tray or packing (Request to vendors for tower internal (packing, distributor, tray) design).
- (4) Determine tower diameter and approximate height.
- (5) Determine tower detail dimension
At first, tray arrangement and detail around reboiler return should be determined.
(Manhole, Feed nozzle, Distributor, Accumulator tray, Trap, Miscellaneous nozzles, Reboiler return nozzle, Liquid level, Skirt height, Vortex Breaker, Baffle and Drain etc.)
- (6) Prepare the skeleton of tower
- (7) Summarize the data sheet of tower, internals.

2.4 Check List

At least, the following should be checked.

- (1) Tray No., tray space and each tray cap or hole number.
- (2) Pass No. change and tray turn.
- (3) Tower diameter and height.
- (4) Each nozzle size and locations.
- (5) Each manhole size and locations.

2.5 Computer Programs

Computer programs, details of which are described in relevant manuals are available to assist the design of towers and their internals as follows.

Table 2.5 List of computer programs

Machine	Name of System	Description
P/C	FLEX PC	Flexi tray design / rating
	SIEV PC	Sieve tray design / rating
	BCAPPC	Bubble cap tray design / rating
	FRI Sieve Tray Rating Program	Sieve tray rating by FRI method
	FRI Dualflow Tray Rating Program	Dualflow tray rating by FRI method
	FRI Bubble Cap Tray Rating Program	Bubble cap tray rating by FRI method
	FRI Packed Bed Rating Program	Packed Bed rating by FRI method
	Norton Packed Tower Design Program	Packed Tower rating with Norton packing or ordinary packing
	Koch Tower Design Program	Tower rating with koch packing & tray
W/S	# TRAY	Design / Rating of Sieve, Flexi, Bubble Cap, and Dualflow Tray
	# PACK	Rating of Raschig Ring, Pall Ring, Perforated Ring, Berl Saddle, Intalox Saddle, PFG, K - PAC, and FLEXIGRID

P/C : Personal Computer
W/S : Work Station

3. DESIGN CRITERIA

3.1 Selection Procedure

3.1.1 Comparison between Trays and Packing

- (1) Table 3.1-1 shows the classification of trays, random packing and structured packing, and their typical examples. In each field, new products have been developed and applied to actual operation. Especially, various types of structured packings have been developed recently, and used instead of ordinary random packings or trays to attain high performance.

Table 3.1.1a Classification of Trays and Packing

			Ordinary Type	New Type
TRAYS	With downcomer		Bubble cap Flexitray (Valve) Sieve	MAX-FRAC, Ultra-FRAC SUPERFRAC, NYE MVG
	Without downcomer		Dualflow Ripple	
	Special use	High liquid load	MD	
		High pressure and high load	Screen	
PACKING	Random	Ring type	Raschig Ring Pall Ring	Cascade Mini Ring
		Saddle type	Berl Saddle Intalox Saddle	IMTP Nutter Ring
	Structured	Grid type	Glitsch Grid Flexigrid	
		Seat metal type	Mellapak	GEMPAK Techno Pack MC Pack
		Mesh type	Sulzer Packing (BX)	Sulzer Packing (CY) MC Pack, Techno Pack

- (2) Relative comparison between trays and packing is summarized in Table 3.1-2. Packings are divided into random and structured types. Gas and liquid contact with trays is achieved by injecting gas to continuous flowing liquid on the trays which are installed every 400 to 1,000 mm in the column. On the other hand, gas and liquid contact with packings is achieved in the thin liquid layer on the surface of packings.

Table 3.1.1b Comparison of Trays and Packing

	Trays	Packing
Design	Required for each case	Standard
Distributor	Simple	Complicated
Opening ratio for vapor pass	Small (5 - 20%/plate)	Large (60 - 95%/volume)
Pressure drop (per one HETP)	Large	Small (about 1/10 of tray)
Efficiency *	Low	High
Capacity	Low	High
Cost (per unit height)	Low	High
Operation range	Wide	Narrow
Maintenance	Easy	Difficult
Material selection	Limited	Wide
Number of applications	Many	Few

* Overall tray efficiency for trays and HETP for packings.

- (3) Therefore, trays are generally thought to be suitable for high liquid (high pressure) service, and packing is thought to be suitable for low liquid (low pressure) service.

- (4) The greatest advantage of packing is the large opening ratio for vapor pass, therefore pressure drop is small and capacity against flooding etc. is high compared with trays.
On the other hand, equal liquid dispersion in the continuous flowing vapor is always a major factor in maintaining high efficiency of packing. Therefore, in many cases, distributors and re-distributors are supplied by the packing vendor to obtain good distribution. Up to this time, packings have been mainly applied to small diameter towers because of their distribution difficulties.
- (5) A disadvantage of packing is the high price per unit height. In addition to the packing cost, the distributors and re-distributors are also expensive.
- (6) Table 3.1.1c shows the typical application of trays and packing in the past. However, many kinds of packings and distributors have been developed recently, and there are many application results of packings to large diameter distillation columns or fouling services, such as vacuum towers, crude towers, and FCC/RCC main columns. Characteristics and advantages of packing application are summarized in Table 3.1-4.

Table 3.1.1c Typical Application of Trays and Packing

	Trays	Packing
High pressure service (High L/V ratio)	O	
Low pressure service (Low L/V ratio)		O
Large diameter tower	O	
Small diameter tower		O
Distillation column	O	
Absorber		O
Fouling service	O	

Table 3.1.1d Characteristics and Advantages of Packing Application

Characteristics	Advantages
Small pressure drop	Reducing tower bottom pressure/temperature (or increasing tower top pressure) ↓ (1) Prevention of product degradation against high temperature (2) Reducing energy consumption (vacuum equipment, reboiler, etc.)
Large opening ratio for rising vapor	Small vapor velocity ⇒ (1) Capacity up or reducing tower diameter (2) Less foaming (Random Packing)
High mass transfer efficiency	(1) Saving energy consumption by reducing reflux ratio or (2) Reducing tower height or (3) Increasing purity of product
Small liquid hold up volume	Reducing cracking or polymerization under high temperature
Variety of material selection	Applicable for corrosive fluid

3.1.2 Selection of Internals for a New Column

To select internals for a new column, the following five points should at least be considered :

- Total column cost
- Operation cost
Packing cost per unit height is higher than trays, and distributors are expensive, but column height and diameter can be reduced by using packing, as shown in Table 3.1.1d. Also, operation cost can be reduced. Therefore, total of column cost and operation cost should be compared with that of trays.
- Process conditions (feed rate, pressure, temperature L/V ratio in the column, fouling, corrosion, solid, etc.)
- Required product quality
- Number of applications

3.1.3 Selection of Internals for Revamp of Existing Column

A revamp of an existing column will require higher capacity, higher separation efficiency or both, so in many cases, change of internals from trays to packing, from ordinary random packing to structured packing, or from ordinary trays to new type trays will be studied.

But at least the 5 points described in section 3.1.2 above should be considered, and the most suitable selection should be made, for example: structured packings are selected for the section above feed nozzle (low L/V ratio) and new type trays are selected for the section below feed nozzle (high L/V ratio), and so on.

3.2 Towers

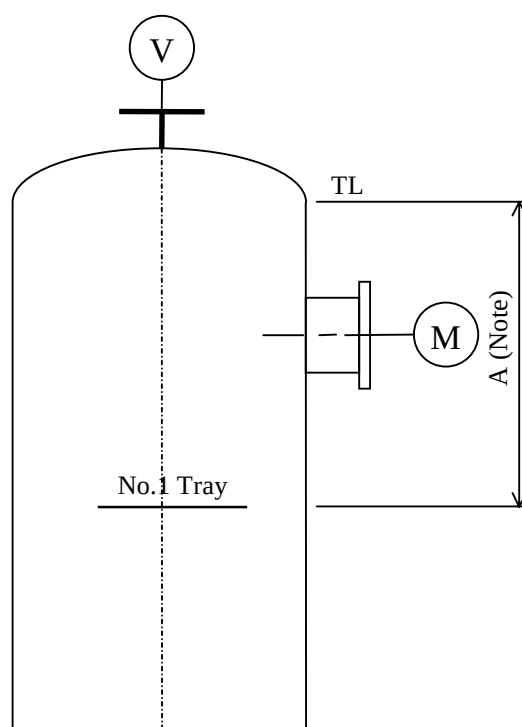
3.2.1 Dimensions around Top Section

3.2.1.1 Side Manhole

- (1) In case where no top manhole can be provided, the side manhole shown in Fig. 3.2.1.1 shall be provided.
- (2) For recommended manhole sizes, see para. 3.2.5.1.

Fig. 3.2.1.1 Geometry of Side Manhole

Note : A = 1,000 mm for 20 inch manhole, and A = 1,200 mm for 24 inch manhole.



$D > 900\text{mm}$

Ⓜ = Manhole

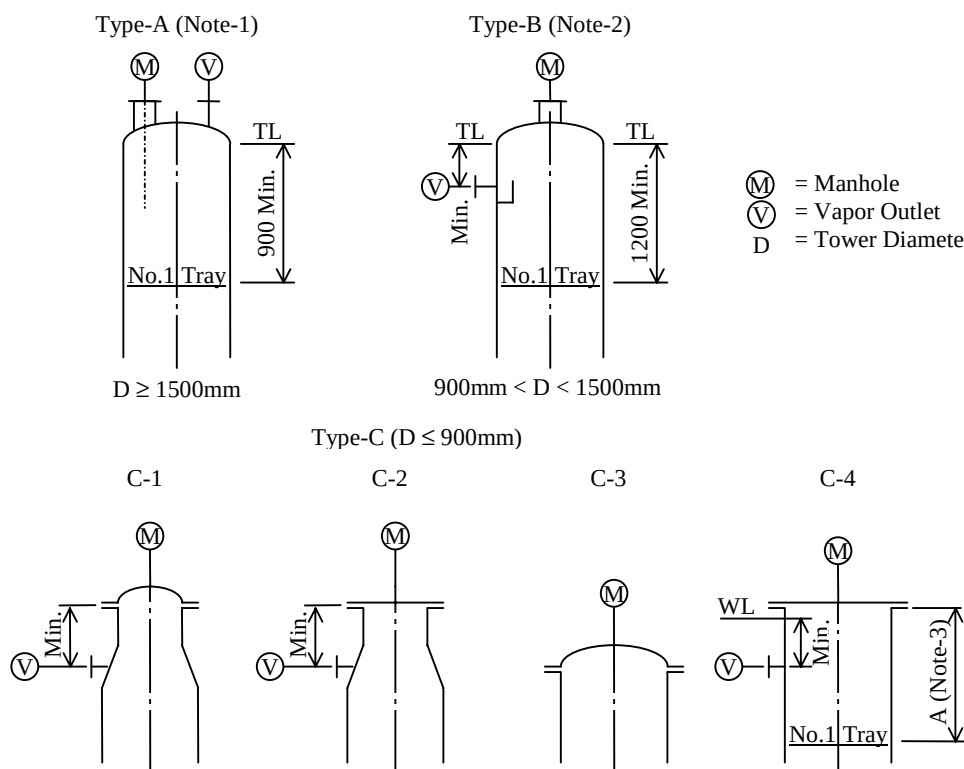
Ⓥ = Vapor Outlet

D = Tower Diameter

3.2.1.2 Top Manhole

- (1) For ease of tray installation, one top manhole shall be provided. If no top manhole can be provided, side manholes shall be provided as described in para. 3.2.1.1.
- (2) Dimensions pertaining to top manholes shall be as recommended in Fig. 3.2-2.

Fig. 3.2.1.2 Geometry of Top Manhole



Note : 1. Maximum nozzle size of Vapor outlet for Type A

D (mm)	18 in. MH	20 in. MH
1,500	4 in.	2 in.
1,700	6 in.	4 in.
1,800	8 in.	6 in.

2. If the vapor outlet is over 10 inches nominal size, when the baffle dimensions are to be determined, should be discussed with specialists in tray design. For determination of baffle dimensions, See Para. 3.2.5.7 (2)
3. A = 900 mm for Tray Space 450 mm, and A = 1,200 mm for Tray Space 600 mm
- (3) Selection of a head type from among those shown in Fig. 3.2.1.2 shall be made based on the following criteria :
- Type A : $D \geq 1500$
- Type B : $900 < D < 1500$
- Type C :
- C-1 : $800 < D \leq 900$ Design press $\geq 10 \text{ kg/cm}^2\text{G}$
- C-2 : $800 < D \leq 900$ Design press $< 10 \text{ kg/cm}^2\text{G}$
- C-3 : $D \leq 800$ Design press $\geq 10 \text{ kg/cm}^2\text{G}$
- C-4 : $D \leq 800$ Design press $< 10 \text{ kg/cm}^2\text{G}$
- (4) For recommended manhole sizes, see para. 3.2.5.1.

3.2.1.3 Liquid Inlet

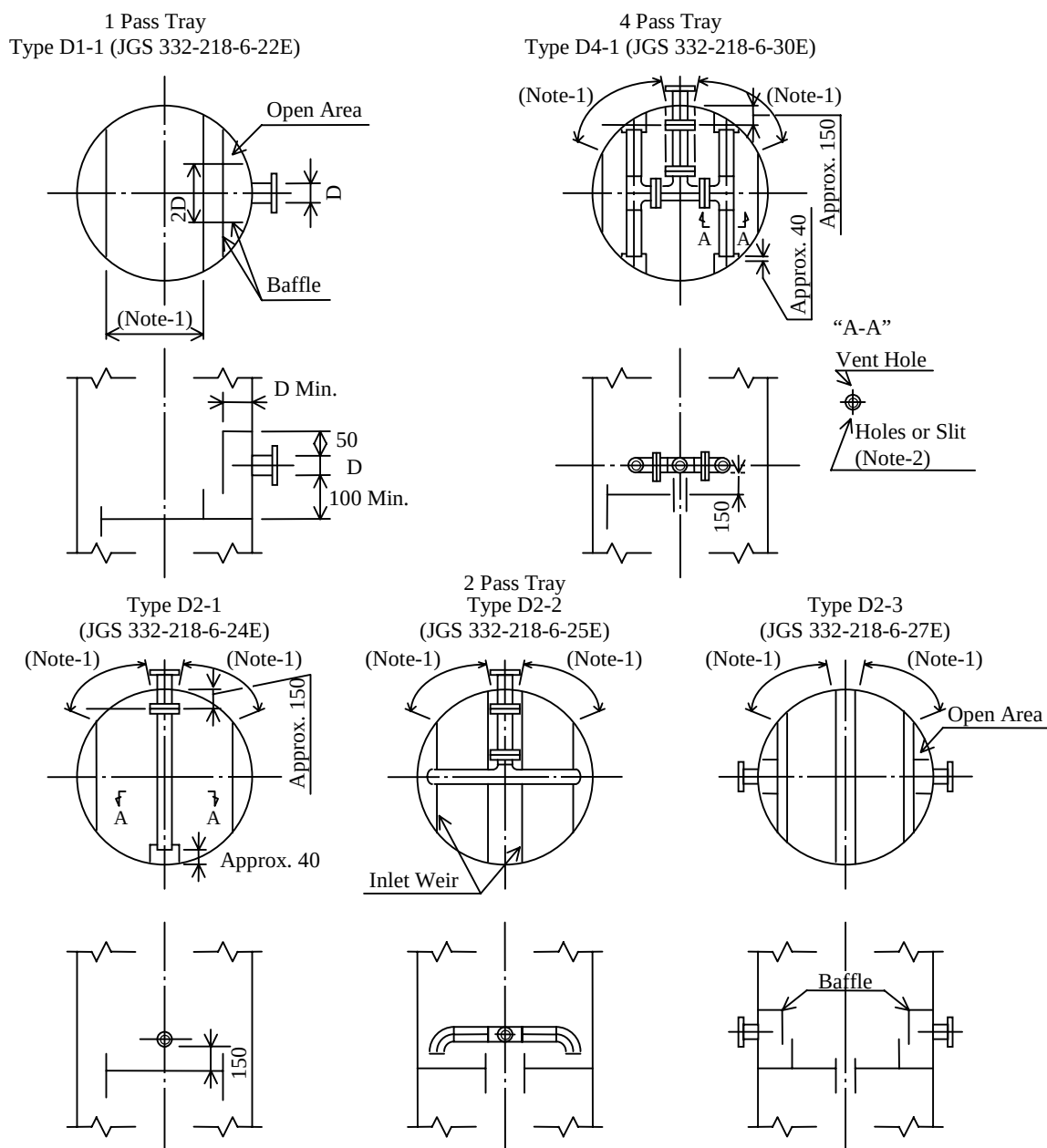
- (1) Reflux return and feed inlet nozzles in top sections shall be of construction as shown in Fig. 3.2-3.
- (2) The following types shall be used as a general rule. However, if their use is impracticable or disadvantageous, some other type can be used.

One pass tray : Type D1-1
 Two pass tray : Type D2-1 (Center)
 Type D2-2 (Side)
 Four pass tray : Type D4-1 (Center)

Fig. 3.2.1.3 Liquid Inlet Nozzle

(Note-1) Manhole area

(Note-2) 20 mm hole (minimum size) or slit. Total hole (slit) area shall be equal to or greater than nozzle cross-sectional area.

**3.2.1.4 Vapor Inlet**

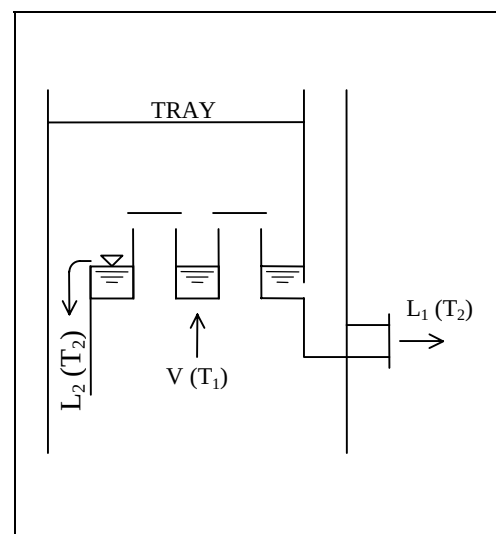
Reference is made to 3.2.3.2 Reboiler Inlet.

3.2.2 Dimensions around Middle Section**3.2.2.1 Accumulator Tray**

This procedure should not applied for packing tower.

(1) Required data

	Temp.(°C)	Flow (kg/h)	Density (kg/m ³)	Surf. Tens. (dyne/cm)
Vapor from below section	T ₁	V	ρ _V	—
Accumulated liquid	T ₂	L ₁ + L ₂	ρ _L	σ
Liquid draw-off	T ₂	L ₁	ρ _L	σ
Overflow liquid	T ₂	L ₂	ρ _L	σ
Tower ID	(mm)			
Tray space of above tray	(mm)			
Tray space of below tray	(mm)			

**(2) Riser area**

The total riser area should be at least 20% of the tower sectional area. This value, however, can be adjustable considering mechanical design requirement and process requirement on pressure drop.

(3) Pressure drop through a riser

Pressure drop through a riser should be calculated according to the following equation :

$$\Delta P = 2.18 \times 10^{-5} \cdot \rho_V \cdot V^2 \quad (\text{kg/cm}^2) \quad (1)$$

$$\Delta P = 0.0160 \cdot \rho_V \cdot V^2 \quad (\text{mmHg}) \quad (2)$$

Where :

ρ_V = vapor density from the below tray (kg/m³)

V = vapor velocity through a riser (m/s)

Confirm that the calculated pressure drop through a riser is within the following allowable pressure drop,

- Atmospheric tower : 3.5 mmHg

- Vacuum tower : 1.5 mmHg

If the calculated value exceeds these values, total riser area should be increased in order to decrease pressure drop. The pressure drop for tray mechanical design, however, should be 7.5 mmHg.

(4) Numbers of risers

At least the following numbers of risers should be provided on an accumulator tray.

Table 3.2.2.1 Numbers of risers

Number of pass of the above tray	Location of downcomer of the above tray	Number of pass of the below tray	Tower diameter	Minimum number of risers
1	—	—	—	1
2	—	—	3600 ≤	2
	—	—	6200 ≤	4
	—	—	6200 >	6
4	Off center	—	—	6
	Center	4	—	6
		2	3600 ≤	2
			6200 ≤	4
			6200 >	6

A square type of riser should be used in principle and also a rectangular type of riser can be used. At least one riser should be larger than 400 mm × 350 mm to use as man way. One riser area should be smaller than 1.5m². Risers should be located evenly in the accumulator tray, considering gas distribution.

(5) Depth of drawoff box

Drawoff nozzle size (D) :

Drawoff liquid velocity in nozzle ≤ 1.0 m/sDepth of drawoff box (A) : $1.5 \times D \leq A \leq (0.2 \times DTS)$ DTS $\geq$ TS : Accumlater Tray space with below tray

WDC : overflow downcommer width

(6) Normal liquid level (NLL)

NLL should be determined to fill the following three (3) conditions, namely accumulated liquid residence time, H, and minimum required NLL.

Atmospheric tower : Minimum 30 seconds based on liquid draw-off (L_1)

Vacuum tower : Minimum 60 seconds based on liquid draw-off (L_1)

Distance between top of draw-off nozzle & NLL (H): $V \leq 2.2 \sqrt{H}$ (m/s)

Minimum required NLL : 250 mm

Where :

v = liquid velocity in the draw-off nozzle (m/s)

(7) Dimensions around riser

The risers are classified into three types as follows :

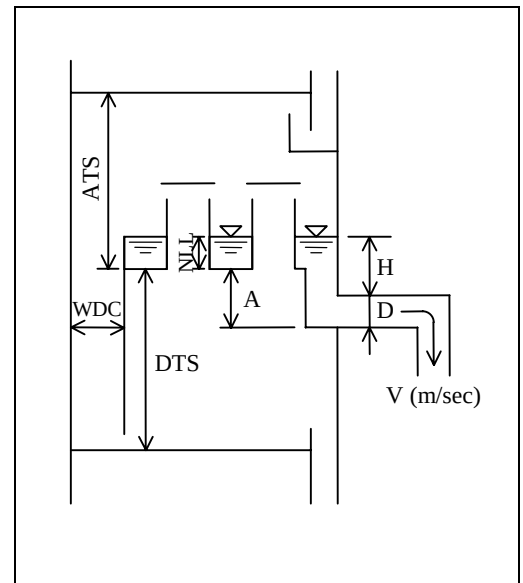
Type - I : no seal pan for the above tray downcomer

Type - II : seal pan for the above tray downcomer below riser hat

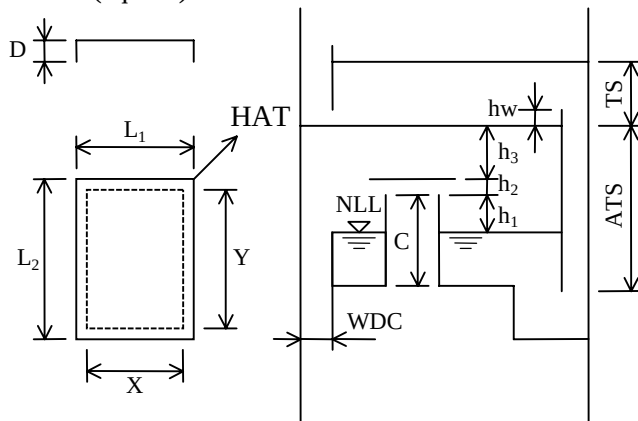
Type - III : seal pan for the above tray downcomer above riser hat

Basically, Type - I or II shall be used. Type - III shall be used only when it is absolutely necessary in connection with the construction.

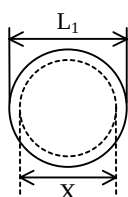
Fig. 3.2.2.1a Type - I : no seal pan for the above tray downcomer



RISER (square)



RISER (circle type)



$$C = NLL + h_1 \quad (\text{mm})$$

$$h_1 \geq 150 \text{ mm}$$

$$h_2 = \frac{XY}{2(X+Y)} (\text{square}), \frac{X}{4} (\text{circle}) \quad (\text{mm}) \quad (\text{Note-1})$$

$$L_1 - X = L_2 - Y = 100 \text{ mm}$$

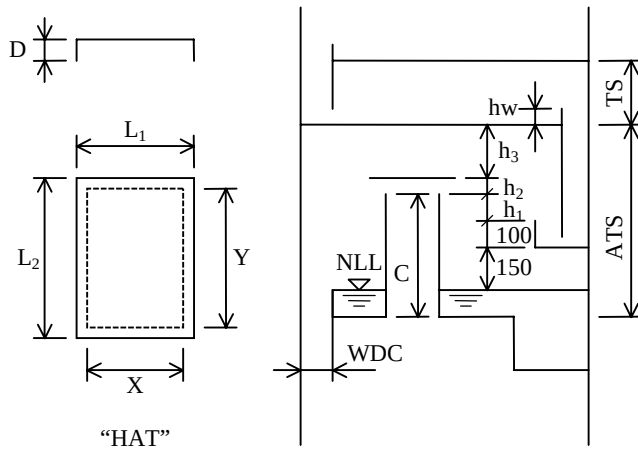
$$D = 0$$

$$ATS \geq TS + NLL - h_w \quad (\text{mm})$$

$$h_3 \geq \frac{\sqrt{L_1 L_2}}{2} \text{ and } 450 \text{ mm} \quad (\text{mm}) \quad (\text{Note-1})$$

(Note-1) : If there are different size risers, biggest value should be selected.

Fig. 3.2.2.1b Type - II : seal pan for the above tray downcomer below riser hat



$$C = NLL + h_1 + 250 \quad (\text{mm})$$

$$h_1 \geq 150 \text{ mm}$$

$$h_2 = \frac{XY}{2(X+Y)} \quad (\text{mm}) \text{ (Note-1)}$$

$$L_1 - X = L_2 - Y = 100 \text{ mm}$$

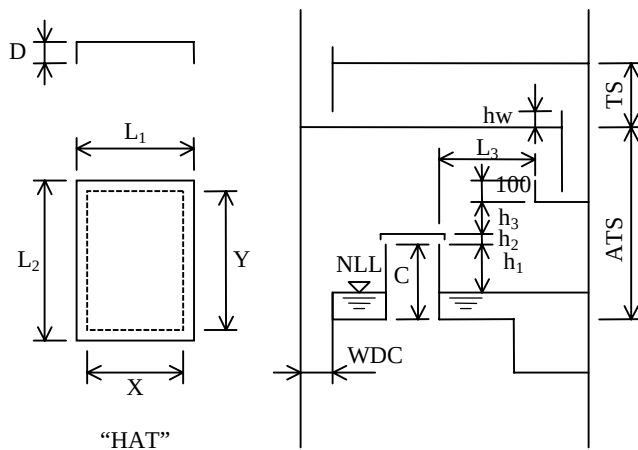
$$D = 0$$

$$ATS \geq TS + NLL - h_w + 250 \quad (\text{mm})$$

$$h_3 \geq \frac{\sqrt{L_1 L_2}}{2} \text{ and } 450 \text{ mm} \quad (\text{mm}) \text{ (Note-1)}$$

(Note-1) : If there are different size risers, biggest value should be selected.

Fig. 3.2.2.1c Type - III : seal pan for the above tray downcomer above riser hat



$$C = NLL + h_1 \quad (\text{mm})$$

$$h_1 \geq 300 \text{ mm}$$

$$h_2 = \frac{XY}{2(X+Y)} \quad (\text{mm}) \text{ (Note-1)}$$

$$L_1 - X = L_2 - Y = 100 \text{ mm}$$

$$D = 10 \text{ mm}$$

$$ATS \geq TS + NLL + h_1 + h_2 + h_3 - h_w + 100 \quad (\text{mm})$$

$$L_3 = 9.43\sqrt{100 + h_2 + h_3} \quad (\text{mm})$$

$$h_3 \geq 200 \text{ mm} \quad (\text{mm}) \text{ (Note-2)}$$

(Note-1) : If there are different size risers, biggest valve should be selected.

(Note-2) : Mechanical engineer to confirm

(8) Draw-off box area

Draw-off box area should be determined based on the para. 3.2.2.2.

(9) Overflow downcomer

Overflow downcomer width (W_{DC}) should be same as that of the below tray.

Tray space between the accumulator tray and the below tray (DTS) should be evaluated based on the operation data for the below tray.

3.2.2.2 Draw-off

- (1) Draw-off boxes shall be provided at downcomer bottoms from which liquid is to be drawn off. The design criteria are as given in Fig. 3.2.2.2b to 3.2.2.2d.
- (2) In downcomers in which excessive foaming is expected to occur, Plural gratings shall be provided as shown in Fig. 3.2.2.2a.
- (3) In cases where draw-off box Type B2-3 or B4-3 is used, the flow velocity in the draw-off box shall not exceed the maximum downcomer velocity calculated by equation (3) at the tray concerned. The concern is vapor liquid separation in the draw off box.

$$U_{DC(max)} = (1 - F_G) \left(\frac{\sigma(\rho_L - \rho_V)}{\rho_L^2} \right)^{1/4} \quad (3)$$

$$F_G = \frac{1}{1 + 1.4 \sqrt{(\rho_L - \rho_V)/\rho_L}} \quad (4)$$

Where :

$U_{DC(max)}$	= maximum downcomer velocity	(m/s)
F_G	= dispersed gas volume ratio in liquid	(-)
ρ_L	= liquid density	(kg/m ³)
ρ_V	= vapor density	(kg/m ³)
σ	= surface tension of liquid	(dyne/cm)

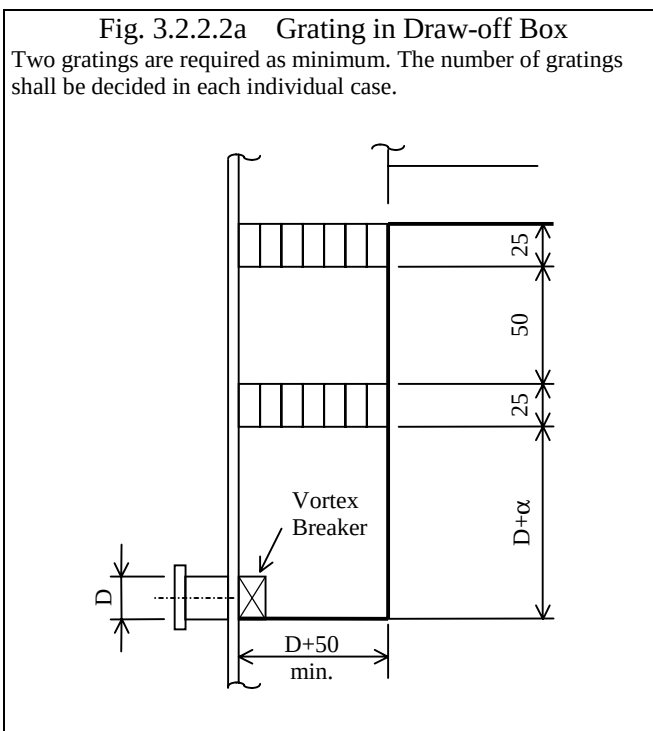


Fig. 3.2.2.2b Draw-off Box (One-pass tray)

(1) Type B1-1 shall be used in cases where the following equation can be satisfied :

$$0.2 \times TS \geq A \geq 1.5 \times D$$

(2) If this equation cannot be satisfied, type B1-2 shall be used, in which case the dimensions shall be as shown below. However, if the dimension "E" is larger than $0.1 \times L$, the weir length shall be reviewed in each individual case.

$$A \leq 0.2 \times TS \quad C \geq 1.5 \times D \quad D + 50 \leq E \leq 0.1 \times L$$

(3) The dimension "B" shall be the same as the downcomer bottom width or nozzle size (D) + 50 mm, whichever is the larger.

In cases where the "B" is determined based on the nozzle size (D) + 50 mm, the other trays shall be reviewed to equalize their downcomer widths to the nozzle size (D) + 50 mm.

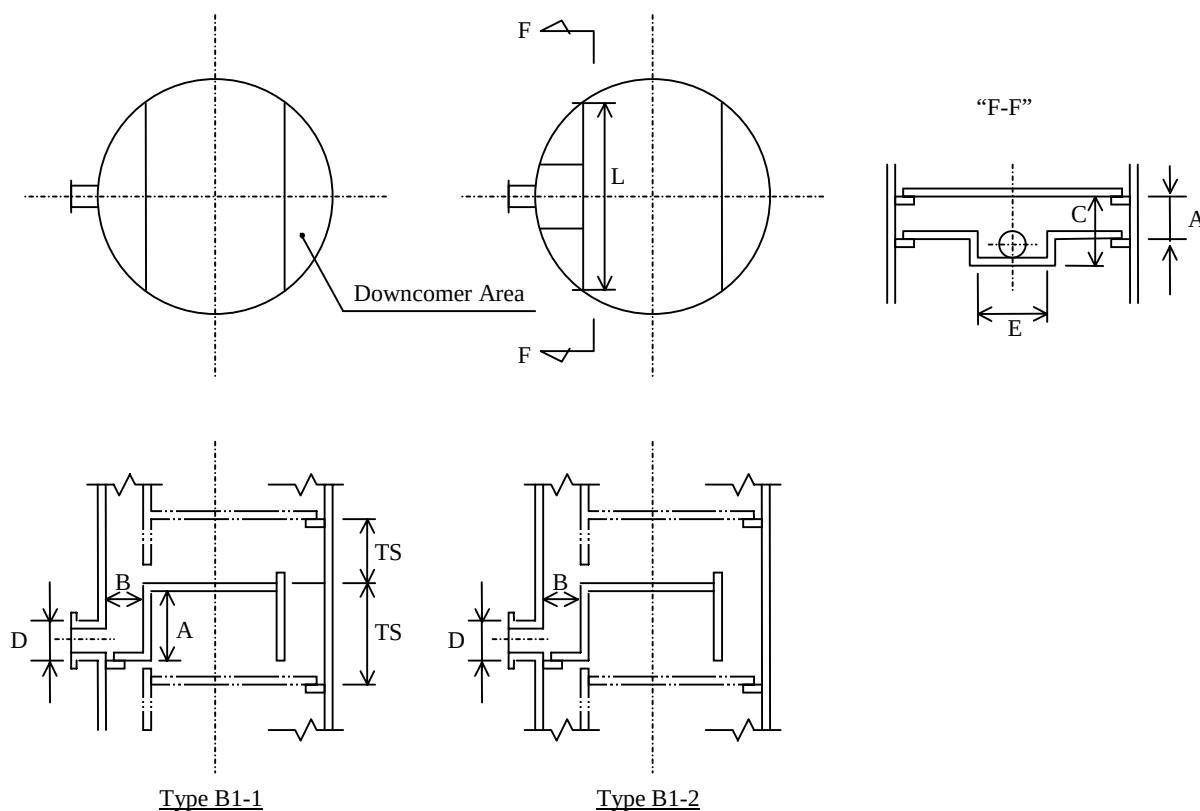


Fig. 3.2.2.2c Draw-off Box (Two-pass tray)

(1) Type B2-1 shall be used in cases where the following equation is satisfied :

$$0.2 \times TS \geq A \geq 1.5 \times D$$

(2) Type B2-2 shall be used, if the above equation cannot be satisfied, in which case the dimensions shall be as follows:

$$A \leq 0.2 \times TS \quad C \geq 1.5 \times D \quad D + 50 \leq E \leq 0.1 \times L$$

If the dimension "E" is larger than $0.1 \times L$, the weir length shall be reviewed in each individual case.

(3) Type B2-3 shall be used in case where the draw-off line requires a large liquid head or the draw-off rate is relatively large as compared with overflow rate to below tray.

$$A \geq 1.5 \times D$$

E : The dimension "E" shall be checked by using the weir equation. If the weir length needs to be reduced ; namely, E is larger than $0.1 \times L$, the tray calculations shall be re-conducted or accumulator trays shall be used.

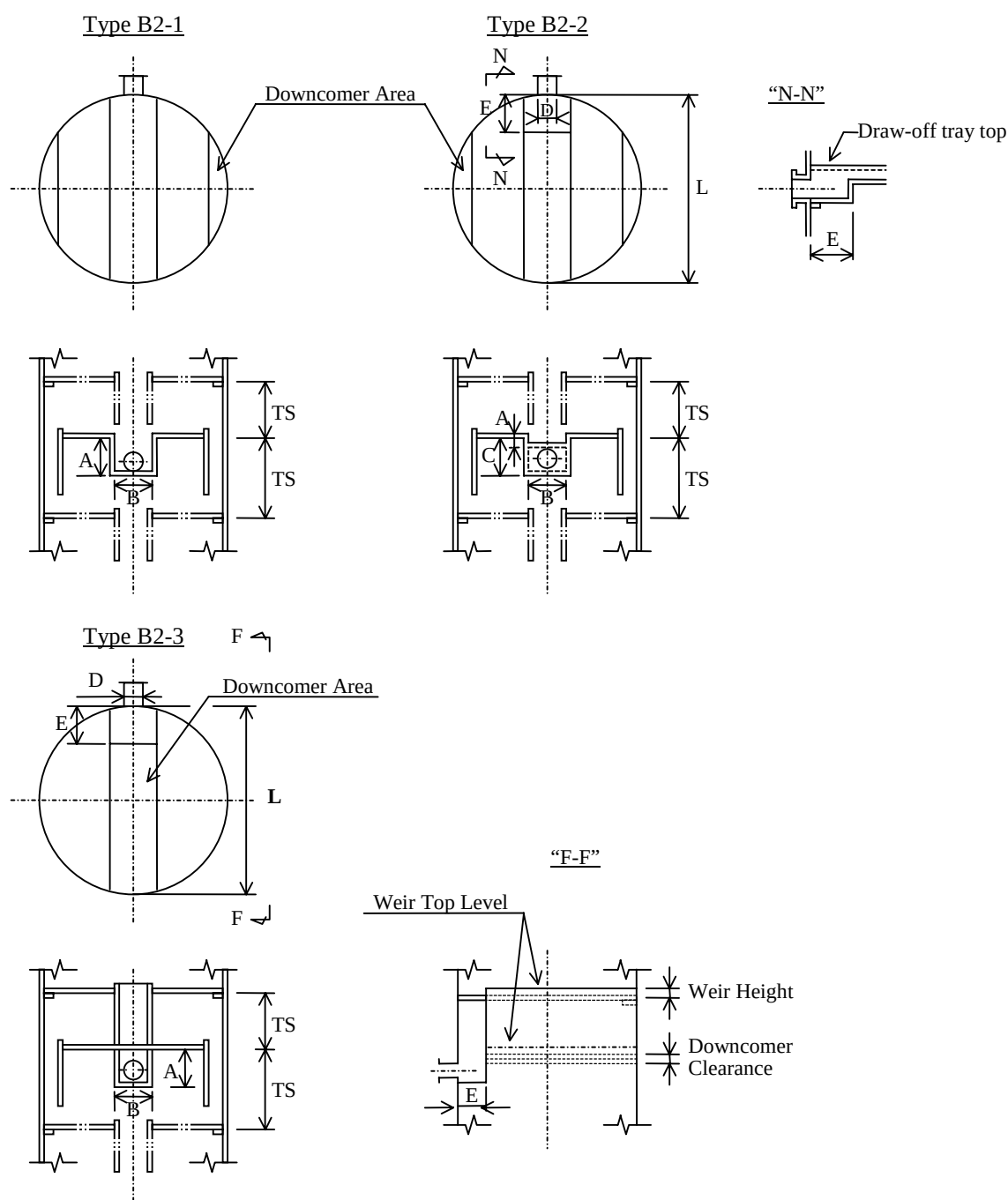


Fig. 3.2.2.2d Draw-off Box (Four-pass tray)

(1) Type B4-1 shall be used in cases where the following equation can be satisfied :

$$0.2 \times TS \geq A \geq 1.5 \times D$$

(2) Type B4-2 shall be used, if the above equation cannot be satisfied, in which case the dimensions shall be as follows :

$$A \leq 0.2 \times TS \quad C \geq 1.5 \times D \quad D + 50 \leq E \leq 0.1 \times L$$

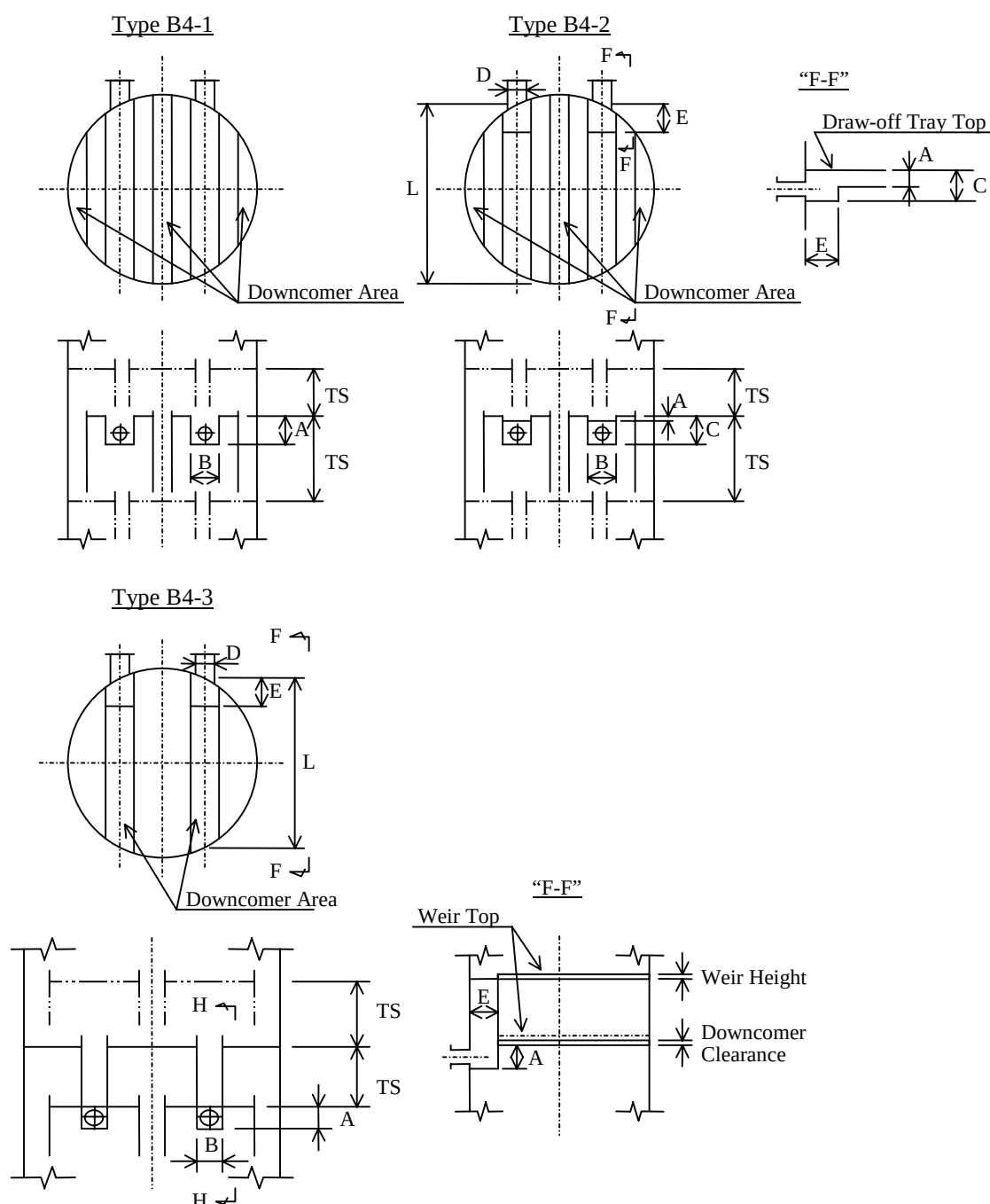
If the dimension "E" is larger than $0.1 \times L$, the weir length shall be reviewed in each individual case.

(3) Type B4-3 shall be used in case where the draw-off line requires a large liquid head or the draw-off rate is relatively large as compared with overflow rate to below tray.

$$A \geq 1.5 \times D$$

E : See Fig. 3.2.2.2c (3)

B : The width B shall be the same as the downcomer bottom width or nozzle diameter (D) +50 mm, whichever is the larger.
When latter is decided on, the other trays shall be reviewed to equalize their downcomer widths.



3.2.2.3 Cone and Shell Flange**(1) Cone :**

Cone dimensions shall be determined with reference to Fig. 3.2.2.3a.

(2) Shell flange :

Shell flanges should be provided at intervals of 6,000 mm for the towers smaller than 800 mm in diameter and higher than 6,000 mm in tray provision height.

3.2.2.4 Trap and Pass Change

The tray pass number shall change when there is large liquid flow difference between the upper and the lower trays. So, the tray pass number change is divided into four cases, as follows :

Case 1 : The liquid feed nozzle between the upper and lower trays

Case 2 : The accumulator tray between the upper and lower trays

Case 3 : The draw off box in the upper tray

Case 4 : No internals between the the upper and lower trays

(1) Trap

In most cases where the tray pass number is changed, traps (extended seal pan) shall be provided for the upper tray downcomer. Fig. 3.2.2.4 shows the standard dimension of the seal pan.

In many cases, notched seal pans are used to prevent the upper downcomer liquid from entering directly to the lower downcomer. Fig. 3.2.2.5 shows an example of trap in case of no tray turn.

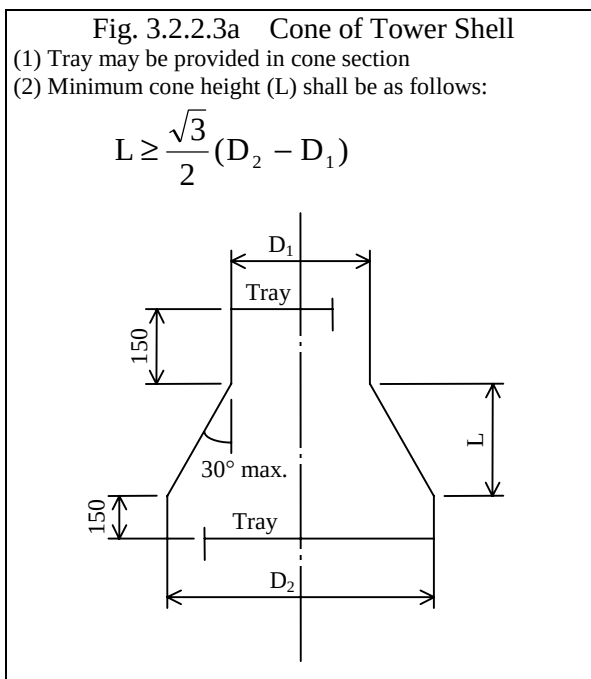
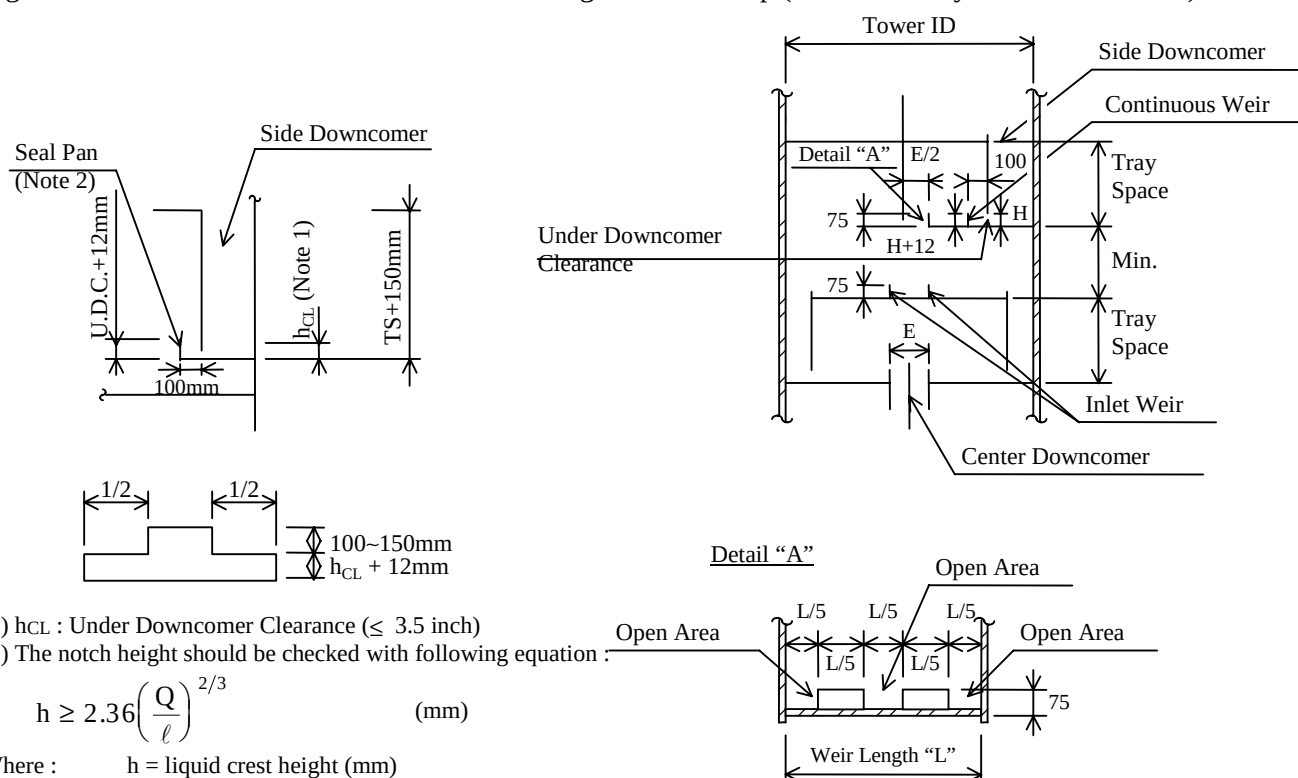


Fig. 3.2.2.4 Standard Dimension of Seal Pan Fig. 3.2.2.5 Trap (in case the tray is not to be turned)



(1) h_{CL} : Under Downcomer Clearance (≤ 3.5 inch)

(2) The notch height should be checked with following equation :

$$h \geq 2.36 \left(\frac{Q}{\ell} \right)^{2/3} \quad (\text{mm})$$

Where :

h = liquid crest height (mm)

Q = liquid flow rate (m^3/h)

ℓ = weir length except notch (m)

(2) Examples of the tray pass number change

(a) Case-1 examples (Fig. 3.2.2.6)

Feed Section of a stabilizer is shown in example-1 and pump around return section of a topper is shown in example-2.

For both examples, trays are turned 90°, and the notched seal pans are designed to prevent the upper downcomer liquid from entering directly to the lower downcomer, and to make flow path of vapor from the lower area of the seal pan.

(b) Case-2 examples (Fig. 3.2.2.7)

Liquid draw off sections of a topper are shown in example-1 and -2. The lower tray is turned 90° in example-1, but not turned in example-2. In example-2, the notched seal pans are designed to prevent liquid from entering to the riser of the accumulator tray, because the notched seal pans are located above the riser hats.

(c) Case-3 example (Fig. 3.2.2.8)

Liquid draw-off section of a topper is shown in this example.

(d) Case-4 example (Fig. 3.2.2.9)

Upper trays of a topper flash zone are shown in this example.

Tabel 3.2.2.4 Tray Turn Summary

S = Side downcomer, C = Center downcomer, OC = Off-Center downcomer
Y = 90 degree turned, N = No turn

(3) Tray turn

Tray turn cases are summarized in Table 3.2.2.4

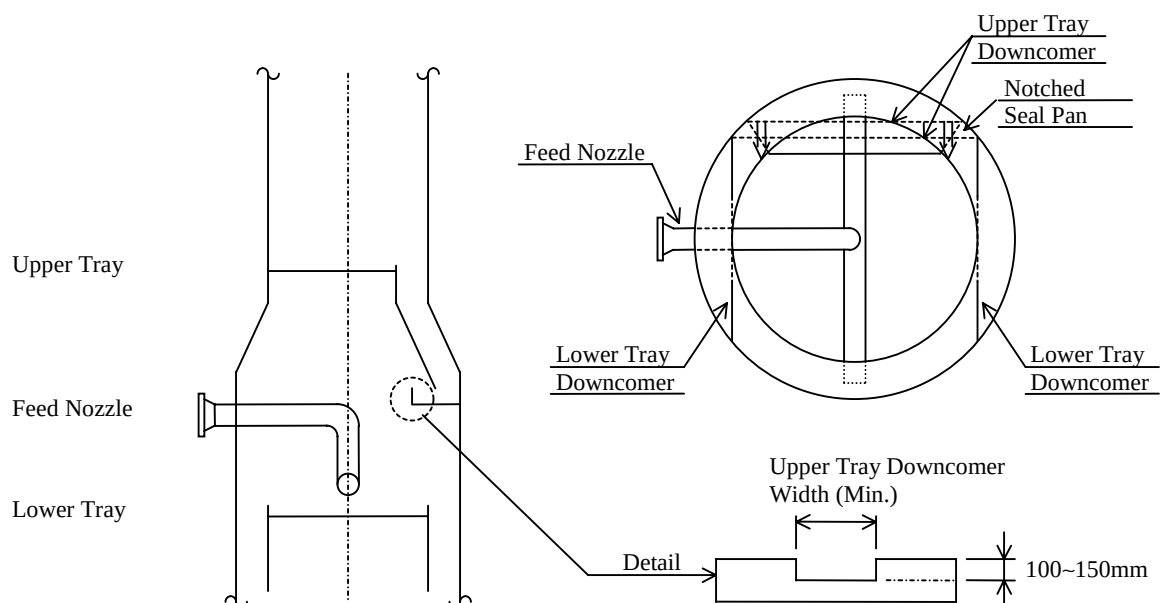
(4) Tray space

For case 1, 2, and 3, the tray spaces should be determined based on the liquid feed nozzle (or cone), the accumulator tray, and the draw-off box, respectively.

Pass No. Change	Pass Number		Internal between Upper and Lower Trays			
	Upper Tray	Lower Tray	Liquid Feed Nozzle	Accumulator Tray + Draw-off Box	Draw off Box	No Internals
Increase (Upper → Lower)	1	2(C)	Y			
		2(S)	Y(N)			
		3	Y			
		4	Y			
		4(OC)	Y			
	2(C)	3	Y			
		4	Y(N)			
		4(OC)	Y			
	2(S)	3	Y(N)			
		4	Y(N)			
		4(OC)	Y			
	3	4	Y(N)			
		4(OC)	Y			
Decrease	2(C)	1		N	N	N
	2(S)	1		Y(N)	Y	Y
	3	1		N(Y)	N(Y)	N(Y)
		2(C)		Y(N)	N	N
		2(S)		N(Y)	Y(N)	Y(N)
	4	1		Y(N)	Y(N)	Y(N)
		2(C)		Y	Y(N)	Y(N)
		2(S)		Y(N)	Y	Y
		3		Y(N)	Y(N)	Y(N)
	4(OC)	1		N	N	N
		2(C)		N	N	N
		2(S)		N	N	N
		3		Y(N)	Y(N)	Y(N)
Same	1	1	N	N	N	N
	2(C)	2(S)	N	Y	N	N
		2(C)	Y	N	Y	Y
	2(S)	2(C)	N	Y	N	N
		2(S)	Y	N	Y	Y
	3	3	N	N	N	N
	4	4(OC)	N	Y	N	N
		4	Y	N	Y	Y
	4(OC)	4	N	Y	N	N
		4(OC)	Y	N	Y	Y

Fig. 3.2.2.6 Tray Pass Change with Liquid Feed Nozzle (Case 1 Examples)

<Example-1>



<Example-2>

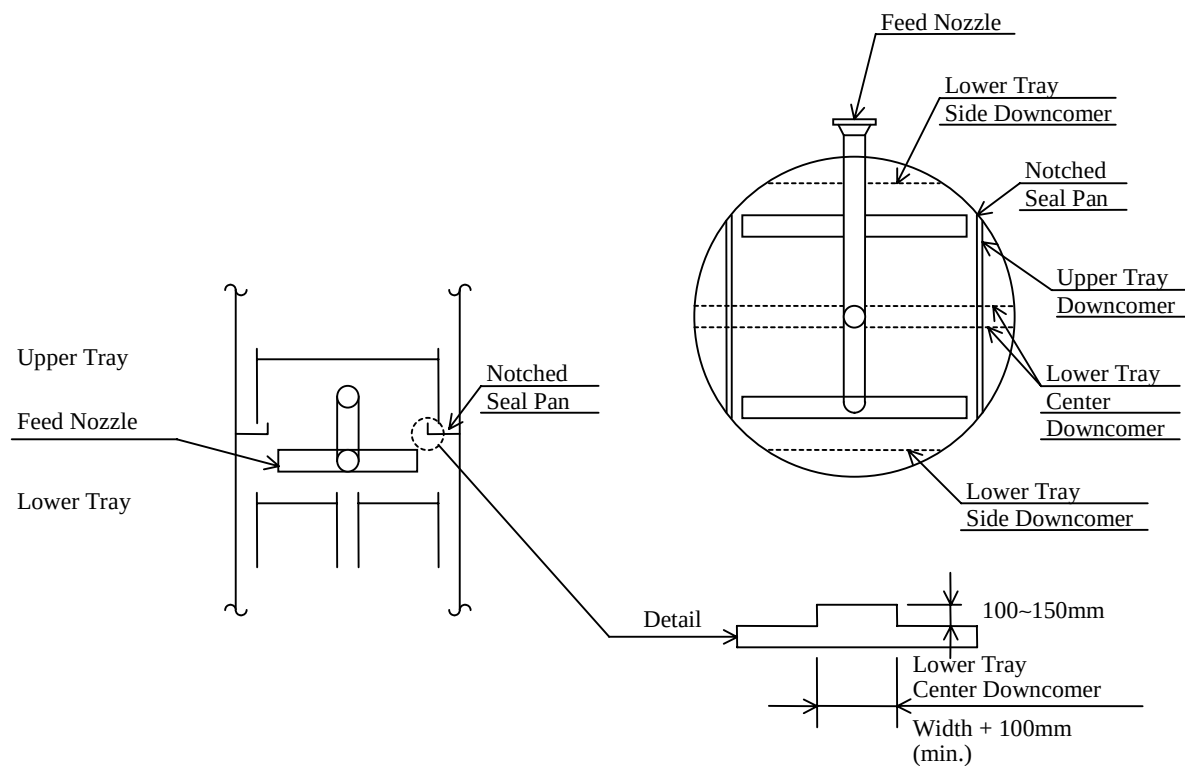
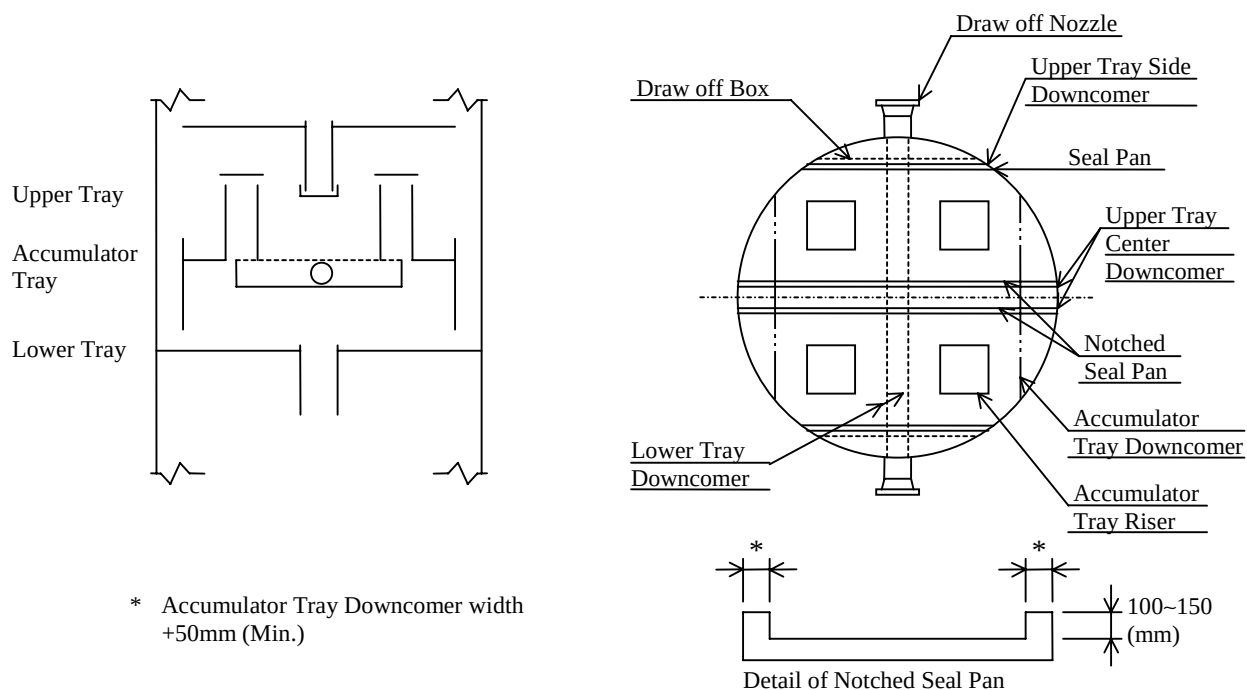


Fig. 3.2.2.7 Tray Pass Change with Accumulator Tray (Case 2 Exaples)

<Example-1>



<Example-2>

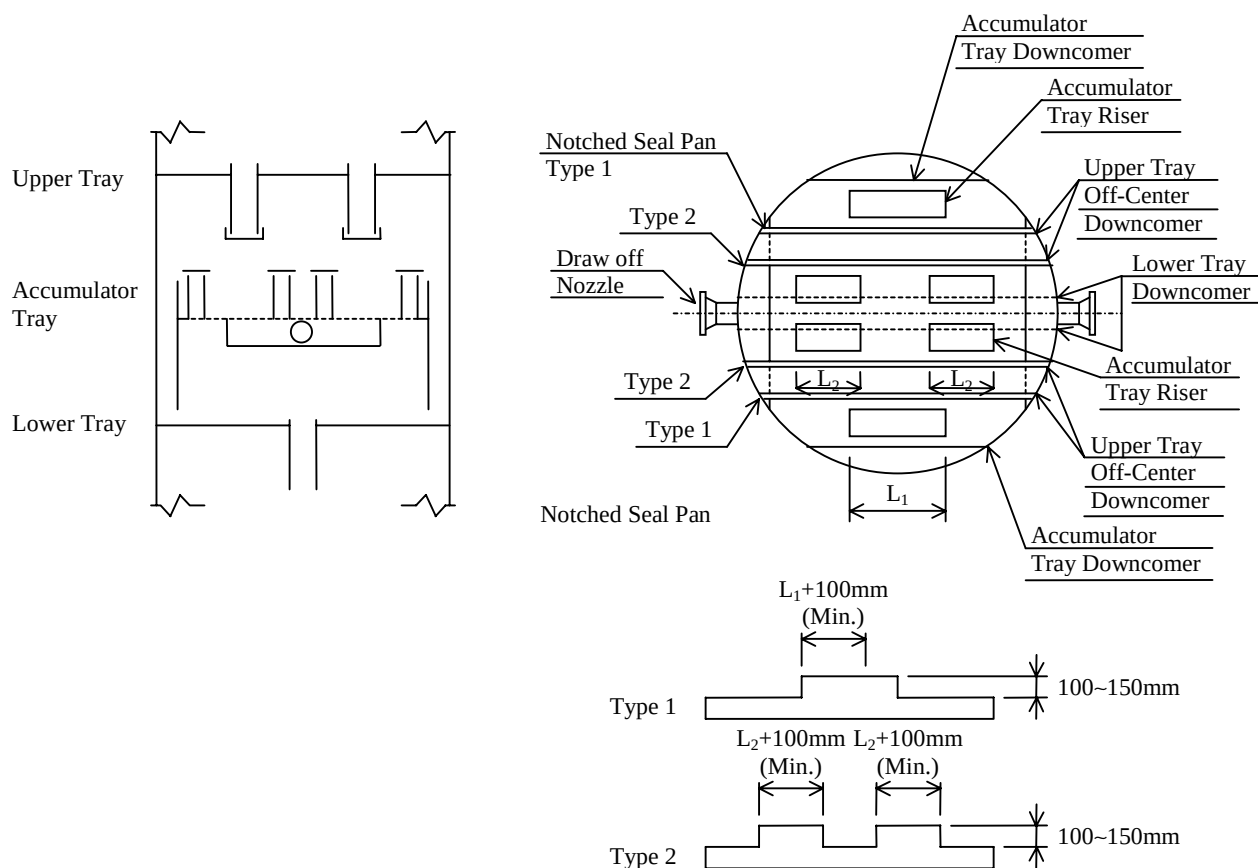


Fig. 3.2.2.8 Tray Pass Change with Draw-off Box (Case 3 Example)

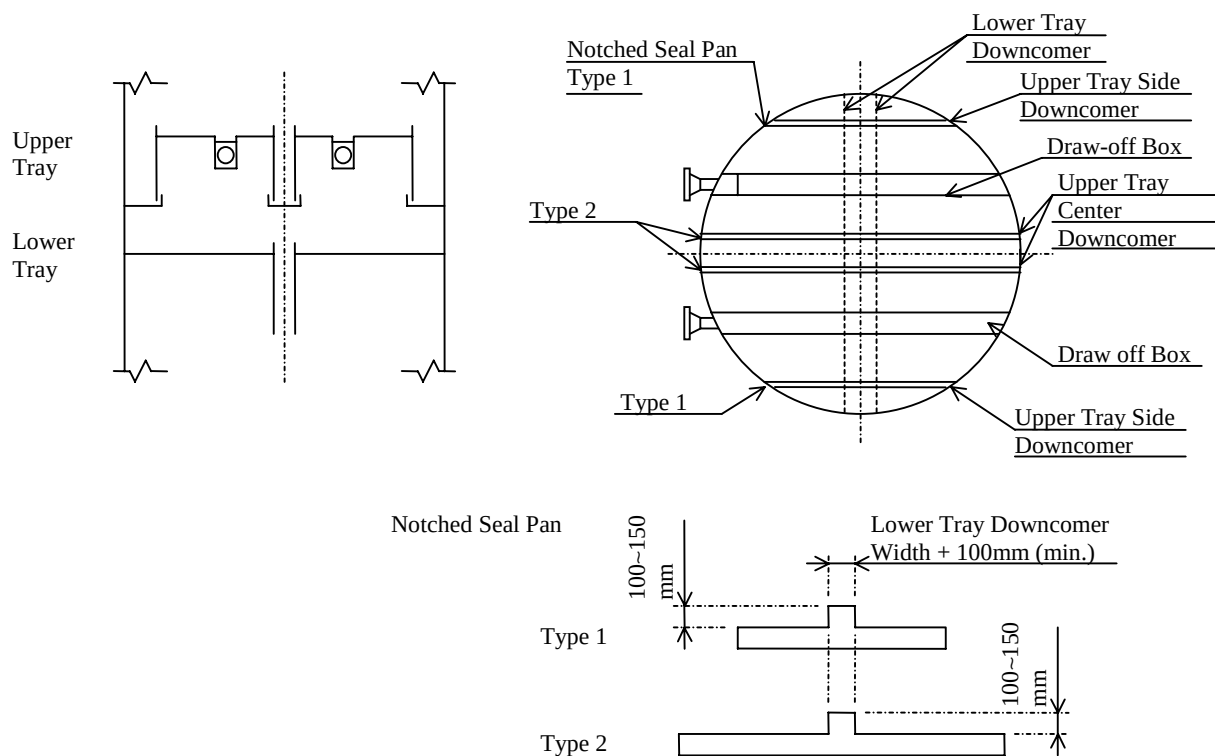
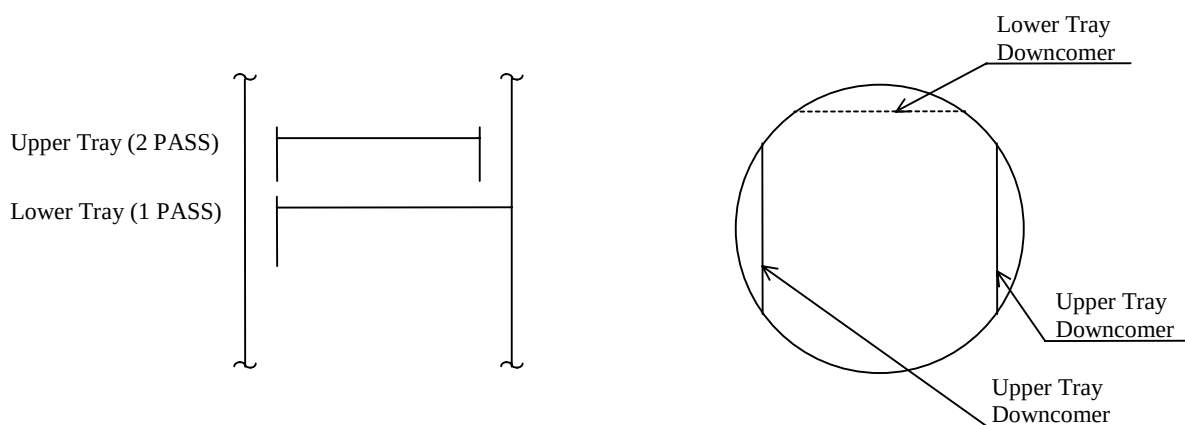


Fig. 3.2.2.9 Tray Pass Change with no Internal (Case 4 Example)



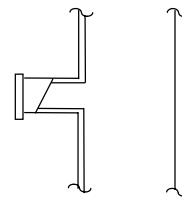
3.2.2.5 Feed Section

(1) Feed nozzles :

- (a) Feed nozzles shall be parallel with the downcomer as a general rule.
- (b) For the liquid feed section, constructions and recommended dimensions are provided in Fig. 3.2-23 to 3.2-25.

(2) Flash feed for small size tower :

No impingement baffle is provided for tower diameter, D , of 1000 mm or less Fig 3.2.2.5a

Fig. 3.2.2.5a Flash Feed ($D < 1,000$ mm)

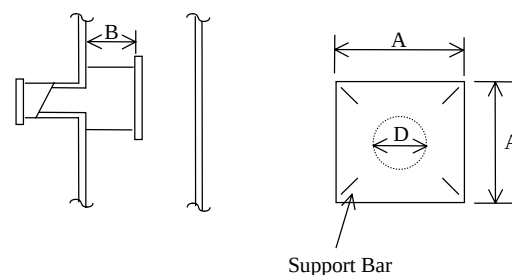
(3) Flash feed for large size tower

When tower diameter, D , is equal to or larger than 1000 mm, the feed nozzle and the impingement baffle should be equipped as shown Fig. 3.2.2.5b

$$A = D_F + (50 \text{ to } 100 \text{ mm})$$

$$B = 0.5 \times D_F$$

D_F = feed nozzle inside diameter (mm)

Fig. 3.2.2.5b Flash Feed ($D \geq 1,000$ mm)

(4) Flash guide for CDU or VDU main column

The purpose of flash guide is centrifugal separation of gas and liquid in the mixed phase feed.

- (a) The flash guide type shall be either of the following two which shall be selected based on the attaching method :

JGS 332-218-6-18E "Flash guide (Assembly type)"

JGS 332-219-6-19E "Flash guide (Welded type)"

These JGC standard drawings indicate basic dimensions only, and detailed dimensions shall be decided by the manufacturer.

Basically, welded type flash guide shall be adopted. Because, several problems, such as bolts removal, vibration, and so on may occur in the assembly type flash guide.

- (b) The relationships between the flash guide and bottom head or below tray are shown in Fig. 3.2.2.5c.

Fig. 3.2.2.5c Flash Guide

(1) Horizontal section

- (a) In the case of welded flash guides, vent holes or holes which can serve as a vent hole, shall be provided in the weir plates without fail.
- (b) The dimension "a" shown right shall be decided within range of 0.7 to 0.8 of the radius "R" after review of the welding edge geometries and welding method of Joint "A".
- (c) The nozzle projection "b" shall be decided with consideration given to the insulation thickness.

(2) Vertical section

$$E \geq 100 \text{ mm} \quad F = 0.13 \times D_i + D \quad G \geq 150 \text{ mm} \quad H \geq T_s$$

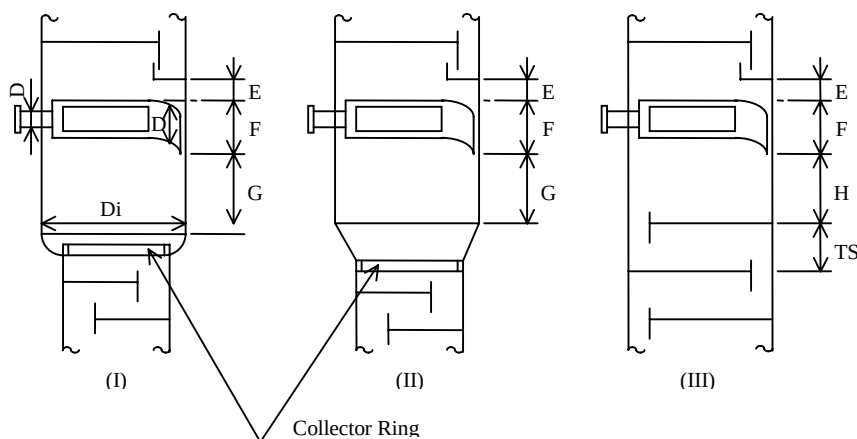
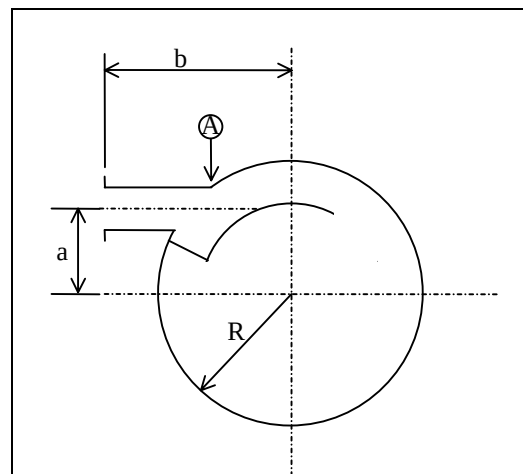
Where :

D_i = tower internal diameter (mm)

D = weir plate width (mm) = $D_f + 300$ mm

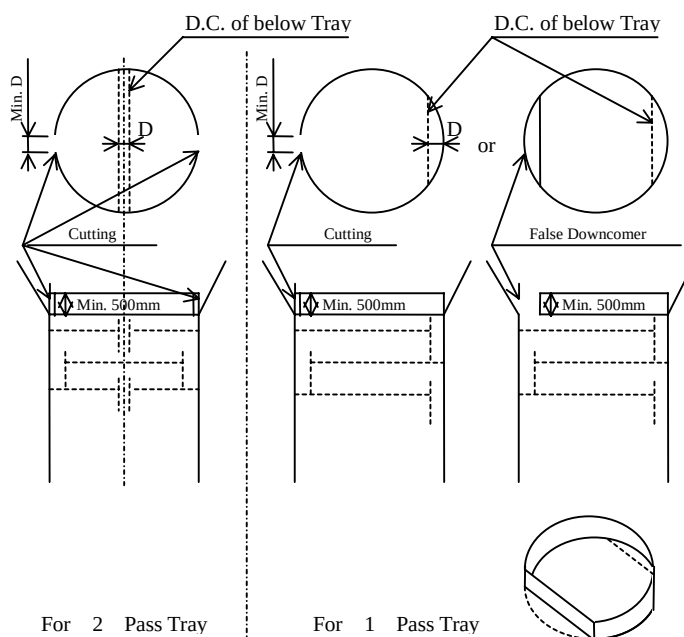
D_f = feed nozzle outer diameter (mm)

Each dimension determined as above should be confirmed by the mechanical engineer.



(3) Collector ring

- (a) In case of type I and II, collector ring should be equipped in order to control liquid flow. Typical collector ring is shown below. Each dimension should be decided based on the liquid flow rate.
- (b) Cutting width should be decided so as to the liquid flow rate between 45 to 90m³/hr. m(60 to 120 GPM/ft).



For 2 Pass Tray

For 1 Pass Tray

(5) Feed nozzle for FCC (RCC) main column

Fig. 3.2.2.5d shows the typical example of FCC (RCC) main column feed section.

Impingement baffle plate should be equipped at the opposite side of the feed nozzle to prevent coke formation and erosion due to high temperature reactor effluent. Baffles or packing height (H) shall be decided, based on the required heat transfer area between feed vapor and liquid. Fig. 3.2.2.5e shows the typical examples of the baffles.

Fig. 3.2.2.5d FCC (RCC) Main Column Feed Section

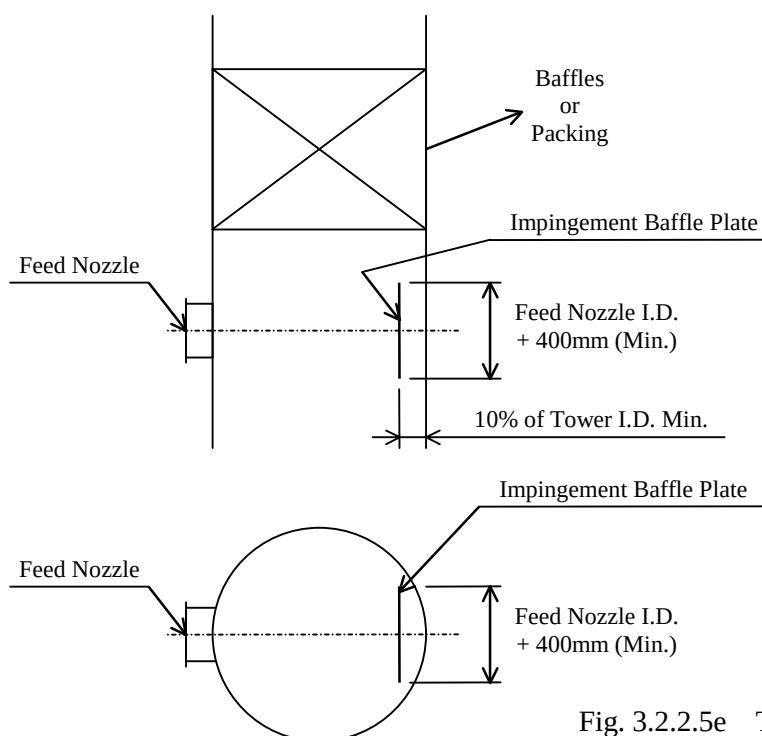


Fig. 3.2.2.5e Typical Baffle Type

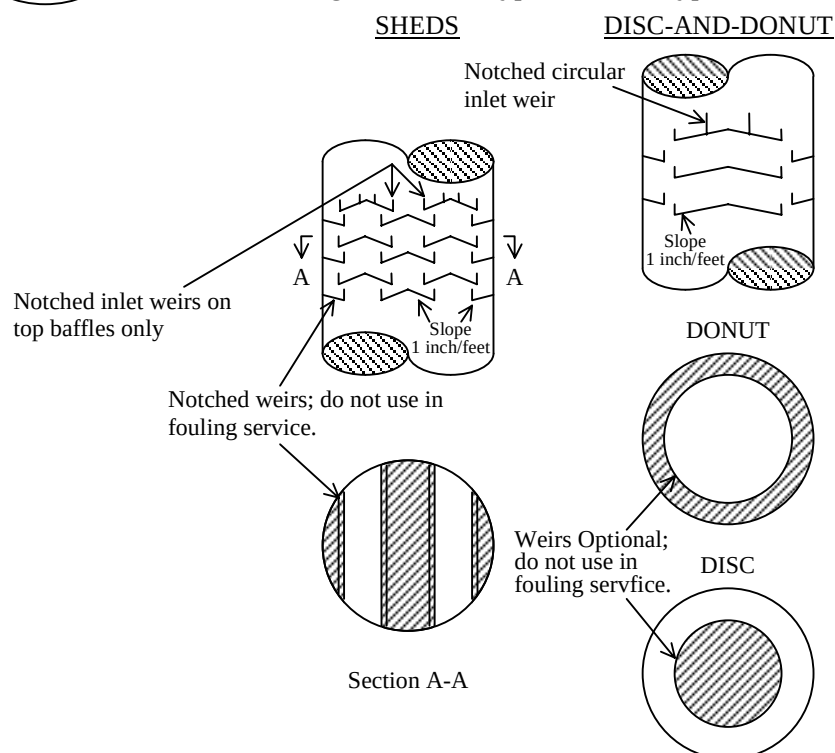


Fig. 3.2.2.5f Feed Nozzle (One-pass tray)

- (1) Tray spaces at which manholes are to be provided, shall be 900 mm minimum regardless of the manhole size.

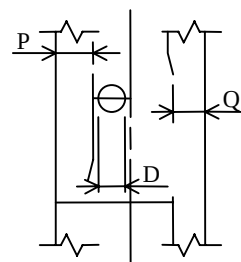
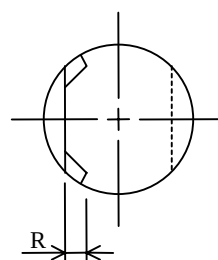
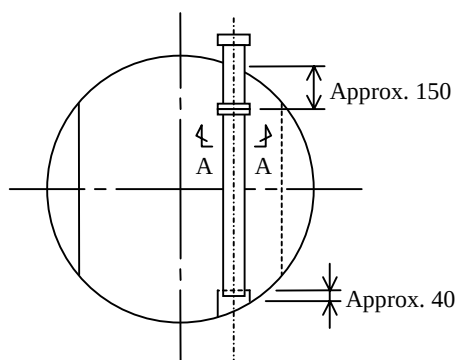
In cases where no manhole is provided, minimum tray spaces shall be as follows :

Tower Diameter	Nominal Feed Nozzle Size	
	Under 6"	6" and over
Under 3,600 mm	600 mm	750 mm
3,600 mm and over	750 mm	900 mm

- (2) In any case, if the following two equations cannot be satisfied, the tray spacing shall be 750 mm+ nozzle outside diameter :

- (i) Straight downcomer without relief weir : $\text{Tower diameter} \geq 2 \times P + D + 500$
(ii) Sloped downcomer with relief weir : $\text{Tower diameter} \geq P + Q + R + D + 560$

Type D1-2 (JGS 332-218-6-23E)



P : Downcomer top width
Q : Downcomer bottom width
R : Set back of relief weir
D : Nozzle outside diameter

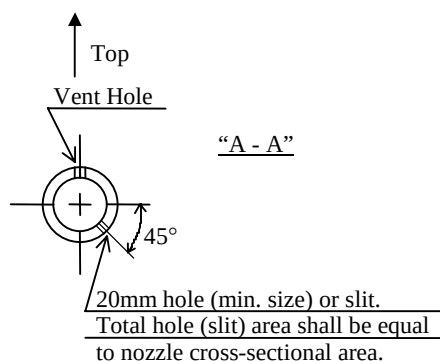
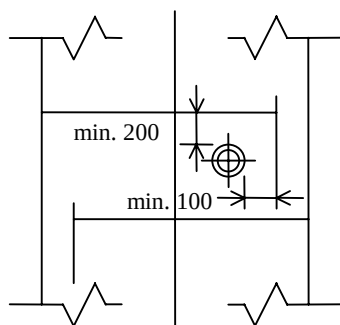


Fig. 3.2.2.5g Feed Nozzle (Two-pass tray)

- (1) In cases where the following types of trays are to be used, the following conditions shall be satisfied :
- (i) Tray spaces at which manholes are to be provided, shall be 900 mm minimum regardless of the manhole size.
- (ii) In cases where no manhole is to be provided, minimum tray spaces shall be as follows :

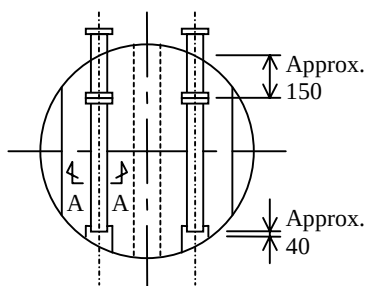
Tower Diameter	Nominal Feed Nozzle Size	
	Under 6"	6" and over
Under 3,600 mm	600 mm	750 mm
3,600 mm and over	750 mm	900 mm

- (2) In any case, if the following equation cannot be satisfied, the tray space shall be 750 mm + nozzle outside diameter :

$$\text{Tower diameter} \geq 2 \times (P + Q/2 + D + 450)$$

Where : P = Side downcomer width, Q = Center downcomer width, D = Nozzle outside diameter

Type D2-4
(JGS 332-218-6-28E)



Type D2-5
(JGS 332-218-6-29E)

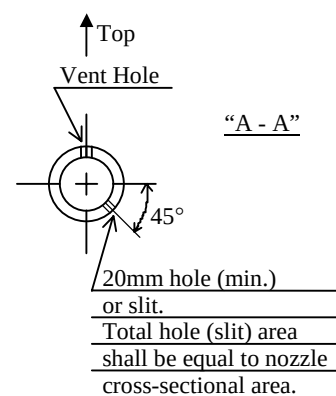
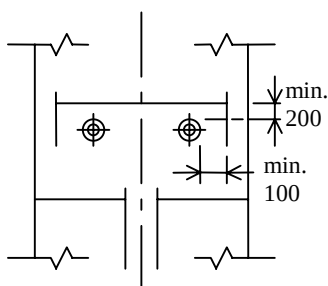
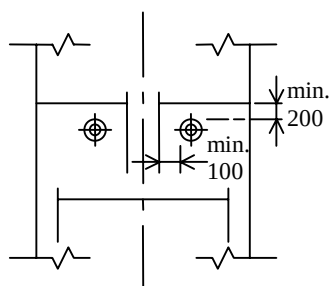
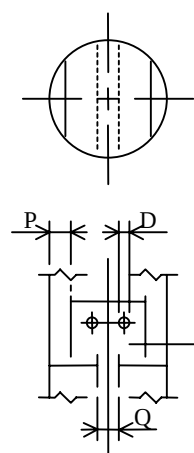
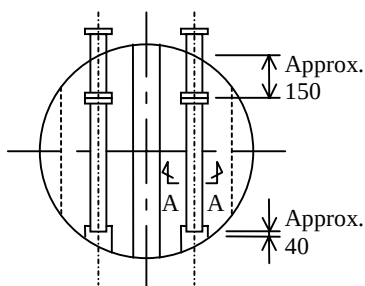


Fig. 3.2.2.5h Feed Nozzle (Four-pass tray)

(1) In the case of Type D4-2, the following requirements shall be satisfied :

- (i) Tray spaces at which manholes are to be provided, shall be 900 mm minimum regardless of the manhole size.
 (ii) In cases where no manhole is to be provided, minimum tray spaces shall be as follows :

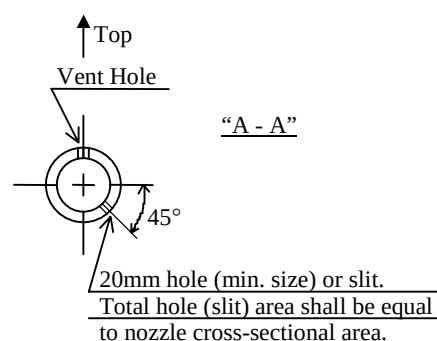
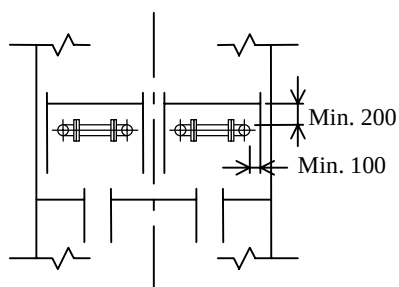
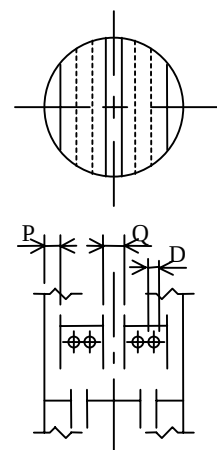
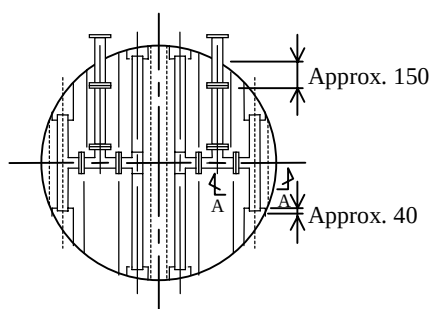
Tower Diameter	Nominal Feed Nozzle Size	
	Under 6"	6" and over
Under 3,600 mm	600 mm	750 mm
3,600 mm and over	750 mm	900 mm

(2) In any case, if the following equation cannot be satisfied, the tray space shall be 750 mm + nozzle outside diameter :

$$\text{Tower diameter} \geq 2 \times P + 3 \times Q + 4 \times D + 900$$

Where : P = Side downcomer width, Q = Center and Off-center downcomer width, D = Nozzle outside diameter

Type D4-2 (JGS 332-218-6-31E)



3.2.3 Dimensions around Bottom Section**3.2.3.1 Liquid Level**

- (1) Determination of a minimum holding time for a typical system is as shown below. In cases where the normal liquid level in the holding portion is affected to a large extent by other factors, separate consideration should be given to the holding time.
- (2) Details for the holding time in liquid-liquid separators are specified in JGS 210-120-1-22E "Drums".

3.2.3.2 Reboiler Return

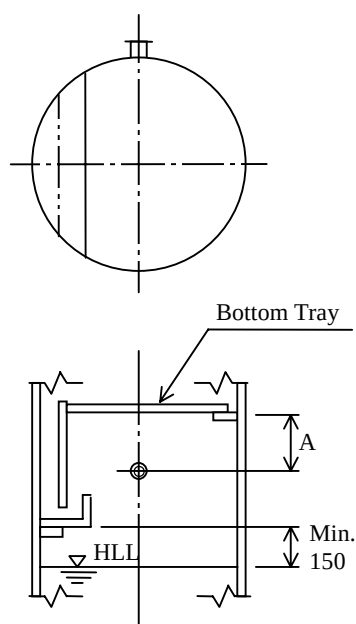
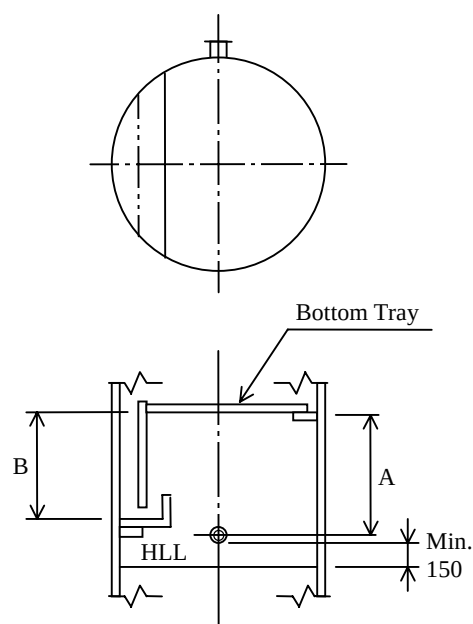
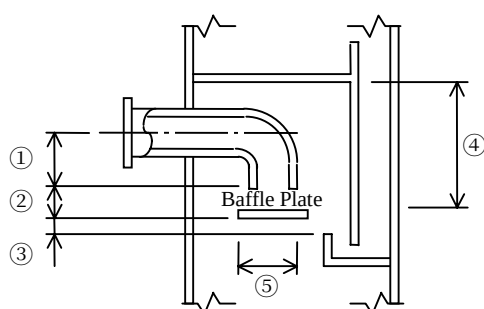
Dimensions and constructions of vapor phase or Mixed phase inlets, such as those for reboiler return shall conform to Figs. 3.2.3.2a to 3.2.3.2c.

Fig. 3.2.3.2a Vapor or Mixed Inlet (One-pass tray)

- (1) Consideration shall be provided so that the inlet fluid will rise evenly without collecting at one point in the active area in the bottom tray.
- (2) The rising fluid shall not obstruct the overflow of liquid from the seal pan.

Dimension "A" (mm)

Nozzle Size	1½" and Under	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24" and Over
Type													
V1-1													
V1-2													

Type V1-1
(Vapor Phase)Type V1-2
(Mixed Phase)

Type V1-3

(Polymerization or Coking Services, such as acrylic acid reboiler return)

D : Feed Nozzle I.D (m/m)

- ① $1.5 \times D$
- ② $0.5 \times D$ or 150mm, Whichever is larger
- ③ Min. 100mm
- ④ Min. Tray Space
- ⑤ Min. $2 \times D$

Fig. 3.2.3.2b Vapor or Mixed Inlet (Two-pass tray)

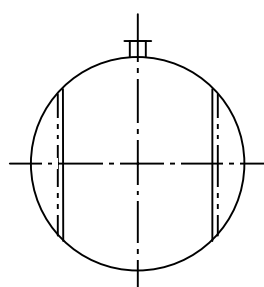
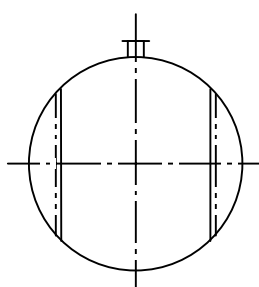
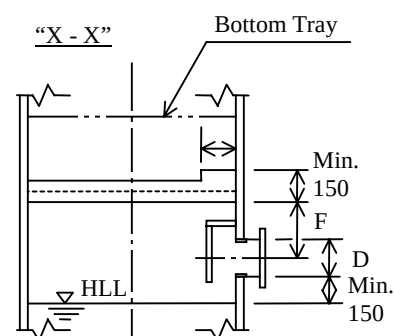
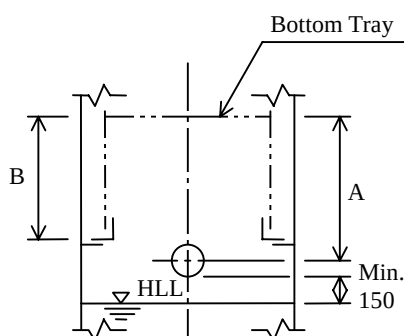
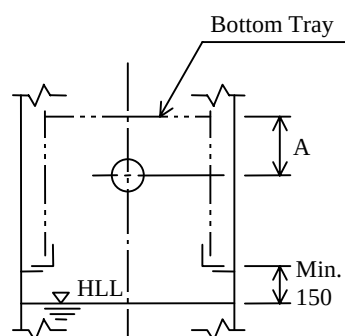
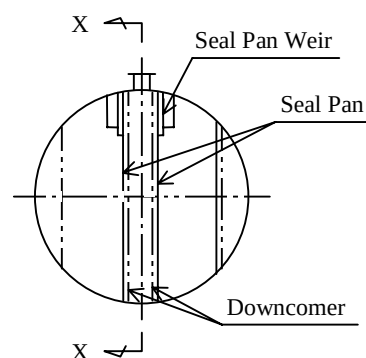
- (1) Consideration shall be provided so that the inlet fluid will rise evenly without collecting at one point in the active area in the bottom tray.
- (2) The rising fluid shall not obstruct the overflow of liquid from the seal pan.
- (3) In the case of two - pass trays, as a rule, Type V2-1 and Type V2-2 shall be used. Type V2-3 shall be used in cases where it is absolutely necessary in connection with the construction.

Dimension "A" (mm)

Nozzle Size	1½" and Under	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24" and Over
Type													
V2-1	290							360			410		460
V2-2	B + 150							B + 300					

Dimension "F" (mm)

Nozzle Size	1½" and Under	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
Tower dia (mm)													
Under 2,000	350					450				570			
2,100 - 4,000	400					500				620			
4,100 - 6,000	450					650				650			700
6,100 - 8,000	600					700				800			850

Type V2-1
(Vapor Phase)Type V2-2
(Mixed Phase)Type V2-3
(Vapor Phase and Mixed Phase)

(Note) As for Baffle size, see Fig. 3.2-38 in para. 3.2.5.7 (2).

Fig. 3.2.3.2c Vapor or Mixed Inlet (Four-pass tray)

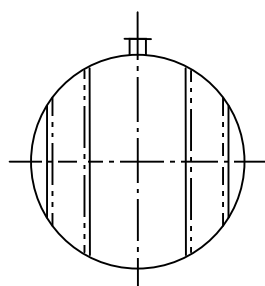
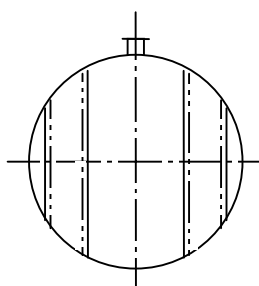
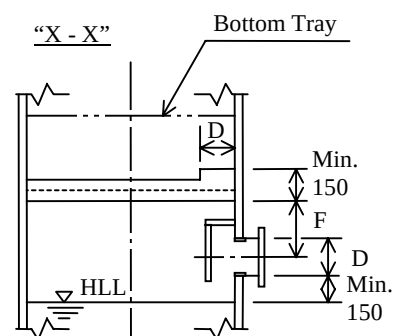
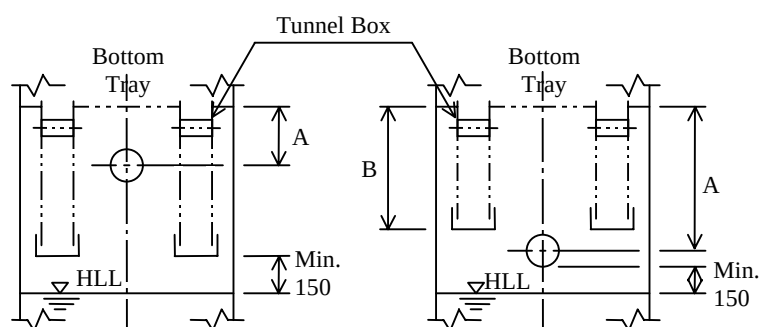
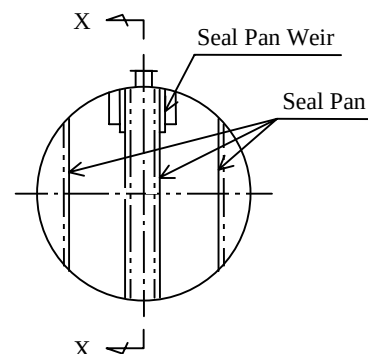
- (1) Consideration shall be provided so that the inlet fluid will rise evenly without collecting at one point in the active area in the bottom tray.
- (2) The rising fluid shall not obstruct the overflow of liquid from the seal pan.
- (3) In the case of four-pass trays, as a rule, Type V4-1 and V4-2 shall be used. Type V4-3 shall be used in cases where it is absolutely necessary in connection with the construction.

Dimension "A" (mm)

Nozzle Size	1½" and Under	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24" and Over
Type													
V4-1	290							360			410		460
V4-2	B + 150							B + 300					

Dimension "F" (mm)

Nozzle Size	1½" and Under	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
Tower dia (mm)													
Under 2,000	350				450				570				
2,100 - 4,000	400				500				620				
4,100 - 6,000	450				550				650			700	
6,100 - 8,000	600				700				800			850	

Type V4-1
(Vapor Phase)Type V4-2
(Mixed Phase)Type V4-3
(Vapor Phase and Mixed Phase)

(Note) As for Baffle size, see Fig. 3.2-38 in para. 3.2.5.7 (2).

3.2.3.3 Draw-off from the Bottom Tray

Draw off from bottom tray such as those for once-through thermosiphon feed, shall be as indicated in Fig. 3.2.3.3a and 3.2.3.3b.

Fig. 3.2.3.3a Draw-off from Bottom Tray (1)

The dimensions "G" and "H" shall be checked by using the weir equation, if liquid flow rate is high.

$G \geq 100 \text{ mm}$, $J \geq D + 50 \text{ mm}$, $H \geq 150 \text{ mm}$

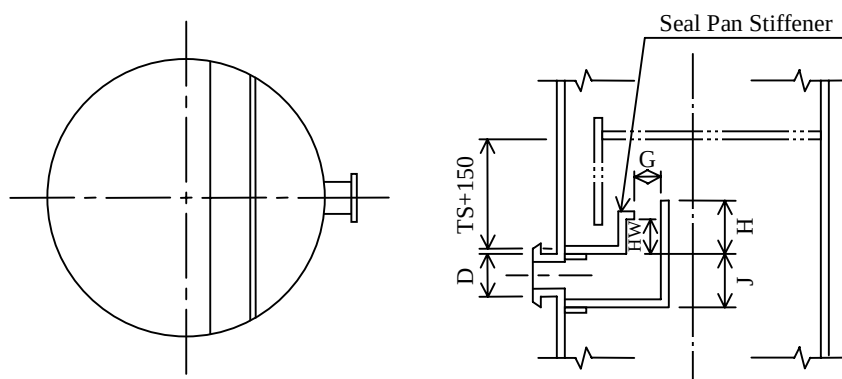
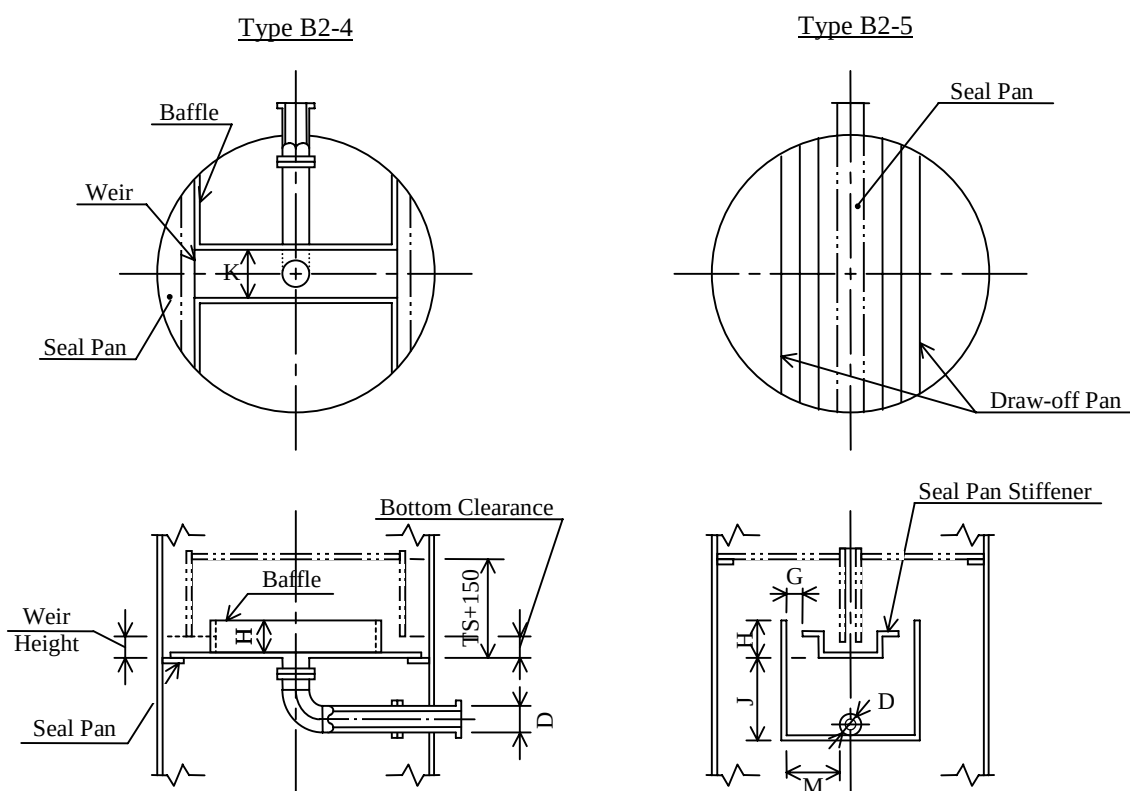


Fig. 3.2.3.3b Draw-off from Bottom Tray (2)

G = 100 mm minimum
H = 150 mm minimum
J = D + 150 mm
M = 25 mm minimum
K = 150 m³/h/m(200 gpm/ft)



3.2.5 Miscellaneous Nozzles**3.2.5.1 Manhole**

(1) Location of manholes :

Manholes shall be provided at least at the following locations :

- On top (Refer to 3.2.1.1 & 3.2.1.2)
- At feed tray
- On bottom
- At accumulator tray
- Every 20 trays as a guide line

(2) Manhole sizes :

Manhole sizes shall be decided based on the following criteria :

Vessel diameters	Nominal manhole sizes
900 and under (mm)	18-inch (413 mm ID)
901 to 1500 (mm)	20-inch (464 mm ID)
1501 and over (mm)	24-inch (560 mm ID)

(3) If the inside diameter is smaller than 901 mm, top shall flange shall be provided.

(4) In cases where no internals are located and the manhole is intended only for use as a manway, its size may be 18-inch in nominal size.

(5) Vessels which are too small for workmen to enter (under 800 mm in vessel diameter), shall be provided with 10-inch handholes.

3.2.5.2 LC-LG Nozzle

(1) Standard nozzle sizes shall generally be as follows :

Level controller, LC	3/4" , 1½" , 2" , 3"
Level gauge, LG	3/4" , 1"
Stand pipe and vessel nozzle	2"

(2) Arrangement details are shown in JGS 210-120-1-56E "Preparation of LC and LG Arrangement"

(3) Nozzle locations shall be as indicated in JGS 210-120-1-22E "DRUMS"

3.2.5.3 Vent and Drain

Vent and drain sizes shall be decided as follows :

Table 3.2-4 Vent and Drain Sizes		
Vessel Volume (m ³)	Vent	Drain
Under 150	1½"	1½"
150 to 400	2"	2"
Over 400	3"	3"

3.2.5.4 TI Nozzle

Standard nozzle size shall generally be 1½".

3.2.5.5 PI/PdI Nozzle

Standard nozzle sizes shall generally be as follows.

PI	1" or 1½"
PdI	¾" or 1"

3.2.5.6 Utility Nozzle

Standard nozzle size for steam out shall generally be 2".

3.2.5.7 Vortex Breaker, Baffle and Drain**(1) Vortex breaker :**

The following three types of vortex breakers are used by JGC as a standard :

Type I (JGS 332-218-6-03E) for Ordinary vessels

Type II (JGS 332-218-6-04E) for Vessels provided with lining

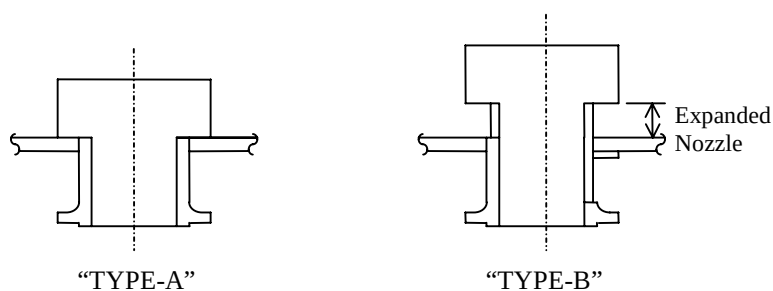
Type III (JGS 332-218-6-05E) for Vessels provided with concrete lining

Each of these types is designed for "A" or "B" shown in Fig. 6-36 based on the following criteria :

Type "A" is used in normal cases.

Type "B" is used in cases where other nozzles, such as boots are provided to draw off heavy components to prevent them from passing to the nozzles concerned or where there is a possibility of sludge accumulation.

Fig. 3.2-36 Vortex Breaker



(2) Baffle :

(a) Unless otherwise specified, the following types shown in JGS 332-218-6-02E shall be followed :

Type I Baffles (for level gauges) : To be located at the part of upper nozzle of level gauge.

Type II Baffles (for level gauges) : To be used in cases where Type II baffles cannot be attached.

Type III Baffles (for gas outlets and liquid inlets) : To be used in cases where gas outlets are located not on top head but on the shell wall. Liquid inlet baffles are to be reversely arranged.

Type IV Baffles (for liquid inlets) : To be used for liquid inlets on the bottom side of horizontal vessels.

Note : Dimensions of Type III baffles shall be decided based on Fig. 3.2-37

(b) In cases where Type V2-3 (Fig. 3.2-27) or Type V4-3 (Fig. 3.2-28) reboiler return are selected, unless otherwise specified, the baffle indicated in Fig. 3.2-38 shall be provided.

3.3. Trays

Fig. 3.2-37 Dimensions of Type - III Baffle

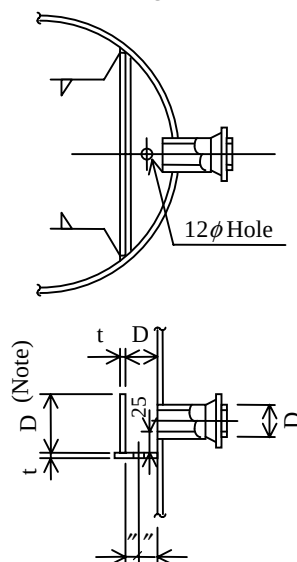
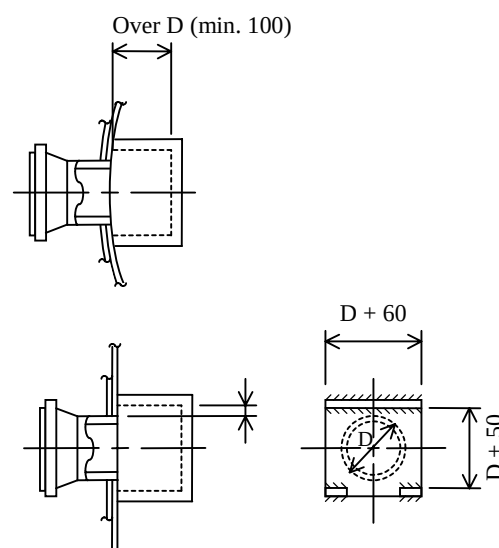
Note : If the baffle dimension $2D$ extends beyond the tangent line, it shall be cut at the tangent line.

Fig. 3.2-38 Reboiler Return Nozzle Baffle

**3.3.1 Selection of Tray Types**

(1) A brief description on the tray selection is provided in Appendix-1 and summarized herein. The selection of trays and internals shall be finalized based on economic evaluation and detailed study on performances.

(2) The tray types considered herein are as follows :

- Bubble cap tray
- Flexitray
- Sieve tray
- Dualflow tray
- Baffle tray
- MAX FRAC tray : new tray
- ULTRA FRAC tray : new tray
- SUPERFRAC tray : new tray
- NYE tray : new tray

- (3) The following table will be useful to choose the tray type as a first assumption. Consult the vendor to obtain performance data and cost for each individual case.

Table 3.3-1 Comparison of Tray Types

	Bubble cap tray	Flexitray	Sieve tray	Dualflow tray	Baffle tray	SUPERFRAC tray	NYE tray
Type of opening	bubble-cap	valve	sieve	sieve	partially sieve	valve	valve or sieve
Capacity	Moderate 80 to 90%	Moderate 100%	Moderate 100%	Good 110 to 130%	Moderate	Good 120 to 130%	Good 110 to 120%
Turn down	Good 1/10	Good 2/10 to 3/10	Moderate 4/10 to 5/10	Poor 7/10 to 8/10	Poor	Good 2/10 to 3/10	Good, same as valve or sieve
Pressure drop (mmHg)	Moderate (Min. 1.6)	Moderate (Min. 2.4)	Good (Min. 1.1)	Good	Good	Moderate	Good with sieve type
Efficiency	Good	Good	Good	Poor	Poor	Good	Good
Fouling	Poor	Poor	Good, with large hole	Good	Good	Poor	Good with sieve type
Corrosion	Good	Poor	Good	Good	Good	Poor	Good with sieve type
Maintainability	Poor	Good	Good	Good	Good	Good	Good
Cost	High 250 to 300%	Standard 100%	Low 80 to 90%	Low 60 to 70%	Low 60 to 70%	High 150 to 200%	High 120%

3.3.2 Efficiency and Heat Transfer Coefficient

3.3.2.1 Tower Efficiency

- (1) Although no satisfactory procedures have yet been established for efficiency estimation, several documents are available as a guide; refer to [1], [2] and [3] in Section 10 of this practice.

The factors influencing the efficiency are as follows :

- K-value estimation method (bases for calculation of theoretical tray numbers)
- Fluids handled
- Pressure drop across tray
- Liquid mixing behavior on tray
- Concentration distribution of components in each tray
- Entrainment, weeping.

- (2) The overall tower efficiencies with K-value estimation method are approximated and summarized in Table 3.3-2. The final value to be used in tower design shall be determined, considering various factors, such as physical properties, operating conditions and tray geometry. The number of trays to be used in the tower design may not so largely differ from those used in previous Projects.

Table 3.3-2 Approximate Tower Efficiency

Field	Process	Service	Section	-- Efficiency (%) --		K - Value	Note
				Ave. or top	Bottom		
Refinery	CDU	Prefractionator		70 - 80		BK10	
		Main Column	Top - Naph	75 - 80		SRK (BK10)	
			Naph - Kero	70 - 80		BK10	
			Kero - LGO	70 - 80		BK10	
			LGO - HGO	65 - 75		BK10	
			HGO - F.Z	65 - 70		BK10	
			Stripping	50 - 60		BK10	
			P.A. Section	50 - 70		BK10 or SRK	
		Side-cut stripper	Naphtha	50		SRK (BK10)	
			Kerosene	50		BK10	
			LGO	40 - 50		BK10	
			HGO	40 - 50		BK10	
		Stabilizer		75 - 85	75 - 80	SRK	
		Gasoline splitter		80-90		SRK(BK10)	
	VDU	Vaccum Distillation	Top - VGO	65 - 70		BK10	
			VGO - WAX	60 - 65			
			WAX -	60 - 65			
			H.Slop	40 - 45			
			H.Slop - F.Z	40 - 45			
	FCC/RCC	Main column	Top - H.Naph	65		GS	
			H.Naph -	50			
			LCO	50			
			LCO - HCO	50			
			HCO -				
			Bottom				
		Absorber		30 - 40		SRK	
			Stripper	35 - 40		SRK	
			Sponge Absorber	35 - 40		SRK	
			Debutanizer	70 - 80	70 - 80	SRK	
			Depropanizer	80 - 90	80 - 90	SRK	
	Hydro-treater	C ₃ /C ₃ ⁺ splitter		90	90	SRK	
			Naphtha Stripper	75 - 80	75 - 80	SRK	
			Kerosene Stripper	75	75	SRK	
			Gas Oil Stripper	50	50	SRK	
			VGO stripper	50		SRK	
	PL - Gas Con.	RCD stripper		50		SRK	
			Deethanizer	70	70	PR	
			Depropanizer	90	90	PR	
			Stabilizer	75	75	SRK	
			Debutanizer	75	75	SRK	
	Hydro-cracker	Deethanizer		70	70	SRK	
				70	70	SRK	
	Aroma. etc	FMT splitter		65	70	SRK	
			CTsplitter	75 - 80		SRK	
LNG/LPG		Stabilizer		50		SRK	
			Deethanizer	60 - 70		SRK	
			Depropanizer	75 - 85		SRK	
			Debutanizer	75 - 80		SRK	
Chemical	Ethylene *1	Primary fractionator		45		BK10	Ripple tray
		Light CBO stripper		40		SRK or PR	Valve tray
		Qnench water tower		25		BK10	Ripple tray
		Distillate stripper		28		SRK or PR	Valve tray
		Gasoline fractionator		50		SRK or PR	Valve tray
		Condensate stripper		45		SRK or PR	Valve tray
		Demethanizer		80		SRK or PR	Valve tray
		Demethanizer prefractionator		60		SRK or PR	Valve tray
		Deethanizer		70		SRK or PR	Valve tray
		No.1/2 Ethylene column		80		SRK or PR	Valve tray
		No.1/2 Depropanizer		70		SRK or PR	Valve or Ripple tray
		Secondary deethanizer		70		SRK or PR	Valve tray
		Propylene column		87		SRK or PR	Valve tray
		Debutanizer		50		SRK or PR	Valve tray
	Ethyl Benzene	Prefractionator		60	60	SRK	
		Benzene Recycle column		68	68	SRK	
		Ethyl Benzene Recovery column		63	63	SRK	
		PEB Recovery column		48	55	SRK	
	Styrene Monomer	Benzene column		57	32	SRK	
		Ethyl Benzene Recycle column		62	98	SRK	
		Stylene Monomer column		53	48	SRK	

*1 Ethylene team to be consulted for detail

3.3.2.2 Heat Transfer Coefficient

Heat transfer coefficient, U_{cal} (Kcal/m².h.°C), can be calculated to determine the required tray number of pump around section.

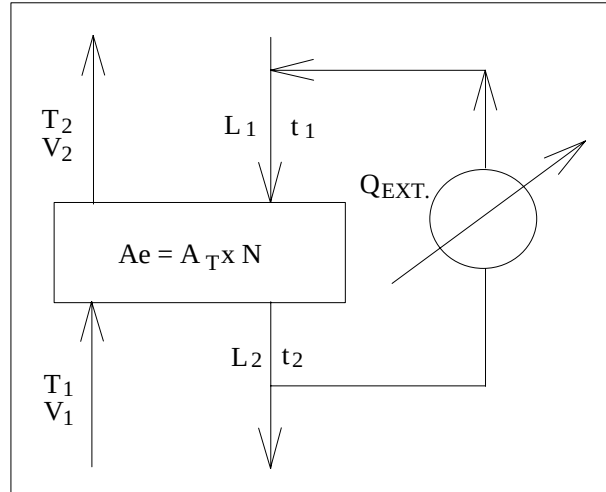


Fig. 3.3-3 Pumparound Section

$$\Delta T = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)} \quad (1)$$

$$U_{Design} = \frac{Q_{EXT}}{A_e \times \Delta T} > U_{cal} \quad (2)$$

Where :

Q_{EXT}	= heat duty	(10 ⁶ Kcal/h)
A_T	= tower area	(m ²)
N	= number of tray	(-)
A_e	= $A_T \times N$	(m ²)
L_1, L_2	= liquid load	(kg/h)
V_1, V_2	= vapor load	(kg/h)
t_1, t_2	= liquid temperature	(°C)
T_1, T_2	= vapor temperature	(°C)

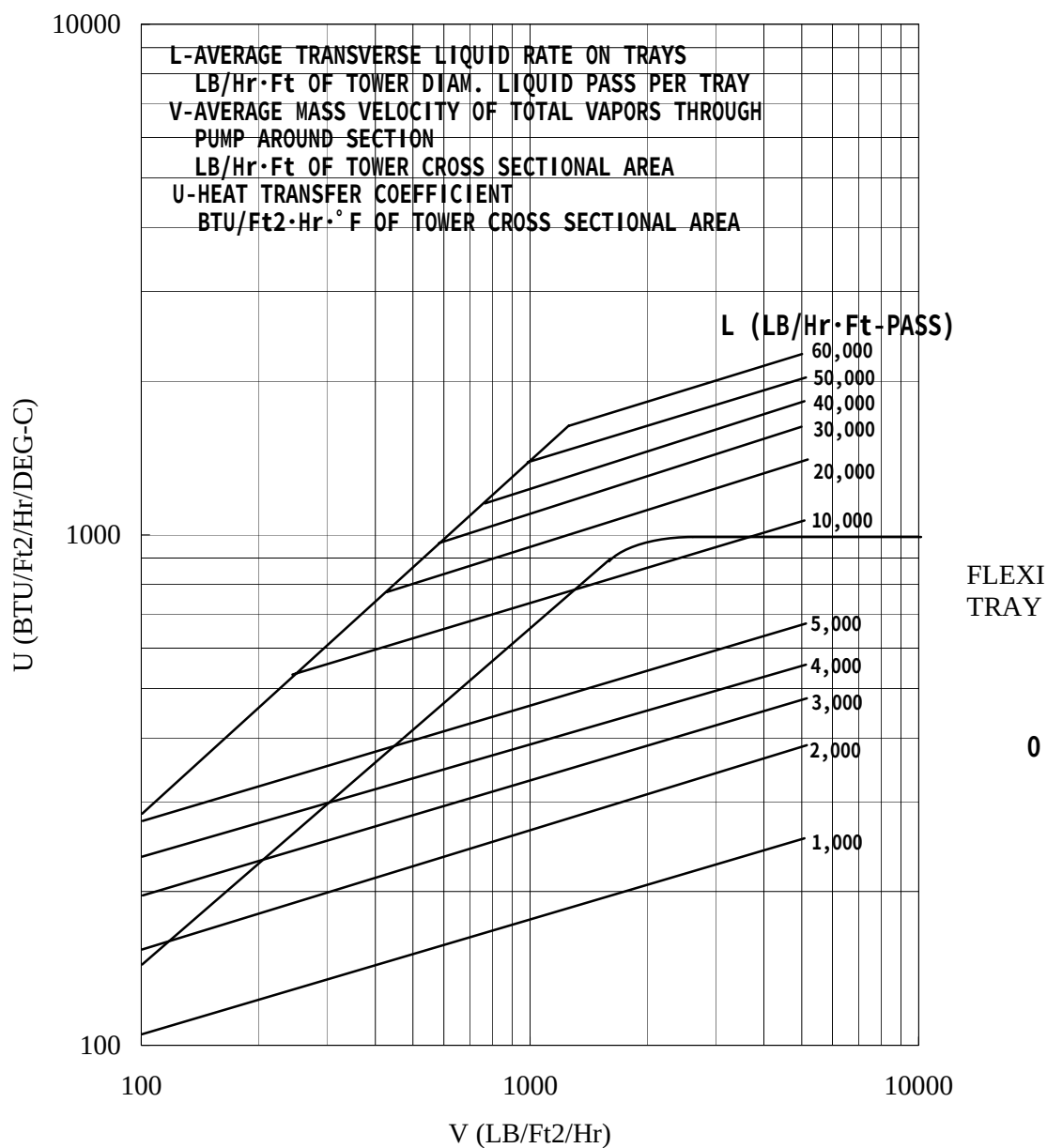
U_{cal} should be calculated by using Fig. 3.3-4 with vapor and liquid flow rate defined as follows :

$$V = \left(\frac{V_1 + V_2}{2} \right) / A_T \quad (\text{kg/m}^2.\text{h}) \quad (3)$$

$$L = \left(\frac{L_1 + L_2}{2} \right) / (\text{Pass no} \times \text{Tower Dia.}) \quad (\text{kg/h/m.pass no.}) \quad (4)$$

Fig. 3.3-4 is used for check of heat transfer.

Fig.3.3-4 HEAT TRANSFER ON BUBBLE CAP PLATES
(DESIGN CURVE EXCLUDING CHIMNEY TRAY)



3.3.3 Design Criteria of Trays

3.3.3.1 De-rating Factors

- (1) The uncertainty in predicting the capacity of a trayed column design occurs for a number of reasons. Inaccurate, or possibly estimated, physical properties and VLE data and errors associated with design correlations for hydraulics and efficiency are among the sources of uncertainty. To account for these uncertainties, the tray design is often derated by applying correction factors, known as de-rating factors, to the design calculations. Three reasons for de-rating are generally recognized, each with a different name for the de-rating factor:
 - foaming (foaming factor),
 - physical properties (system factor), and
 - uncertainty in the design correlations (safety factor).
- (2) De-rating factor
 - (a) Foaming factor :

The foaming factor is the most common type of de-rating factor. The hydraulic capacity of column trays is reduced by the presence of foam. The higher the foaming tendency, the lower the foaming factor. Foaming factors normally range from 0.5 to 0.9 depending on the severity of the foam.
 - (b) System factor:

The system factor is a de-rating factor applied to the capacity correlation for reasons other than foaming. System factors provide a margin of safety when designing outside the range of the physical property data bases of empirical design correlations.
 - (c) Safety Factor:

The safety factor is applied to account for deviations of a particular correlation from its available data base. Safety factors allow for uncertainty in the application of capacity, pressure drop or efficiency calculations. Note that the safety factor defined by F.R.I. is greater than one, unlike foaming factors and system factors used in the vendor procedures, which are all less than one. The reciprocal of the F.R.I. safety factor can be used for direct comparison. Safety factor may be alternatively expressed as a design percentage of the correlation, typically 85%.
- (3) The de-rating may be based on one or more of these considerations. Where two or more de-rating factors are considered applicable, the judgment of the experienced designer is required to decide how these factors may be combined to avoid excessive de-rating. Excessive de-rating of a design can result in a greatly oversized tower, which will in turn lead to oversized auxiliaries.
- (4) De-rating is most commonly applied to capacity correlations. To obtain the actual or de-rated flood load for a given system, the predicted flood vapor load (entrainment flooding) or liquid load (downcomer choke) obtained from the correlation is multiplied by the de-rating factor. In case of downcomer backup flood, the froth height predicted from the correlation is divided by the de-rating factor. A consolidated listing of published de-rating factors is provided in Table 3.3-3.
- (5) The application of de-rating factors is fraught with confusion. Caution is required, especially when communicating with an outside company whose de-rating practices may differ. The following need to be carefully specified.

-
- The flooding mechanism to which the de-rating factor applies (entrainment flood, downcomer backup, downcomer choke, or all)
-
- Avoiding double de-rating. The application of de-rating factors will double-derate the flood calculation if applied jointly with a correlation or criterion that already takes foaminess into account. Only one of the factors from Table 3.3-3 should be applied to a single system.
-
- Choosing the appropriate value for the de-rating factor. De-rating factors vary from source to source, and may depend on the correlation used as well as the application. The de-rating factors in Table 3.3-3 are useful as a guide, but are not absolute.
-

Table 3.3-3 Derating Factors

(1) Non-foaming

System	Factor	Reference	Notes
Nonfoaming regular systems	1.0	1,2,3	
High pressure ($\rho_V > 28.8 \text{ kg/m}^3$)	$2.93/\rho_V^{0.32}$	1	Do not double-derate.

(2) Low-foaming

H2S strippers	0.9 0.85	3 1	
Fluorine systems(Freons,BF ₃)	0.9	2	
Hot carbonate regenerators	0.9	1	

(3) Moderate-foaming

Deethanizers			0.77 for Flexi tray (BET Report No. 90 - 016)
Absorbing type,top section	0.85	1,2,3	
Absorbing type,bottom section	0.85	1,2	
Refrigerated type,top section	0.8	3	
Refrigerated type,bottom section	1.0	2,3	
Demethanizers			0.71 for Flexi tray (BET Report No. 90 - 016)
Absorbing type,top section	0.85	1,2,3	
Absorbing type,bottom section	1.0 0.85	3 1,2	
Refrigerated type,top section	0.8	3	
Refrigerated type,bottom section	1.0	3	
Oil absorbers			
Above 0°F	0.85	1,2,3	Ref.1 proposes these for "absorbers" rather than "oil absorbers.
Below 0 °F	0.95 0.85 0.8	3 2 1	
Crude towers	1.0	3	
Crude vacuum towers	1.0 0.85	3 1	
Furfural refining towers	0.85	1	
Furfural fractionator	0.85	1	
Sulfolane systems	1.0	3	with antifoamer
CO ₂ regenerator	0.85	1	
K ₂ CO ₃ still	0.85	1	
Glycol regenerators	0.85 0.8 0.65	2 3 1	
Hot carbonate absorbers	0.85	1	

(4) Heavy-foaming

Amine-absorbers	0.80 0.75 0.73	1 3 2	
CO ₂ absorber	0.80	1	
Glycol contactors	0.72 0.65 0.50	2 3 1	Ref.1 recommends 0.65 for glycol contactors in glycol synthesis gas service, 0.5 for others.
K ₂ CO ₃ absorber	0.80	1	
MEA,DEA absorber,regenerator	0.70	1	
Sour water strippers	0.5 - 0.7 0.6	3 1	
Oil reclaimer	0.7	1	
UDEX stripper	0.65	1	
ADIP regenerator	0.65	1	
MEK units	0.6	2	
Glycol still	0.65	1	
Caustic regenerators	0.6 0.3	1 2	
Caustic wash	0.65	1	
ADIP absorber	0.53	1	
Alcohol synthesis absorbers	0.35	1	

Reference : 1. Koch Engineering Co.,Inc., "Design Manual-Flexitray," Bulletin 960-1, Wichita, Kansas, 1982.
 2. Glitsch, Inc., "Ballast Tray Design Manual," Bulletin 4900, 4th ed., Dallas, Texas, 1974.
 3. Nutter Engineering, "Float Valve Design Manual," Tulsa, Oklahoma, 1976.

3.3.3.2 Design Variables

---- Later ----

3.3.4 Standard Tray Dimensions**3.3.4.1 Main Dimensions****(1) Tower diameters :**

Standard tower diameters shall be rounded as follows :

- 50 mm steps ; Tower diameter $\leq$ 1,000 mm
 100 mm steps ; 1,000 mm < Tower diameter $\leq$ 3,000 mm
 200 mm steps ; Tower diameter > 3,000 mm

Tower diameters in feet shall be rounded in 0.5 feet steps for any diameter.

Minimum tower diameter restricted from tower construction shall be as follows :

- 1-pass tray No limitation
 2-pass tray $\geq$ 1,200 mm
 3-pass or more $\geq$ (number of pass) $\times$ 750 mm

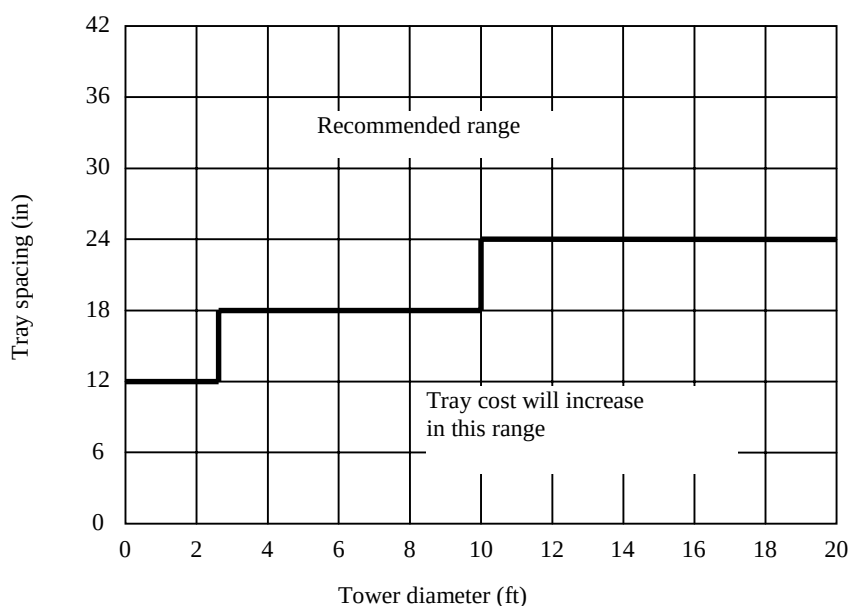
(2) Tray spacing :

Tray spacing shall be 300 mm (12 inch) minimum, rounded in 150 mm (6 inch) steps as a standard.

Tray spacing most preferable are 300, 450, 600, 750 and 900 mm or 12, 18, 24, 30 and 36 inch.

Minimum tray spacings restricted from tower construction are shown in Fig. 3.3-5. In case tower diameter is less than 10 ft and service is clean, 18 inch tray spacing is recommendable from a viewpoint of total tower cost.

Fig. 3.3.5 Minimum Tray Spacing

**(3) Number of passes :**

One(1) pass or two(2) pass trays may preferably be used as a general rule.

3.3.4.2 Downcomers**(1) Downcomer width :**

Downcomer widths shall be rounded in 10 mm (0.5 inch) steps as a standard.

(a) Segmental downcomers (Fig. 3.3-6) :

- Side projected weir lengths and side actual weir lengths shall be both equal to "L" shown in Fig. 3.3-6
- Flow pass length shall be longer than 510 mm (20 inch) for 750 mm or larger diameter towers to provide a manway. Hence, downcomer widths shall be as follows :

$$W \leq \frac{D_T + K_B - 510}{2} \quad (5)$$

Where :

W = Downcomer width (mm)

D_T = Tower diameter (mm)

K_B = Kick back (mm)

- Weir lengths shall be larger than 60% of the tower diameter to obtain good liquid distribution on the tray.

$$W/D_T \geq 10\% ; L/D_T \geq 60\% ; A_D/A_T \geq 5\% \quad A_T = \frac{\pi}{4} D_T^2 \quad (6)$$

- Minimum downcomer widths restricted from fabrication of tray and tower shall be as given in Fig. 3.3-7.

Fig. 3.3-6 Segmental Downcomer

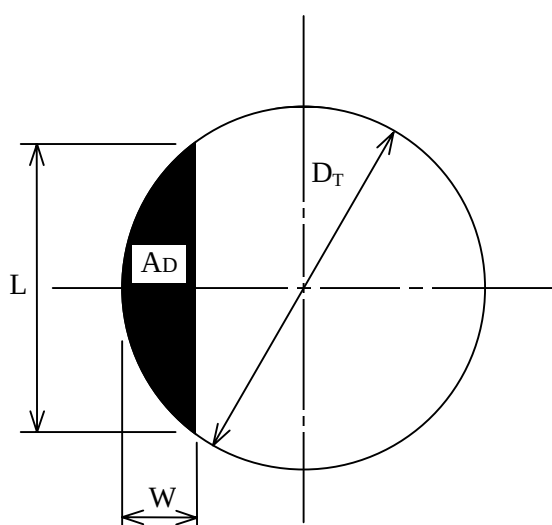
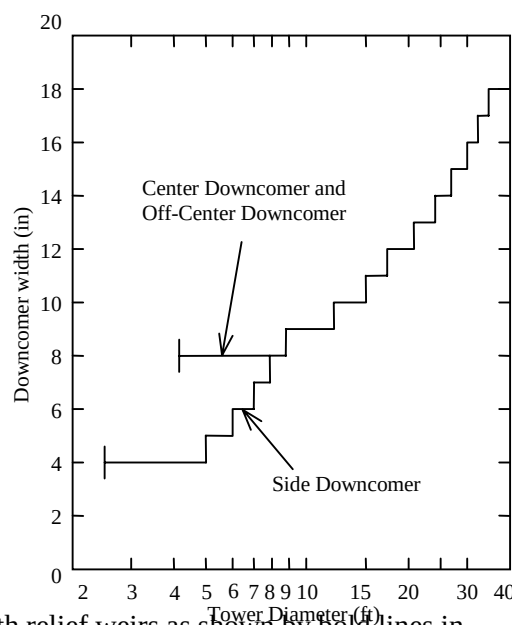


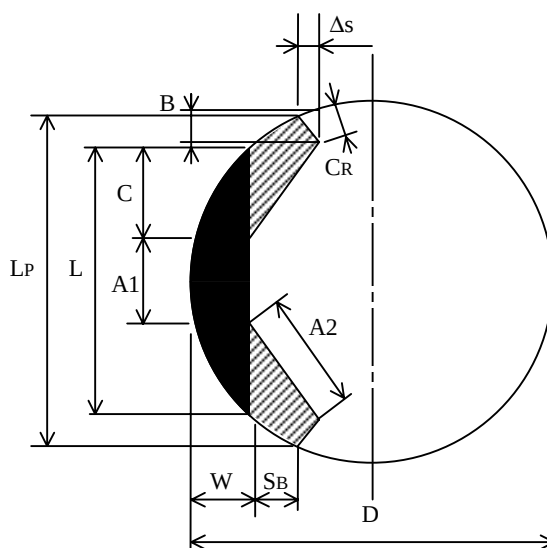
Fig. 3.3-7 Minimum downcomer width

**(b) Relief downcomers (Fig. 3.3-8) :**

Relief downcomer is a segmental downcomer equipped with relief weirs as shown by bold lines in Fig. 3.3-8. The dark portions in Fig. 3.3-8 is at the same level as the tray plate and the weir is provided along the bold line.

- No relief weir shall be provided in any of the following cases :
 - Where liquid rate is less than 2 gpm/inch of projected weir when pressure drop is not a limitation.
 - Where the tower diameter is less than 1,200 mm (4 ft)
 - Where the downcomer width "W" is greater than 20% of the tower diameter.
 - Limitations on segmental area : All requirements for the segmental downcomer are applied to the segmental portion of relief downcomer. Further, the dimension "A₁" shall be 400 mm or over to provide a manway.
 - Minimum downcomer width restricted from fabrication shall be as given in Fig. 3.3-7.
 - Koch regards the relief area as a part of the downcomer area while UOP does not permit this. The precautions to be taken in the design of trays for a UOP process are given in the reference [1].
- (c) For other types of downcomers, refer to the tray design manual [1].

Fig. 3.3-8 Relief Downcomer



(2) Kick backs :

Kick backs will be provided to increase the active area especially in high pressure towers.

Kick backs shall be rounded in 10 mm (0.5 in) steps, with maximum kick back of 100 mm.

Downcomer bottom area shall be greater than 55% of top area. If the bottom area become 50% or less, twice the bottom area shall be used as the top area in performance calculation.

No kick back shall be provided if the tray spacing is 450 mm (18 inch) or less.

(3) Weir heights and under downcomer clearances :

The following values are standard which shall be adjusted for use based on the design conditions in each individual case :

(a) Maximum weir heights shall be 1/6 of the tray spacing or 75 mm (3 inch), whichever is smaller.

(b) Minimum weir heights shall usually be 25 mm (1 inch).

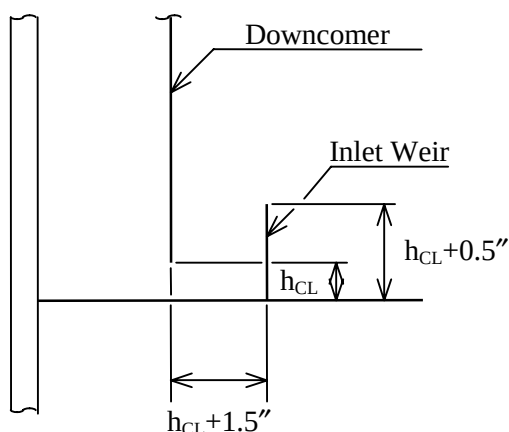
(c) For sieve trays, a weir height of 0 - 25 mm (0 - 1 inch) can be used if downcomer sumps are provided.

(d) Under downcomer clearances shall be 3/4 inch minimum. Maximum under downcomer clearances shall be the weir height minus 0.25 inch. When the liquid rate is high, the under downcomer clearance may be equal to the weir height.

(e) For clean and high liquid load service, inlet weirs can be adopted as shown in Fig. 3.3-9 ; the under downcomer clearance can be larger than the weir height. Do not count the area upstream of the inlet weir into the active area.

(f) Normally, the liquid velocity through the downcomer clearance shall be limited to give head loss of 1.6 inch-liquid or less.

Fig. 3.3-9 Dimensions Associated with Inlet Weir



3.3.4.3 Tray Opening

(1) Hole diameters :

Hole diameters of sieve and dual flow trays shall be 6, 12, 25 or 39 mm as a standard.

Large holes may be used for large diameter towers and foul service, 12 mm holes are usually used.

(2) Hole area percents of sieve tray :

Hole area percentages to the bubbling (active) area shall be 5% minimum and 20% maximum, with 1% of increment. Usually, the following hole area percents will be used :

- | | | |
|------------------------|---|----------|
| - High pressure towers | : | 5 - 8% |
| - Atmospheric towers | : | 8 - 10% |
| - Vacuum towers | : | 10 - 15% |

(3) Cap types :

Flexitray caps used as a standard are T_O, T-16&18, T-14&16, and A-14&16.

Since Type A-14&16 are of low cost, they are most frequently adopted.

Type T are adequate for foul services. In cases where Type T-16&18 are used, the pressure drop is somewhat smaller than in cases where Type T-14&16 are used. Type T_O shall be used for vacuum towers where allowable pressure drop is limited at low value.

3.4. Packings

3.4.1 Selection of Packings and Internals

3.4.1.1 Selection of Packings

(1) Packings can be classified into three categories as follows :

Categories	Available in market
(a) Random packing	Flexiring or Pall ring, Flex Max, Intalox metal tower packing (IMTP), Cascade mini-ring (CMR), K-pack
(b) Structured packing	Mellapak, Gempak, MC pack
(c) Grid packing	Flexigrid, Glitsch grid

A brief comparison of the packings is summarized in Table 3.4-1 to ease preliminary selection of packing.

(2) Final selection of packing and internals shall be decided based on economic evaluation and detailed study on performances.

3.4.1.2 Selection of Distributor and Redistributor Type

(1) Reference is made to JGC design manual “Distributor” (Japanese).

(2) Distributor selection criteria are as follows :

(a) Weir type distributors are desirable for the following reasons :

- High liquid distribution performance and wide turn down
- Broad applications
- Same type as redistributors can be used.
- Small space required

(b) Disadvantages of the weir type distributors are as follows:

- Instability at a low liquid rate.
- Difficult to handle liquid containing crystallized solids and high viscous liquid.
- Relatively large pressure drop ($\Delta P \geq 1$ mmHg is indicated from actual operating data).

(3) Alternates of distributor type

(a) Spray nozzles shall be used for low liquid load services (under 1 - 5 m³/hr/m² of tower cross sectional area). Otherwise, the weir type distributor with short stand-pipes shall be used to compensate for the liquid distribution instability. Such short stand-pipes whose top ends are notched, are fixed on every holes.

(b) Branch pipe distributors, spray nozzles or trough type distributors shall be used to reduce the pressure drop (1 mmHg or less)

(c) Trough type distributors shall be used where crystallization is possible.

(d) Branch pipe type distributors or spray nozzles shall be used where viscous liquid (10 cP or over) is to be handled.

(4) For reference, the features of distributors are summarized in Table 3.4-2.

Table 3.4-1 Comparison of Packings

Category	Random Packing				Structured Packing			Grid Packing	
Packing	Flexiring	IMTP (Note-2)	CMR (Note-3)	K-pac	Mellapack	Gempack	MC Pack	Flexigrid	Glitsch grid
Supplier	Koch	Norton	Dodwell	Koch	Sulzer	Glitsch	Mitsubishi	Koch	Glitsch
Capacity	BASE (100%)	110%	120%	110 - 120%	150%	150%	150%	150 - 200%	150 - 200%
Efficiency	BASE (100%)	100 - 110%	100 - 110%	100 - 110%	100 - 140%	100 - 140%	100 - 140%	80%	80%
Pressure drop	BASE (100%)	60%	50%	90%	20%	20%	20%	6%	6 - 10%
Max. bed height (mm)	3,000	8,000	9,000	7,000	H/D < 8	6,000	NA	3,000	3,000
Surface area / volume	Low - Medium				High			Low	
Liquid distribution	Good, but affected by distributor				Good			Good, but affected by distributor	
Fouling and Foaming	Moderate				Poor			Good	
Scale-up	Good for (Packing size) / (Tower diameter) ≤ 10				Good			NA	
Maintainability	Good				Poor			Good	
Cost / unit volume	BASE (100%)	110%	130%	100%	200%	200%	200%	150%	150%
Typical application	General use for distillation Absorption Vacuum distillation				High purity distillation Vacuum distillation			Cooling tower Washing section of vacuum	
Remarks	(Note-1)								

NA = Not available

(Note-1) Same as Pallring (Norton)

(Note-2) IMTP : Intalox Metal Tower Packing

(Note-3) CMR : Cascade Mini-Ring

Table 3.4-2 Special Features of Distributors

	Weir Type	Trough Type	Pipe Branch Type	Spray Nozzle
Fabrication costs	Base	Slightly low.	Low	Low to High, depending on supplier
Stability at low liquid rate	Unstable, if level not aligned. Provide short notched-pipes at holes.	Unstable because of difficulty in level alignment.	Theoretically stable, but no design procedure to distribute liquid equally.	Stable
Turn - down	Large (over 2.0)	Large (over 2.0)	Small (?)	Medium (approx. 2.0)
Effects of feeding on liquid distribution	Little effect	Little effect	No effect	No effect
Fouling	Inadequate for slurry	Adequate for foul liquid	Inadequate for slurry or liquid containing solid particles	Inadequate for slurry or liquid containing solid particles
Possibility of flooding	Possible to flood, if holes are blocked with foreign matter	No possibility of flooding.	No possibility of flooding.	No possibility of flooding. (but massive entrainment will occur)
Liquid distribution	Generally good.	Generally good	No design procedure to distribute liquid equally.	Generally good.
Other Matters		Redistributors to be weir type.	- Redistributors to be weir type. - Feed liquid to be pressurized.	- Redistributor to be weir type. - Feed liquid to be pressurized.

3.4.1.3 Selection of Packing Supports

(1) The types of packing supports are as follows : (See Fig. 3.4-1)

(a) Perforated plate type ("A" in Fig. 3.4-1):

This type is the simplest; open area is small and ΔP is large. This support type is used with structured packings because of its flat deck.

(b) Grid type ("B" in Fig. 3.4-1):

This type is most general and of high strength, consisting of slender plates arranged in a grid.

(c) Multi-beam gas injection type ("C" Fig. 3.4-1):

Plates with slots are assembled in a trapezoid beam form. This type has a large open area (approx. 85%) and high strength.

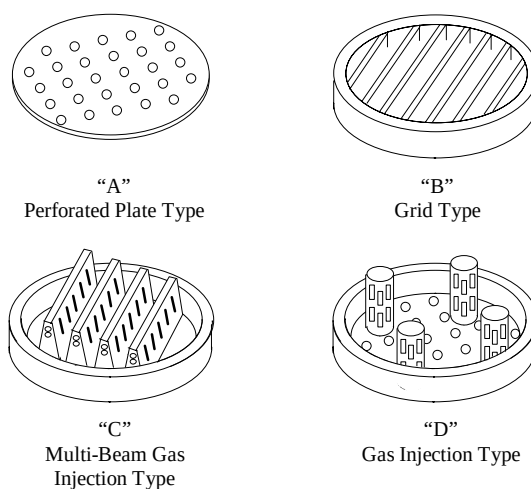
(d) Gas injection type ("D" in Fig. 3.4-1):

This type consists of a flat plate and risers with bore hole through which vapor is evenly distributed.

(2) Grid type shall usually be used for structured packings.

Multi-beam gas injection type and gas injection type can be used for random packings.

Fig. 3.4-1 Type of packing support



4. RELATED DOCUMENTS

The following publications constitute a part of this standard practice. Unless otherwise specified, refer to the latest edition. Applicable publications for the Project will be specified in each of the Project Specifications.

JGS (JGC Standard Practice)

JGS 210-120-1-18E	Determination of Design Conditions
JGS 210-120-1-22E	Basic Design of Drums
JGS 220-210-1-01	Practice of Detailed Design for Vessels (Japanese)
JGS 332-210-6-01E	Standard Drawing - "Tolerances for towers and drums"
JGS 332-218-6-02E	Standard Drawing - "Baffle for tower and vessel"
JGS 332-218-6-03E	Standard Drawing - "Vortex breakers Type "I" "
JGS 332-218-6-04E	Standard Drawing - "Vortex breakers Type "II" "
JGS 332-218-6-05E	Standard Drawing - "Vortex breakers Type "III" "
JGS 332-218-6-08E	Standard Drawing - "Allowable tolerances for installation of tray supports "
JGS 332-218-6-18E	Standard Drawing - "Flash guide (assembly type)"
JGS 332-218-6-19E	Standard Drawing - "Flash guide (assembly type)"
JGS 332-218-6-21E	Standard Drawing - "Type"D1-1-1" distributor 1 pass tray "
JGS 332-218-6-22E	Standard Drawing - "Type"D1-1-2" distributor 1 pass tray "
JGS 332-218-6-23E	Standard Drawing - "Type"D1-2" distributor 1 pass tray "
JGS 332-218-6-24E	Standard Drawing - "Type"D2-1" distributor 2 pass tray "
JGS 332-218-6-25E	Standard Drawing - "Type"D2-2" distributor 2 pass tray "
JGS 332-218-6-26E	Standard Drawing - "Type"D2-3-1" distributor 2 pass tray "
JGS 332-218-6-27E	Standard Drawing - "Type"D2-3-2" distributor 2 pass tray "
JGS 332-218-6-28E	Standard Drawing - "Type"D2-4" distributor 2 pass tray "
JGS 332-218-6-29E	Standard Drawing - "Type"D2-5" distributor 2 pass tray "
JGS 332-218-6-30E	Standard Drawing - "Type"D4-1" distributor 4 pass tray "
JGS 332-218-6-31E	Standard Drawing - "Type"D4-2" distributor 4 pass tray "
FORM 437	Skeleton of Vessel (Datasheet for Vertical Vessel)
FORM 438	Skeleton of Vessel (Datasheet for Horizontal Vessel)

ASME (American Society of Mechanical Engineers)

Section VIII, Division 1 Boiler and Pressure Vessel Code

ISHL (Industrial Safety and Health Law)

Notification 65 Construction Code for Boilers

Notification 66 Construction Code for Vessels

JIS (Japanese Industrial Standards)

B8210 Steam Boilers and Pressure Vessels - Spring Loaded Safety Valves

B8270 Pressure Vessels (General Standard)

5. DEFINITIONS

Design Rating : is the margin for towers design.

Flow Rate - Normal : is the normal flow rate or maximum flow rate among the normal flow rates (normal maximum flow rate) defined in the process specifications, such as in the heat and material balance for the process.

Flow Rate - Design : is the flow rate of design base for sizing towers.

Flow Rate - Maximum : is the flow rate with some extra margin added to normal flow rate, decided by plant capacity or anticipated operation (start - up or shutdown)

Flow Rate - Minimum : is the flow rate of lowest operating range of the process unit.

Turn down : is the ratio of the minimum flow rate to the normal flow rate.

Operating Range : is the range in which towers can be operated under satisfactory performance.

Entrainment : is the small particle of liquid entrained in vapor stream.

Overall Tower (Tray) Efficiency : is the ratio of ideal stage number under ideal liquid - vapor equilibrium to the actual stage number.

Height equivalent to a theoretical plate (HETP) : is the packing height equivalent to one theoretical stage.

De - rating Factors : is the design margin of a tray and a down comer predicted capacity.

6. REFERENCES

- [1] F.J.Lockhart and C.W.Leggett, " New Fractionating Tray Design ", Advance in Petroleum Refinery and Chemistry, **1** (1958)
- [2] H.E.O'Connel, " Plate Efficiency of Fractionating Columns and Absorbers ", Trans. Am. Inst. Chem. Engrs., **42** p.741 (1946)
- [3] H.G.Drikamer and J.R.Bradford " Overall Plate Efficiency of commercial hydrocarbon fractionating columns as a function of viscosity " Trans. Am. Inst. Chem. Engrs., **38**, p.319 (1943)
- [4] Tray design manual
- [5] FRI tray design manual
- [6] Guide to estimation of tray efficiencies
- [7] Vacuum flasher design manual
- [8] Distributor design manual

APPENDIX-1 SELECTION OF TRAYS

A1.1 General

- (1) A brief description on tray selection is provided in this Appendix. The selection of trays and internals shall be finalized based on economic evaluation, maintaining the performances within specification.
- (2) The tray types considered herein are as follows :
 - Bubble cap tray
 - Flexitray
 - Sieve tray
 - Dualflow tray
 - Baffle tray
 - SUPERFRAC tray : new tray
 - NYE tray : new tray
- (3) The tray types shown above, except SUPERFRAC and NYE trays, are compared under limited conditions. Due to the comparison under limited conditions, final selection in individual cases may differ from those herein.

A1.2 Comparison of Tray Types

A1.2.1 Capacity

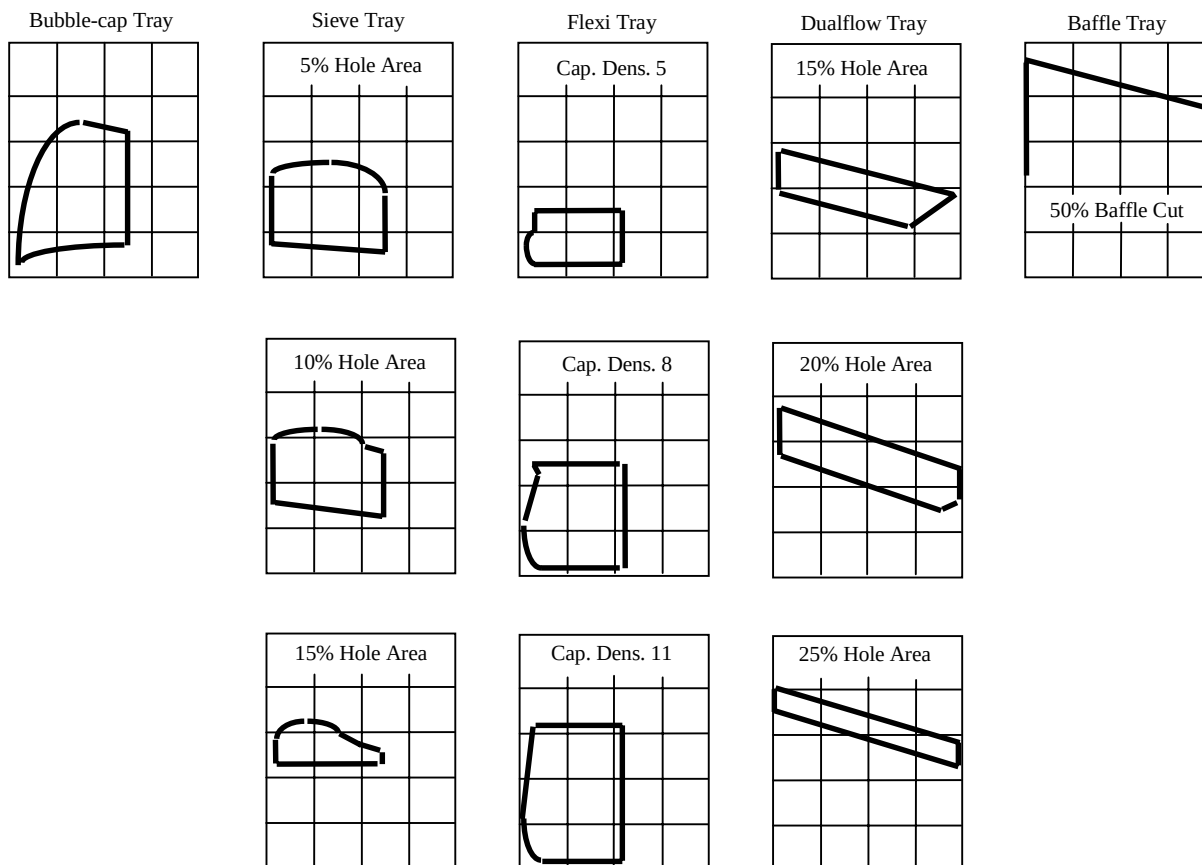
- (1) Fig. A1.1 shows the capacity graphs of the trays with geometry given in Table A1.1.
- (2) Since the capacity and turn down ratio of the same tray vary depending on the operating conditions (vapor liquid ratio), comparison at one point is of little significance. In each individual case, it would be helpful to trace a fixed vapor-liquid ratio in Fig. A1.1.
- (3) Generally, if the tray open area percent increases, the capacity will increase, and the pressure drop and efficiency will decrease.
- (4) As shown in Fig. A1.1, the lower limit of the sieve trays is high, due to FRI's conservative calculation method. Actually, the lower limit can be lowered more than that.

Table A1.1 Calculation Basis for Comparison of Tray Performance

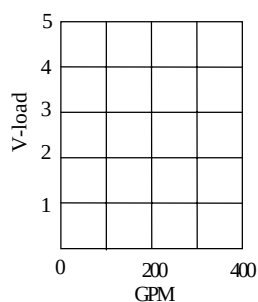
	Unit	Bubble-cap tray	Sieve tray	Flexitray	Baffle tray	Dualflow tray
Tower diameter	Ft	4.0	→	→	→	→
Tray space	in	24	→	→	→	→
Pass number	-	1	→	→	Side - Side	None
Downcomer width	in	7.5	→	→	12	None
Downcomer area %	%	10	→	→	50	None
Weir height	in	3.0	2.0	→	None	None
Downcomer clearance	in	1.5	→	→	None	None
Tray opening		Standard FRI cap 35 caps	12 mm hole Hole area % = 5% = 10% = 15% = 20%	T-14 & 16 G No. of cap = 48 = 78 = 107	None	12 mm hole Hole area % = 15% = 20% = 25% = 30%

Calculations are based on a design rating of 85%. Downcomer back-up and pressure drop are not considered as limitations.

Fig. A1.1 Performances of Various Trays



- (1) For all trays:
Tower Diam. 1200 mm ϕ
Tray Space 600 mm
- (2) See also Table 3-1 for detailed tray construction.
- (3) Scale of vapor and liquid flow rate is as shown right.



A1.2.2 Pressure Drop

- (1) Since pressure drops also depend on the tray construction, their comparison is also of little significance. However, comparison of lowest attainable pressure drop may be useful for actual design. Table A1.2 shows, as a guideline, the lowest attainable pressure drop in each tray type.
- (2) The values in the table are based on a liquid density of 1,000 kg/m³, the lowest attainable pressure drops become low in proportion to the decrease in the liquid density.
- (3) The lowest attainable pressure drop of flexitrays is larger than in other types, because caps of flexitrays cause about 1 mmHg of pressure drop in lifting themselves.
- (4) Since the tower diameter will be increased about 20% to reduce only 0.2 mmHg pressure drop in critical case, care must be taken in tray selection.

Table A1.2 Lowest Attainable Pressure Drop

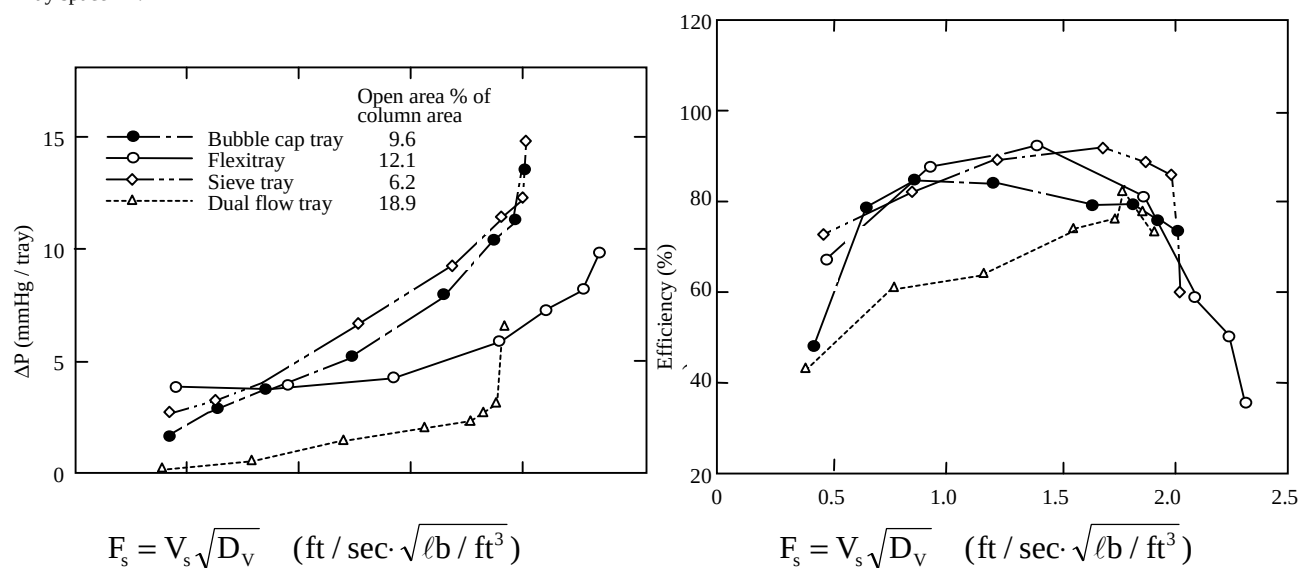
Tray	Lowest attainable pressure drop (mmHg)	Remarks
Bubble-cap tray	1.6	0" slot static seal
Sieve tray	1.6	1" weir height
	1.1	0" weir height with sump pot
Flexitray	2.4	1" weir height, T _O

A1.2.3 Efficiency

- (1) Fig. A1.2 shows tray efficiencies of each tray type.
- (2) Flexitrays have a high efficiency over a wide range.
- (3) For sieve trays, if the hole area percent is small, the efficiency will be high; for instance, sieve trays with 14% of hole area will give approximately 80% of the maximum efficiency.
- (4) Since tray efficiencies will vary remarkably, depending on the tray design, careful consideration must be given in the tray design.

Fig. A1.2 Trays Efficiencies and Pressure Drops (FRI test data)

System : C6/C7 24 psia
 Tower diam. : 4 ft (*8 ft)
 Tray space : 24 in



A1.2.4 Fouling

- (1) Dual flow trays are superior for foul services. Sieve trays with large hole area percent come next.
- (2) Flexitray are not superior in foul services. Do not apply to adhesive foul services.
Flexitray with T-type cap will be relatively better than the other cap types for foul services.
- (3) Inlet weirs and downcomer sumps are not recommendable for foul services. Liquid velocities should be increased when the flow rate is low or when some obstacles are provided in the liquid flow pass.

A1.2.5 Corrosion

- (1) Flexitrays are inadequate for corrosive services. In the worst case, the caps will be completely corroded away.
- (2) For corrosion protection, material selection is important rather than tray type selection.

A1.2.6 Maintainability

- (1) To ease maintenance, bubble cap trays are somewhat inferior due to heavy weight and high cap height, and consequent poor workability in the towers.
- (2) Trays with small spacing cannot provide good workability and may require a high construction cost. For trays with manways, tray spacing of about 600 mm may be used.

A1.3 Selection of Tray Types

Tray selection can be classified into selection of downcomer type and selection of tray opening such as hole, cap, slit and so on. Refer to para. A1.3.3 for downcomer type selection.

A1.3.1 New Installation

- (1) Usual design:
First, sieve trays should be considered. The turn down limit of sieve trays is 4/10 - 5/10.
- (2) Wide operating range is desired :
Flexitrays are recommendable. If they are unsatisfactory, bubble cap trays should be considered. The turn down limit is 2/10 - 3/10 for flexitrays and about 1/10 for bubble cap trays.
- (3) Low pressure drop is desired :
Sieve trays are effective. If their turn-down limits are unsatisfactory, bubble cap trays are available.
Flexitrays have little advantage.
Also, segmental or arc downcomers are recommendable ; the latter are effective, if liquid rate is high.
- (4) Fouling service :
Dual flow trays are most desirable, next come sieve trays with large hole sizes. Flexitrays and bubble cap trays are not recommendable for fouling service or adhesive fouling service.
- (5) Residence time :
If short residence time on the tray is desired, dualflow trays stand first. Sieve trays without outlet weirs come second, however, the residence time in the downcomers must be reduced to a minimum.
If long residence time is desired, bubble cap trays stand first, flexitrays come second and sieve trays come third ; they should be used with high weirs.

A1.3.2 Modification of Existing Towers

- (1) Increase in capacity :
If the capacity is to be increased without decreasing the efficiency, SUPERFRAC or NYE trays stand first. Sieve trays with high hole area percent may be applicable. Dualflow trays are also available for the purpose, although the efficiency falls rapidly with decrease in the load.
- (2) Increase in efficiency :
The following measures are applicable to increase tray efficiencies :
 - (a) Decrease the hole area percent
 - (b) Increase the weir height
 These measures are intended to increase the vapor-liquid contact time or to cause turbulence in the vapor flow near the holes to increase the material transfer rate. For sieve trays, sharp-edge holes or larger holes will possibly increase the efficiency, but the effectiveness is unclear as far as FRI's data is concerned.

A1.3.3 Selection of downcomer types

- (1) The following downcomers are effective in many cases :

Table A1.3 Selection of downcomer type

Ratio of Downcomer Area to Tower Area	Downcomer Type
Under 5%	Arc or swept-back downcomer
5 to 15%	Segmental or relief downcomer
Over 15%	Segmental downcomer

- (2) For the following two purposes, the number of flow passes may be increased :

- (a) Increase in the liquid flow rate
(b) Reduction in the pressure drop.

There is no criterion for the determination of tray pass numbers, but as the tray cost increases 5 - 10% with each one pass increase, the pass number is selected through cost comparison.

- (3) In any case, three (3) and more passes may not be used. Especially 3 or 5 passes would cause unbalanced vapor-liquid distribution.

A1.4 New Trays

A1.4.1 MAX-FRAC Tray

MAX-FRAC tray is a proprietary design supplied by Koch Engineering Co., Inc. (USA).

- (1) Application

Applicable for capacity up from existing conventional type of trays such as sieve tray, valve tray, etc.

- (2) Advantages

- 5 to 20% higher capacity and almost the same efficiency and pressure drops, compared to conventional valve trays.
- The existing support rings and bolt bars can be fully reused, therefore costs of modification tower itself is very limited.

- (3) Features

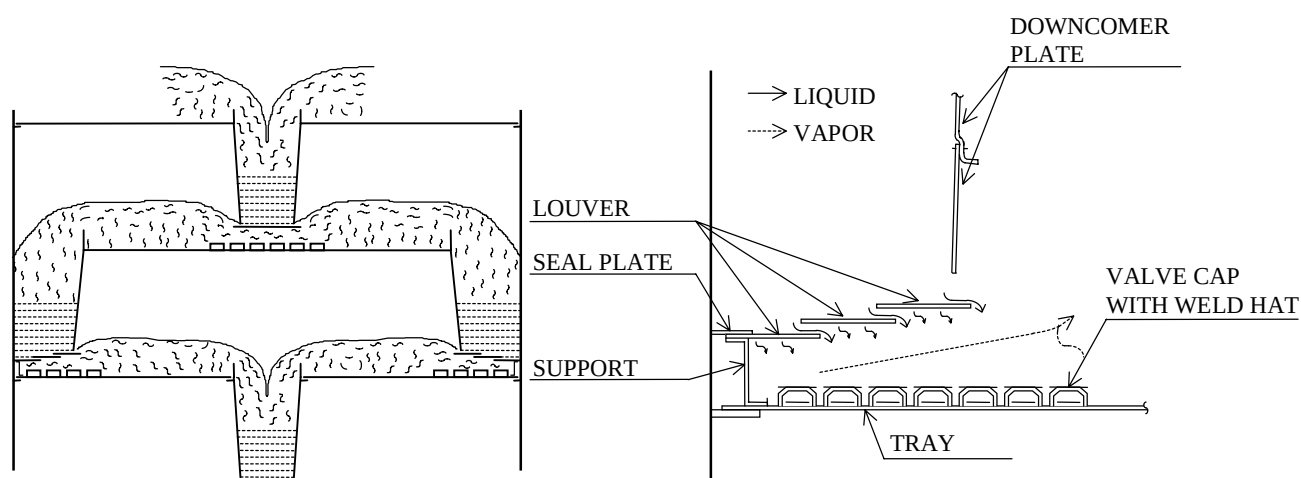
An improved design of conventional valve tray;

- Utilizes area under downcomer using louvered floor plates.
- Splitting the vapor and liquid mixing area by louvered floor plates.
- Louvered floor plates are protecting vapor by passing up the downcomer.
- The valves located under the downcomer are all T type with a cover welded on top of the cap holddowns. The first two rows of caps from the inlet are also with welded covers. These welded covers protect any effects of liquid flow through the louvered floor plates. (Refer to Fig-A.1.4.1)

Table A1.4.1 Actual Record of MAX-FRAC TRAY

DIAMETER	NO. OF PASS	SERVICE
3353 MM	2 & 3 PASS	EXTRACT COLUMN
2591 MM	1 & 2 PASS	FINISHING COLUMN
2100 MM	1 PASS	ISOLENE STABILIZER
3000 MM	2 PASS	ISOLENE STABILIZER
1100 MM	1 PASS	DEETHANIZER
1000 MM	1 PASS	DEPROPANIZER
1200 MM	1 PASS	DEPROPANIZER
6200 MM	4 PASS	TOPPER
6600 MM	4 PASS	TOPPER
2440 MM	3 PASS	EXTRACTIVE STRIPPER

Fig. A.1.4.1 MAX FRAC TRAY

**A1.4.2 SUPERFRAC Tray**

SUPERFRAC tray is a proprietary design supplied by Glitsch, Inc. (USA).

(1) Application

Applicable for capacity up of existing tower, and effective in high pressure service or high liquid load service.

(2) Advantages

20 to 30 % higher capacity and almost the same efficiency, compared to conventional valve trays.

(3) Features

An improved design of conventional Ballast tray ;

- distributing Mini valves, half diameter of Ballast valve, on the tray densely to obtain high opening area,
- elevating downcomer outlet from tray floor to provide larger active area,
- providing vapor flow into the liquid region descending from the raised downcomer outlet to increase vapor-liquid contact.

Refer to Fig. A1.4.2.

Fig. A1.4.2 SUPERFRAC Tray

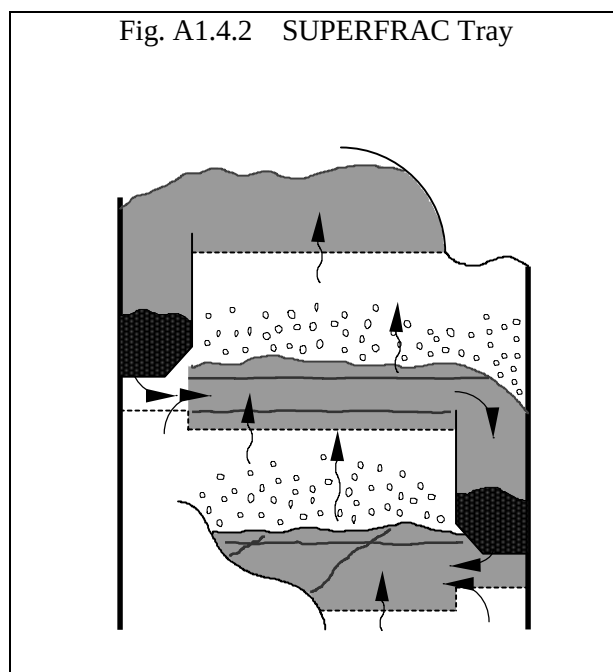


Table A1.4 Actual Record of SUPERFRAC Tray

Delivery Year	Location	Tower Name	Diameter	Quantity of Trays
1991	Thai	CRUDE TWR. BTM P/A	3,350 mm	3
1991	Singapore	CRUDE TWR. LN/HN	2,600 mm	15
1991	Singapore	STABILIZER	1,200/2,000 mm	16/16
1991	Japan	ADIP REGENERATOR	1,100 mm	16
1991	Japan	FCCU GASOLINE RERUN	1,500 mm	11
1991	Japan	NAPHTHA STABILIZER	2,200 mm	15
1992	Japan	SCOT QUENCHER & ABSORBER	1,600 mm	5
			1,300 mm	9
1992	Japan	SCOT QUENCHER & ABSORBER	1,500 mm	6
			1,400 mm	11
1992	Japan	PREFRACTIONATOR	2,134 mm	8
1992	Japan	TOPPER MID P/A	6,300 mm	2
1992	Japan	TOPPER STRIPPER	1,300 mm	4
1993	Japan	RECYCLE GAS SCRUBBER	2,290 mm	21
1993	Japan	FCCU PRIMARY ABSORBER	1,400 mm	35
1993	Japan	FCCU DEBUTANIZER	1,675 mm	16
1993	Japan	N - STABILIZER	2,100 mm	16

A1.4.3 NYE Tray

NYE tray is a proprietary design supplied by Glitsch, Inc. (USA).

(1) Application

Applicable for capacity up of existing tower or new tower, and effective in high pressure service or high liquid load service.

(2) Advantages

10 to 20 % higher capacity and almost same efficiency, compared to conventional valve trays.

(3) Features

An improved design of conventional valve or sieve tray ;

- elevating downcomer outlet from tray floor to provide larger opening area,
- providing vapor flow from active inlet area below the downcomer to increase vapor-liquid disengagement.

Refer to Fig. A1.4.3.

Fig. A1.4.3 NYE Tray

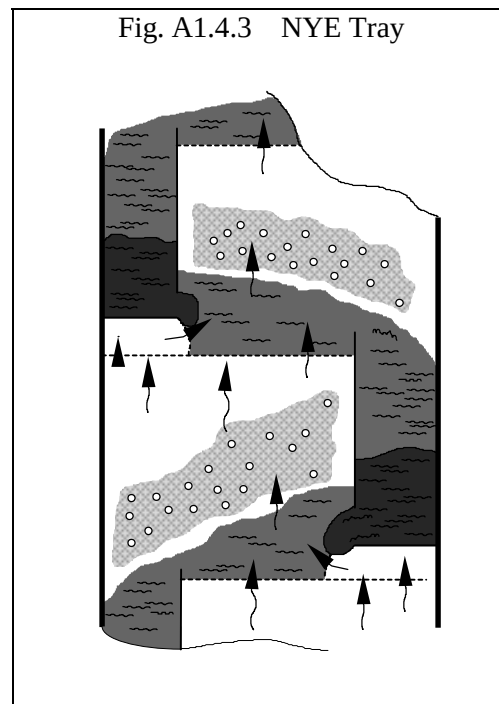


Table A1.5 NYE Tray References

Delivery Year	Location	Tower Name	Diameter	Quantity of Trays
1988		DIB	8' -6"	60
1989		DIB	8' -6"	20
1988		DIB	18' -6"	80
1989		DE - C2 (TOP)	9' -6"	25
1989		P - P SPLITTER	11' -6"	128
1989		P - P SPLITTER	11' -6"	112
1990		BUTAMER STABILIZER	7' -6" / 11' -6"	30
1990		DIB	12' -0"	70
1990		DIB	18' -6"	80
1991		DIB	10' -0"	110
1991		PENTANE STRIPPER	10' -0"	34
1991		PENTANE STRIPPER	10' -0"	60
1991		DIB	9' -6"	66
1991		DIB	10' -0"	66
1991		DIB	18' -6"	90
1991		BUTAMER STABILIZER	13' -0"	40
1991		ALKYLATE SPLITTER	5' -0"	20
1992		NAPHTHA STABILIZER	3' -3"	17
1992		DEETHANIZER	8' -0" / 13' -0"	44
1992		DEPROPANIZER	9' -0"	40
1992		DEBUTANIZER	9' -0" / 11' -0"	56
1992		REFORMATE STABILIZER	5' -0"	44
1991		PUMP AROUND (AT)	11' -0"	1
1991		PUMP AROUND (ACT)	16' -0"	6
1992		PUMP AROUND (FCC)	4,700 mm	3
1993	Japan	DEMETHANIZER	1,900 mm	4
1993	Japan	DEETHANIZER	2,350 mm	14
1993	Japan	FCC DEPROPANIZER	1,900 mm	14
1994	Japan	FCC DEBUTANIZER	2,000 mm	12

APPENDIX-2 SKELETON OF TOWER

Skeletons of towers shall basically be prepared as follows :

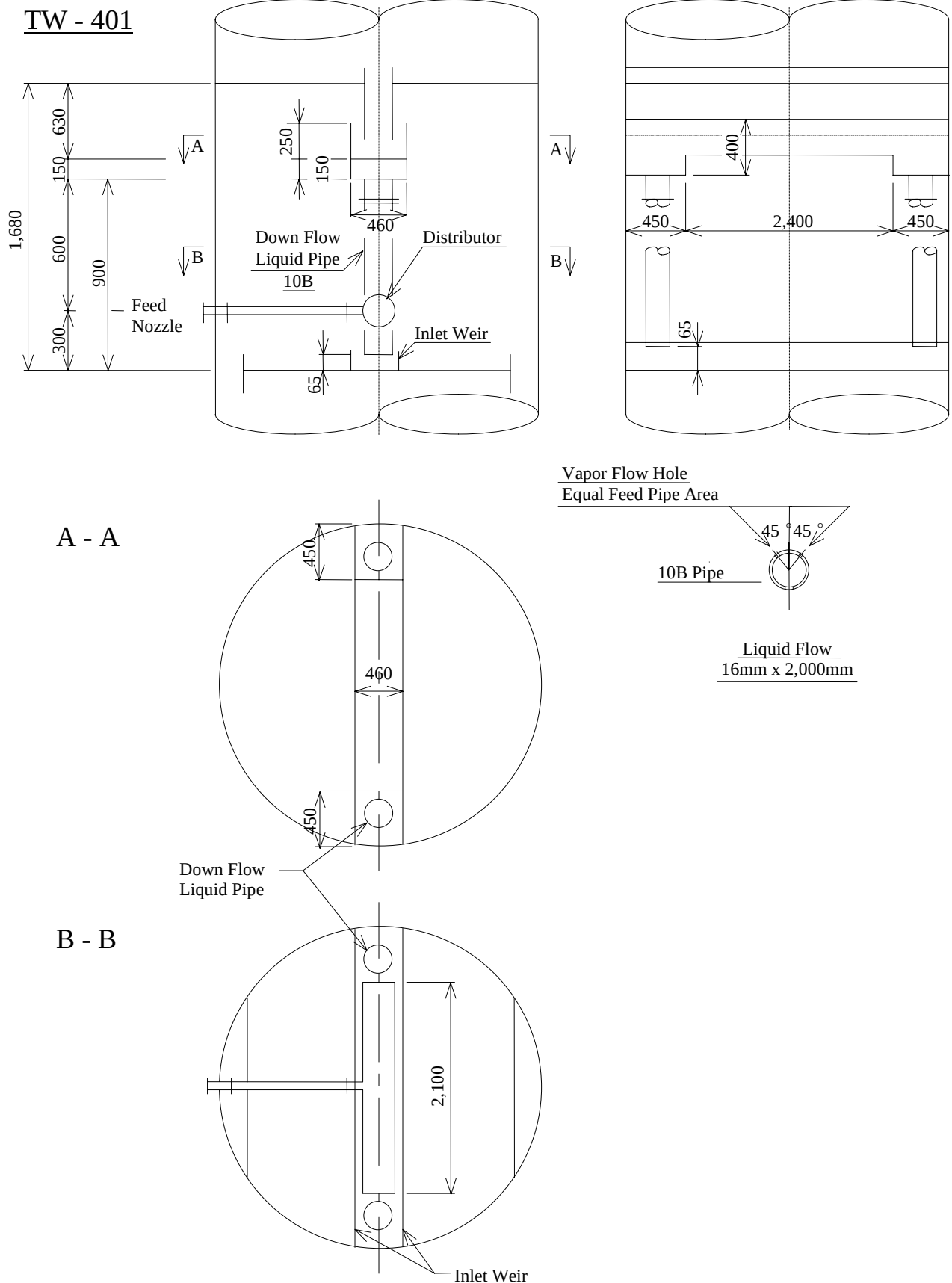
- (1) General :
 - (a) Skeletons shall be nearly to scale.
 - (b) Skeletons shall not include insignificant values and data.
 - (c) Nozzles shall be identified by alphabetical (capital) letters, excepting the letters "I" and "O".
- (2) Nozzles :
 - (a) Nozzles shall be entered on the skeleton in the following order :
Main nozzles (shown on the process flow sheet) shall be shown in order from top to bottom.
Then, vents, manholes and LC nozzles shall be shown.
 - (b) The bottom nozzle shall be one in number.
 - (c) Numbers of nozzle shall be shown in the number column of the skeleton of vessel.
- (3) Trays :
 - (a) The trays and tray numbers to be shown shall be as follows :
 - Top tray
 - Feed tray
 - Bottom tray
 - Trays where the pass number and/or geometry are/is to be changed.
 - Collector trays and distributor trays
 - Trays where the manhole is to be provided
 - (b) The tray pass number and downcomer location (side downcomer (right or left) or center downcomer) shall be checked and shown.
- (4) Manholes :
 - (a) Provision and locations (tray numbers) of manholes shall be decided by the process engineer. For the procedure, see para. 8.5.1 hereof.
 - (b) Detailed dimensions, such as elevation of manhole need not be shown if no problem is expected from the process standpoint.
- (5) LC - LG :
 - (a) Normal liquid levels shall be shown.
 - (b) LC control ranges shall be shown in length.
 - (c) LC - LG nozzle to nozzle distances need not be shown if no problem is expected.
- (6) Miscellaneous :
 - (a) Dimensions of the cone section where the tower diameter is to be changed, shall be determined in accordance with para.8.2.3 hereof.
 - (b) Tower dimensions shall be shown on the right side of tower drawings.
 - (c) The following shall be shown in the note column or on the skeletons :
 - Tray : Cap type, pass number, weir height, etc.
 - Liquid : Bottom liquid density, residence time, etc.
 - Packing : Sizes, bulk density, type, material, etc.
 - (d) Both design temperatures and operating temperatures shall be shown on the side portion of the drawings if they are to be different in each section of the same tower.

APPENDIX-3 SAMPLE OF SKELETON**A3.1 Skeleton of Trayed Tower**

SKELETON OF VESSEL																																																																																																																																																																																		
SIZE <u>3,300ϕ × 30,700L</u> QUANTITY <u>1</u>																																																																																																																																																																																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td colspan="4" style="padding: 2px;">CODE</td></tr> <tr><td colspan="4" style="padding: 2px;">SPEC.</td></tr> <tr><td style="padding: 2px;">DESIGN</td><td style="padding: 2px;">3.5/HALF V</td><td style="padding: 2px;">kg/cm²G</td><td style="padding: 2px;">155 / 120 °C</td></tr> <tr><td style="padding: 2px;">OPERATING</td><td style="padding: 2px;">1.1</td><td style="padding: 2px;">kg/cm²G</td><td style="padding: 2px;">123 °C</td></tr> <tr><td colspan="3" style="padding: 2px;">SHOP HYDROSTATIC TEST</td><td style="padding: 2px;">kg/cm²</td></tr> <tr><td colspan="4" style="padding: 2px;">RADIOGRAPH</td></tr> <tr><td colspan="2" style="padding: 2px;">STRESS RELIEVE</td><td style="padding: 2px;">EFF.</td><td style="padding: 2px;">%</td></tr> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="padding: 2px;"></th> <th style="padding: 2px;">TOTAL TH'K mm</th> <th style="padding: 2px;">CORRO. ALLOW. mm</th> <th style="padding: 2px;">MATERIALS</th> </tr> <tr><td style="padding: 2px;">HEADS</td><td></td><td>1.0</td><td>C.S</td></tr> <tr><td style="padding: 2px;">TYPE</td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;">SHELL</td><td></td><td>1.0</td><td>C.S</td></tr> <tr><td style="padding: 2px;">INSULATION</td><td></td><td></td><td>ケイ酸カルシウム</td></tr> <tr><td style="padding: 2px;">LINING</td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;">SADDLE</td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;">SUPPORT</td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;">WIRE MESH PAD</td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;"></td><td></td><td></td><td></td></tr> <tr><td style="padding: 2px;"></td><td></td><td></td><td></td></tr> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td colspan="2" style="padding: 2px;">TRAY SPACING</td><td style="padding: 2px;">380</td></tr> <tr><td colspan="2" style="padding: 2px;">TRAY TYPE</td><td style="padding: 2px;">FLEXITRAY</td></tr> <tr><td style="padding: 2px;">GAUGE GLASS</td><td style="padding: 2px;">SIZE</td><td style="padding: 2px;">Q'TY</td></tr> <tr><td colspan="3" style="padding: 2px;">RELIEF VALVE</td></tr> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td colspan="2" style="padding: 2px;">ACCESSORIES APPLIED BY FABRICATOR</td></tr> <tr><td style="padding: 2px;">LADDER & PLATFORM CLIPS</td><td style="padding: 2px;">YES</td></tr> <tr><td style="padding: 2px;">INSULATION CLIPS</td><td style="padding: 2px;">YES</td></tr> <tr><td style="padding: 2px;">DAVIT SUPPORT</td><td style="padding: 2px;">YES</td></tr> <tr><td style="padding: 2px;">TRAY SUPPORT RINGS</td><td style="padding: 2px;">YES</td></tr> </table> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td colspan="5" style="padding: 2px;">NOZZLES & MANHOLES</td></tr> <tr> <th style="padding: 2px;">MARK</th> <th style="padding: 2px;">No.</th> <th style="padding: 2px;">SIZE</th> <th style="padding: 2px;">RATING/FACING</th> <th style="padding: 2px;">SERVICE</th> </tr> <tr><td style="padding: 2px;">A</td><td style="padding: 2px;">1</td><td style="padding: 2px;">8B</td><td style="padding: 2px;">150#RF</td><td style="padding: 2px;">FEED</td></tr> <tr><td style="padding: 2px;">B</td><td style="padding: 2px;">1</td><td style="padding: 2px;">20B</td><td style="padding: 2px;">150#RF</td><td style="padding: 2px;">VAPOR OUT</td></tr> <tr><td style="padding: 2px;">C</td><td style="padding: 2px;">1</td><td style="padding: 2px;">6B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">REFLUX IN</td></tr> <tr><td style="padding: 2px;">D</td><td style="padding: 2px;">1</td><td style="padding: 2px;">8B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">BOTTOM OUT</td></tr> <tr><td style="padding: 2px;">E_{1,2}</td><td style="padding: 2px;">2</td><td style="padding: 2px;">10B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">TO REBOILER</td></tr> <tr><td style="padding: 2px;">F_{1,2}</td><td style="padding: 2px;">2</td><td style="padding: 2px;">20B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">FROM REBOILER</td></tr> <tr><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;">LG</td></tr> <tr><td style="padding: 2px;">H_{1,2}</td><td style="padding: 2px;">2</td><td style="padding: 2px;">2B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">LC</td></tr> <tr><td style="padding: 2px;">G₁₋₃</td><td style="padding: 2px;">3</td><td style="padding: 2px;">1B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">TI</td></tr> <tr><td style="padding: 2px;">J</td><td style="padding: 2px;">1</td><td style="padding: 2px;">2B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">STEAM OUT</td></tr> <tr><td style="padding: 2px;">K</td><td style="padding: 2px;">1</td><td style="padding: 2px;">2B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">VENT</td></tr> <tr><td style="padding: 2px;">M₁₋₃</td><td style="padding: 2px;">3</td><td style="padding: 2px;">20B</td><td style="padding: 2px;">150# RF</td><td style="padding: 2px;">MAN HOLE</td></tr> <tr><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td></tr> <tr><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td><td style="padding: 2px;"></td></tr> </table>					CODE				SPEC.				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UNIT	<u>PCR 組成改善工事</u>	0	<u>DEC. 17, '98</u>			
NAME OF VESSEL	<u>C7L NO. 1 SPLITTER</u>	1				
ITEM No.	<u>TW-401</u>	2				

Skeleton of Tower (continued) -- Detail of Internals --



APPENDIX-4 PRELIMINARY SIZING (FLEXITRAY TOWER)

Chart Fig. a-1 provides a quick approximation only of column diameter and should be verified by a detailed design before the column diameter is finalized.

The steps for using Fig. A-1 are as follows:

- (1) Determine the vapor rate in actual cubic feet-per-second (ACFS), the liquid rate in gallons-per-minute (GPM), the vapor and liquid densities in pounds-per-cubi foot, all at actual tower operating conditions of temperature and pressure. Then decide on the tray spacing to be used.
- (2) Calculate the square root factor,

$$\sqrt{\frac{d_v}{d_l - d_v}}$$

Where: d_v = vapor density, lbs./ft³.
 d_l = liquid density, lbs./ft³.

- (3) Calculate the vapor loading factor,

$$\text{ACFS} \sqrt{\frac{d_v}{d_l - d_v}}$$

- (4) Correct the vapor loading factor and liquid rate by dividing by the tray space factor (Table A.4) and system factor (Table 3.3.3.1).

$$\text{Corrected vapor load factor} = \frac{\text{ACFS} \sqrt{\frac{d_v}{d_l - d_v}}}{(\text{Tray space factor}) (\text{System factor})}$$

$$\text{Corrected liquid rate} = \frac{\text{GPM}}{(\text{Tray space factor}) (\text{System factor})}$$

- (5) Plot the corrected vapor loading factor and corrected liquid rate on Chart Fig. A-1.
 - (6) Read the minimum diameter from Chart Fig. A-1 noting that in many cases the minimum diameter will depend on the number of liquid flow passes per tray.
- After preliminary diameter, number of liquid passes and tray spacing have been established, a detailed tray design is made and then checked against the capacity correlation.

Fig. A-1 FLEXITRAY TOWER SIZING

