Education Institute for

Equipment & Process Design

Doc.PV-2005
Rev.1

Tower Design

Tower Data Input

Maximum Load in different Zones

Vapor Load in Zone 1

Performance point	Design
Temperature	102
Gas flow	440752
Gas density	4,07
Gas viscosity	0,012
Gas molecular weight	32,04

Vapor Load in Zone 1

Performance point	Design
Temperature	109
Gas flow	422422
Gas density	4,23
Gas viscosity	0,013
Gas molecular weight	30,52

Vapor Load in Zone 1

Performance point	Design
Temperature	116
Gas flow	402338
Gas density	4,3
Gas viscosity	0,013
Gas molecular weight	29,70

Liquid Load in Zone 1

Performance point	Design
Temperature	104
Liquid flow	359831
Liquid density	709
Liquid viscosity	0,225
Liquid surface tension	15

Liquid Load in Zone 1

Performance point	Design
Temperature	111
Liquid flow	460397
Liquid density	727
Liquid viscosity	0,221
Liquid surface tension	17

Liquid Load in Zone 1

Performance point	Design
Temperature	116
Liquid flow	406821
Liquid density	751
Liquid viscosity	0,221
Liquid surface tension	20

Tower ID Sizing

1. **Use C-factor method or Koch-Glitsch diagram for first estimation of Diameter**

$$\vartheta_m = C\sqrt{\frac{\rho_l - \rho_v}{\rho_v}}$$

- Vm = maximum acceptable vapor velocity in the space below one tray, (m/h),
- ρl = liquid density at operating temp. and pressure of the tray (kg/m3),
- ρv = vapor density at operating temp. and pressure of the tray (kg/m3),
- C = Souders-Brown factor given by figure 12, in m/h versus tray spacing in cm and liquid surface tension in N/m,

Service	Tray spacing		
	18 in (46 cm)	24 in (61 cm)	30 in (76 cm)
Absorbers glycol	-	153	168
Absorbers amine	-	107	120
Fractionators	134	165	183

$$D = \sqrt{\frac{Q}{(0.7854)\vartheta_m}}$$

- D = inside diameter of the column in meters,
- Q = vapor flowrate at actual tray conditions (m3/h),
- This method was originally developed for bubble cap trays and gives a rough diameter value, especially for other types of trays.

- Koch-Glitsch diagram

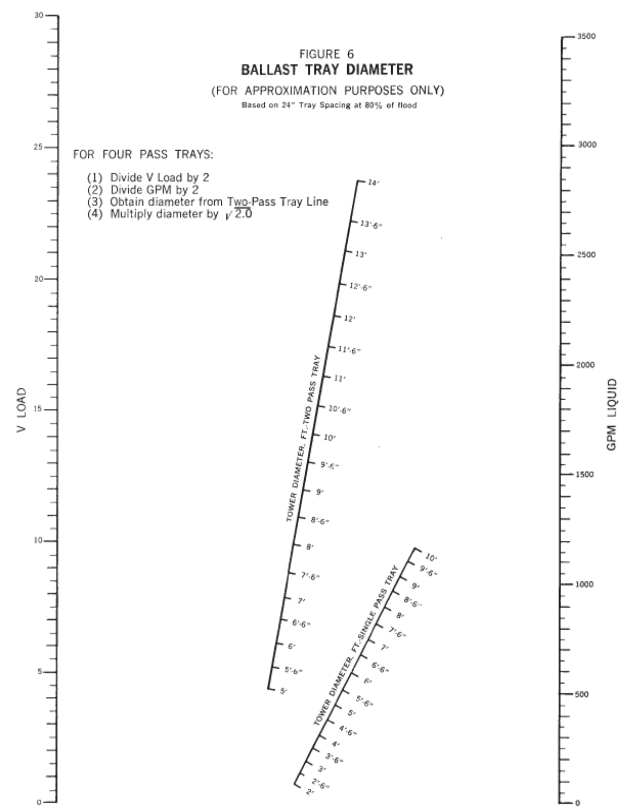
$$V_{load} = Q_v \sqrt{\frac{\rho_v}{\rho_l - \rho_v}}$$

Q_v = vapour flow rate (m^3/s),

ρ_l = liquid density at operating temperature and pressure of the tray (kg/m^3),

ρ_v = vapour density at operating temperature and pressure of the tray (kg/m^3),

V_{load} = vapour load (m^3/s) used in figure 13 (Glitsch nomograph for Ballast type valve tray).



Results for C-factor Method for T-5003

Tray Spacing	C	V-max	Diameter	V-Load	V-Liquid
600 mm	165	2156.8	7.67 m	2.12	10.54

2. Determine Flow Path Length

$$(FPL) = 0.75\,\frac{(DT)}{(NP)}$$

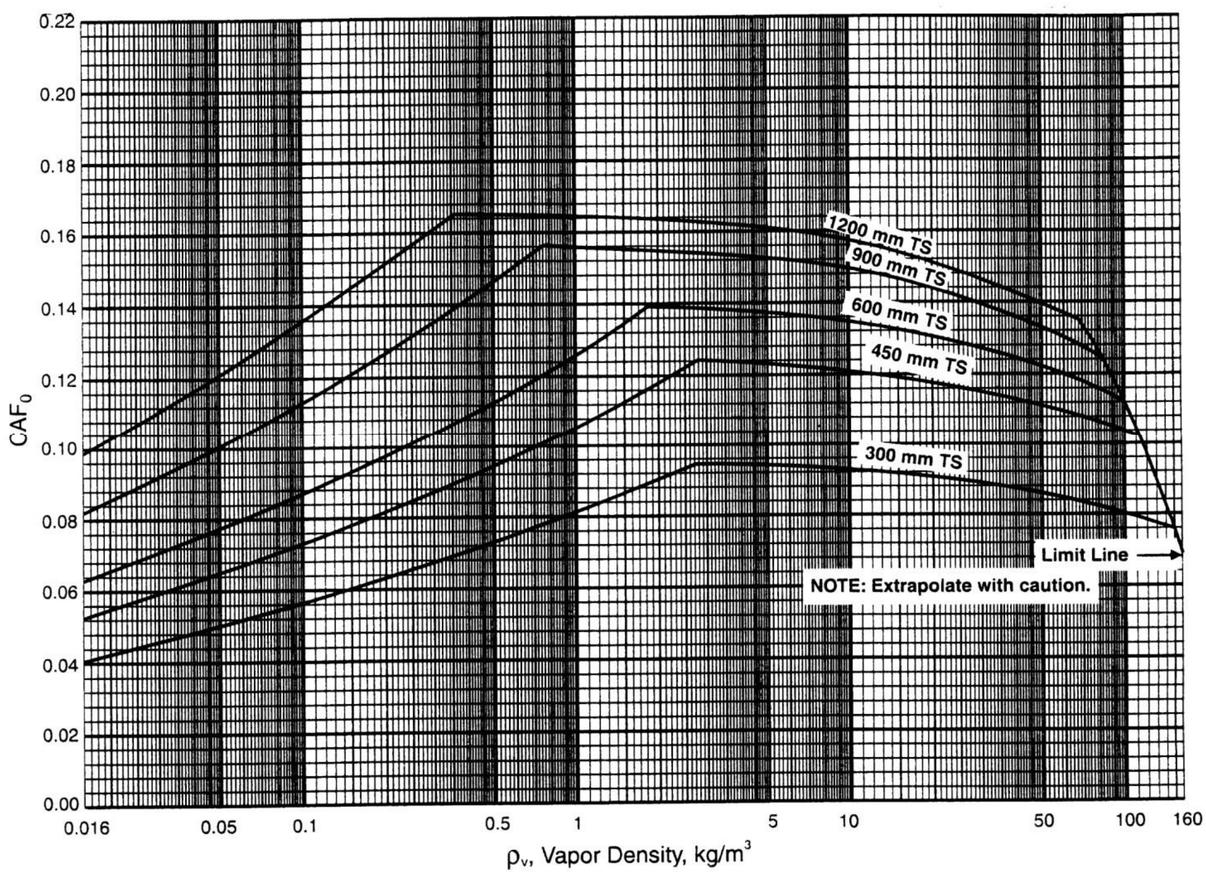
(FPL) = flow path length (m),
(DT) = internal diameter of the column (m),
(NP) = number of pass

3. Determination of Vapor Capacity Factor (CAF)

Figure 14 allows to determine the vapour capacity factor (CAFo) in meter per second, versus vapor density and tray spacing for nonfoaming fluids. For foaming fluids this vapour capacity factor must be corrected by the system factor value indicated in the table of figure 15.

$$(CAF) = (SF)\ (CAF_o)$$

(CAF) = vapour capacity factor (m/s),
(SF) = system factor (dimensionless),
(CAF_o) = vapour capacity factor for non foaming fluids (m/s)



Systems with foaming tendencies are taken into account by using a factor to derate the capacity of a given tray design. A list of the more common foaming systems and their recommended factor is below.

System	Factor
Absorbers (over -18°C)	0.85
Absorbers (below -18°C)	0.80
Amine Contactor	0.80
Vacuum Towers	0.85
Amine Stills (Amine Regenerator)	0.85
H_2S Stripper	0.85
Furfural Fractionator	0.85
Top Section of Absorbing Type Demethanizer/ Deethanizer	0.85
Glycol Contactors	0.50
Glycol Stills	0.65
CO_2 Absorber	0.80
CO_2 Regenerator	0.85
Caustic Wash	0.65
Caustic Regenerator, Foul Water, Sour Water Stripper	0.60
Alcohol Synthesis Absorber	0.35
Hot Carbonate Contactor	0.85
Hot Carbonate Regenerator	0.90
Oil Reclaimer	0.70

The capacity of a given tray design used in *high pressure fractionation service* with a vapor density of 28.8 kg/m^3 and higher should be derated by a system factor calculated by the following formula:

$$\text{System factor} = \frac{2.93}{(\rho_v)^{0.32}}$$

Results for FPL and CAF

FPL = 0.75 * 7.67 / 2 = 2.87

Note that 2 pass has been selected

CAF = CAF0 * SF = 0.14 * 1 = 0.14

Note that CAF0 is determined by Diagram on last page

3. Determination of the Downcomer Velocity (VDdsg)

The procedure used in this method for establishing downcomer area is based on a "design " velocity in meter per hour given by figure 16 for non-foaming fluid or by equation as follows:

$$(VD_{dsg}) = (0{,}909)\sqrt{(TS)}\,\sqrt{(\rho_l - \rho_v)}\,(SF) = (SF)\left(VD^*_{dsg}\right)$$

(VD_{dsg})	=	downcomer velocity (m/h),
(TS)	=	tray spacing (mm),
ρ_l	=	liquid density at operating temperature and operating pressure of the tray (kg/m^3),
ρ_v	=	vapour density at operating temperature and operating pressure of the tray (kg/m^3),
(SF)	=	system factor,
$\left(VD^*_{dsg}\right)$	=	downcomer velocity for non foaming fluids (m/h) (given by figure 16).

4. Determination of Active Area (AAM)

- The minimum active area is a function of vapor and liquid loads, system properties, flood factor and flow path length.
- The flood factor (FF) is used in certain equations for purpose of estimating column size. It is the “design percent of flood" expressed as a fraction.
- A value of not more than 0.77 is normally used for vacuum columns and a value not more than 0.82 is used for other services.
- For demethanisers and near critical point values, it is recommended to adopt a value in the range 0.6 to 0.7.
- These values are intended to give not more than approximately 10 % entrainment.
- Higher flood factors may result in excessive entrainment and/or a column sized too small for effective operation.
- Flood factor of 0.65 to 0.75 should be used for column diameters under 36" (90 cm).

- The minimum active area is determined with equation as follows:

$$(AAM) = \frac{V_{load} + (Q_L)(FPL)/44.14}{(CAF)(FF)}$$

(AAM)	=	minimum active area (m^2)
Q_L	=	actual liquid flow rate through the tray (m^3/min),
(FPL)	=	flow path length (m),
(CAF)	=	vapour capacity factor (m/s),
(FF)	=	flood factor (dimensionless) (usual value = 0.82),
V_{load}	=	vapour load of the tray (m^3/s).

5. Determination of the Downcomer area (ADM)

The minimum downcomer area is a function of liquid rate, downcomer design velocity and flood factor.

$$(ADM_m) = \frac{60 \times Q_L}{(VD_{dsg})(FF)}$$

Q_L	=	actual liquid flow rate through the tray (m^3/min),
VD_{dsg}	=	downcomer velocity calculate in 3th step (m/h),
FF	=	flood factor defined in 4th step (dimensionless),
(ADM_m)	=	minimum downcomer area (m^2).

If the downcomer area calculated by this equation is less than 11 % of the active area (AAM) adopt for (ADM) the smaller value of relations as follows:

$$(ADM) = (0.11)(AAM)$$
$$\text{or } (ADM) = 2\,(ADM_m)$$

Results for Vd and AAM

Vd	AAM	ADMm	ADMsel
598.6	24.45	1.28	2.57

Note that FF = 82%

Note that since ADMm is less than 11% AAM, 2.57 has been selected

6. Determination of the minimum inside diameter (DC) of the column

The approximate column cross sectional area is calculated by equations as follows:

$$(ATM) = (AAM) + 2\,(ADM)$$
$$\text{or}\ (ATM) = \frac{V_{load}}{(0.78)(CAF)(FF)}$$

The higher value is adopted.

Minimum inside diameter of the column (DC) in meters is calculated with relation:

$$(DC) = \sqrt{\frac{(ATM)}{0.7854}}$$

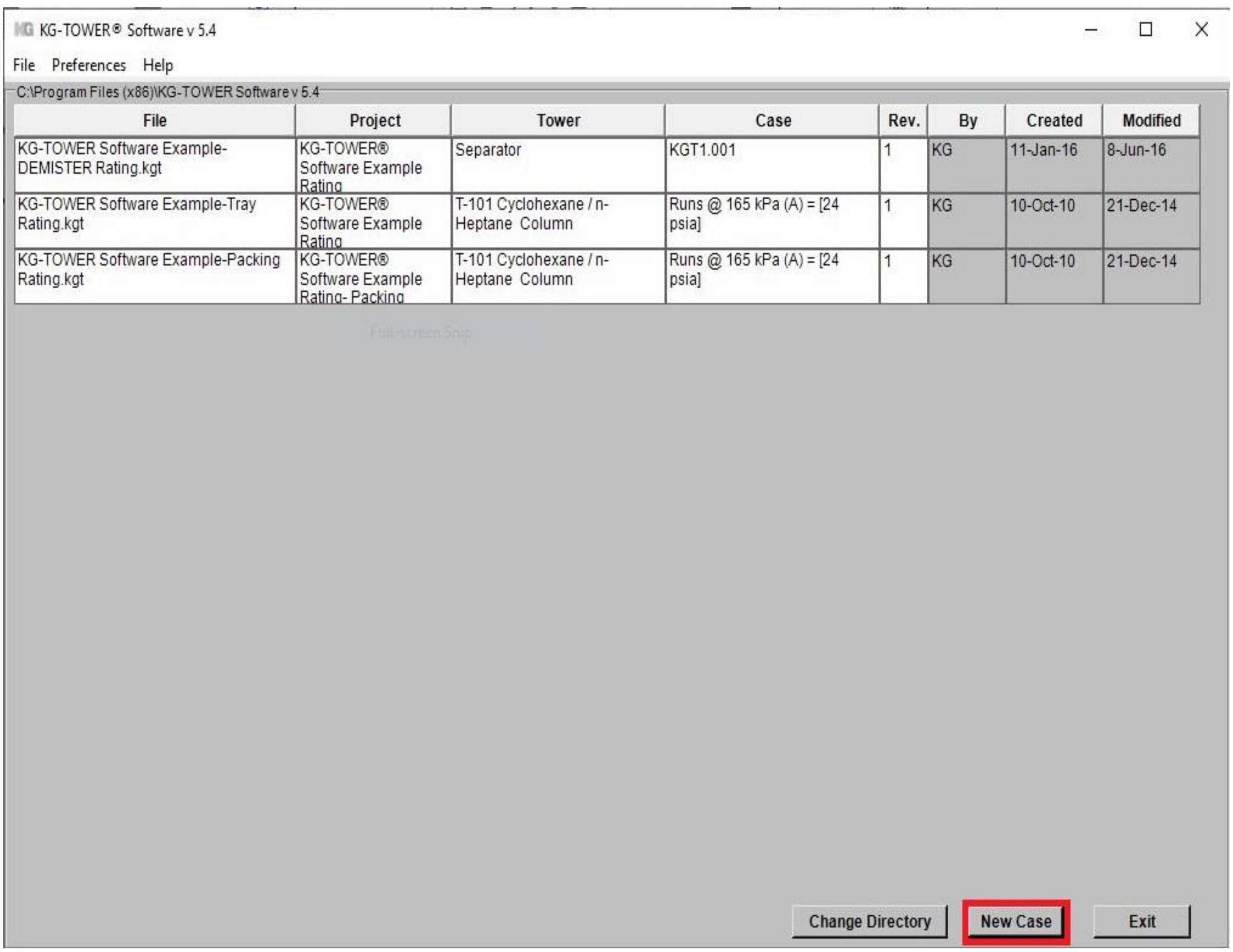
Results for calculated ATM and Tower Diameter

ATM	Diamater
29.61	6.15

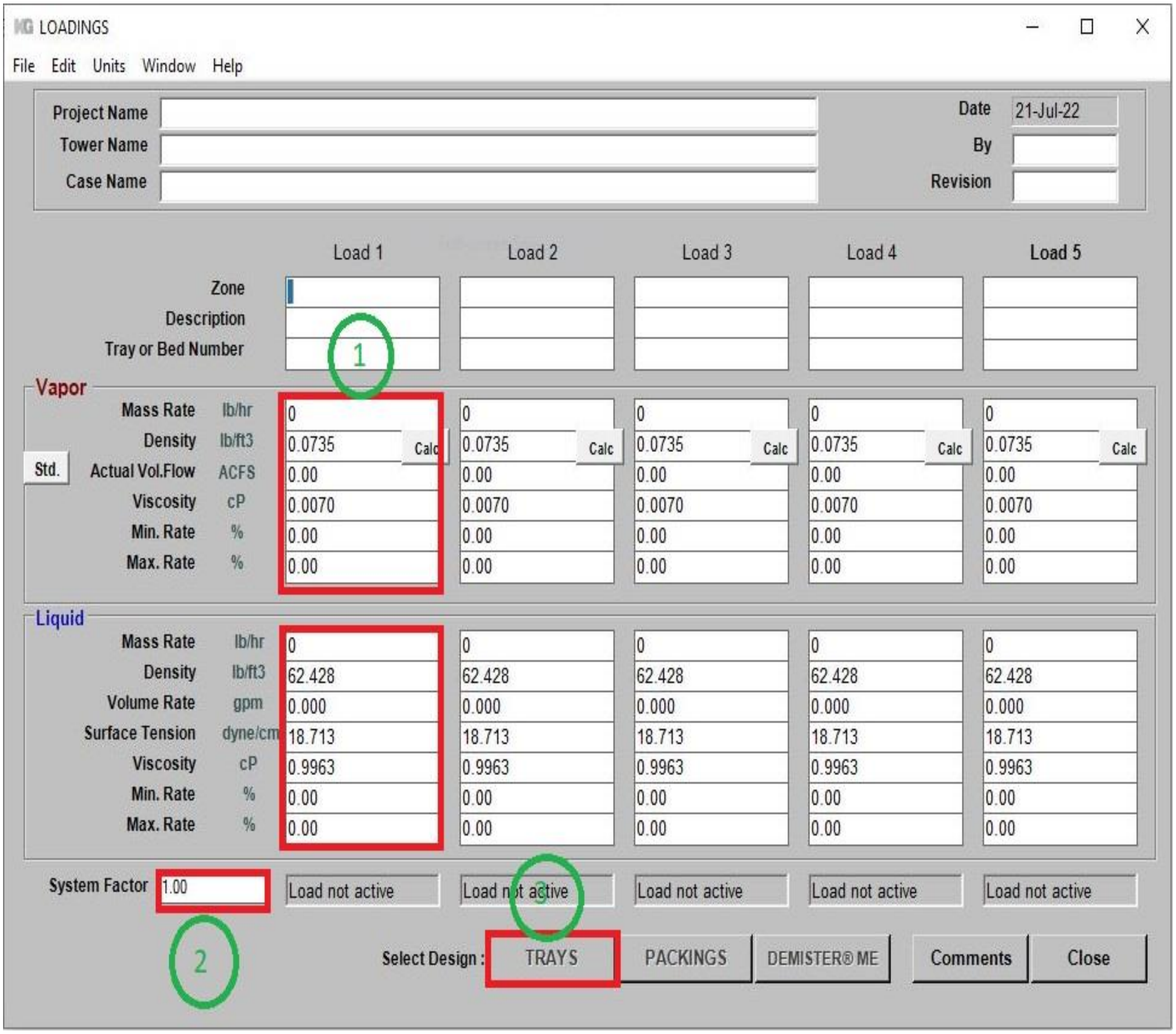
Note that 2 ATM are calculated and the higher one is selected

7. KG TOWER Confirmation

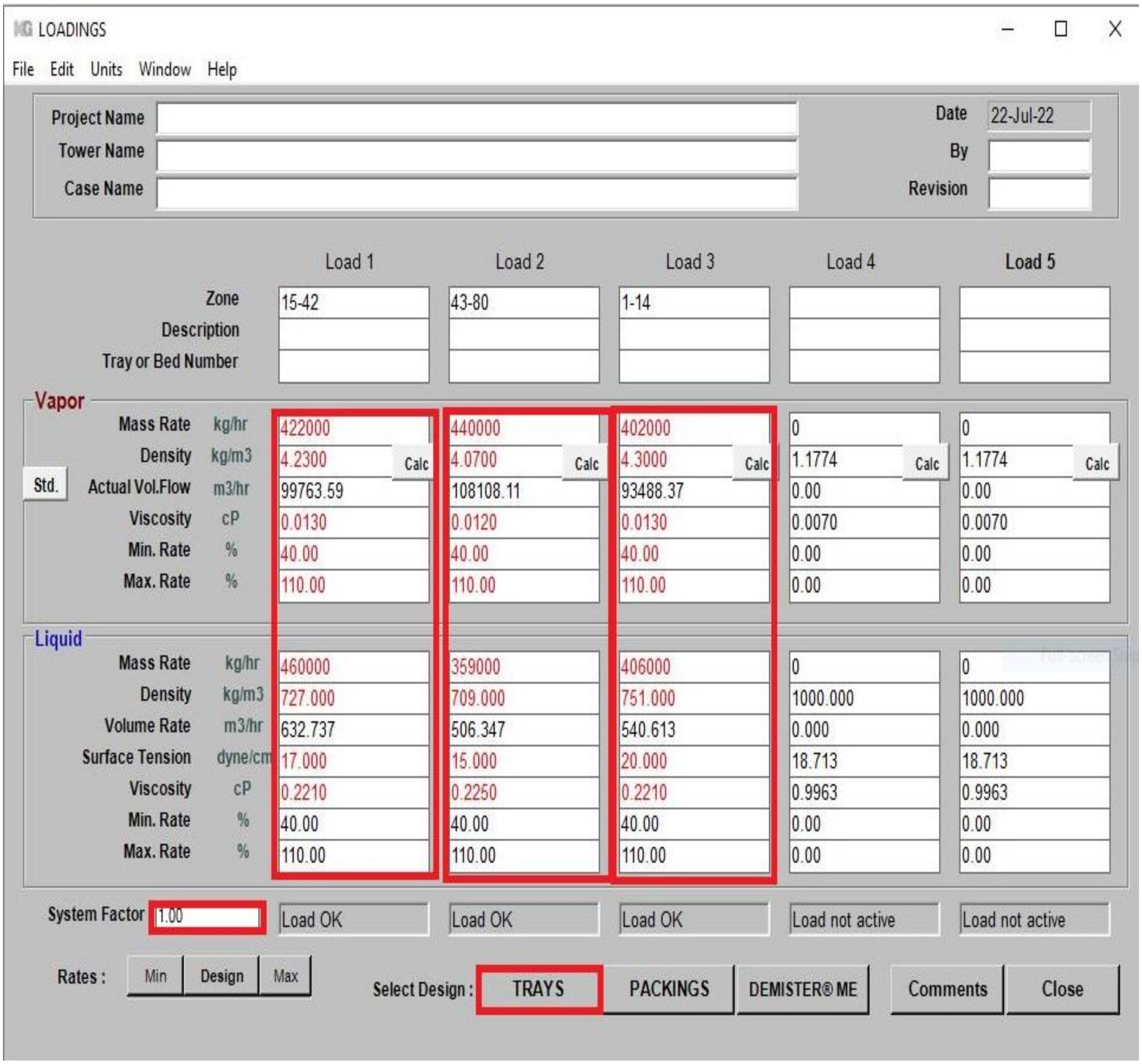
Open the software and select a new case



- Fill-up box 1 and 2 and then click ***Tray***



T-5003 Input



LOADINGS

File Edit Units Window Help

Project Name		Date	22-Jul-22
Tower Name		By	
Case Name		Revision	

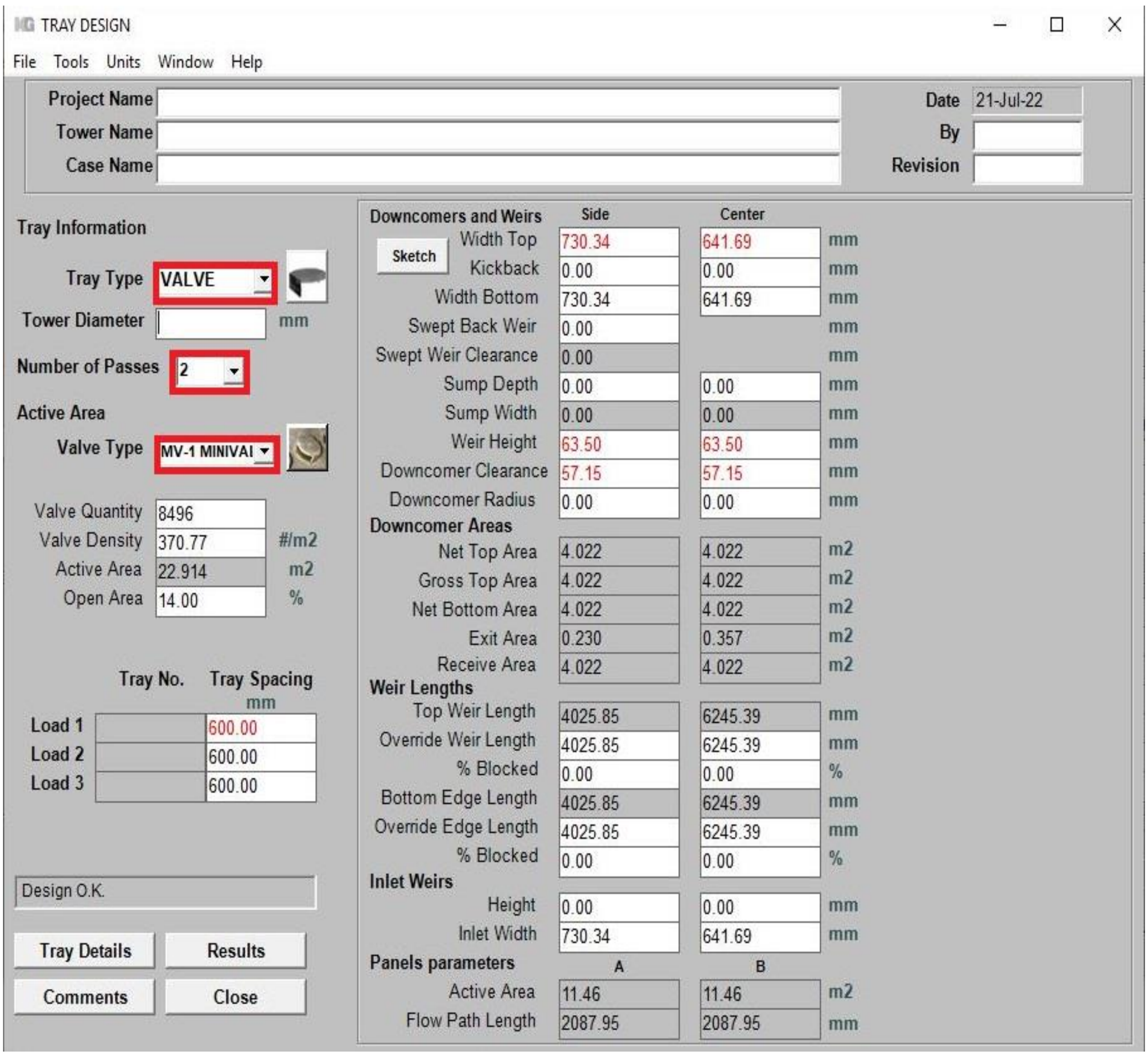
		Load 1	Load 2	Load 3	Load 4	Load 5
Zone		15-42	43-80	1-14		
Description						
Tray or Bed Number						
Vapor						
Mass Rate	kg/hr	422000	440000	402000	0	0
Density	kg/m3	4.2300	4.0700	4.3000	1.1774	1.1774
Actual Vol.Flow	m3/hr	99763.59	108108.11	93488.37	0.00	0.00
Viscosity	cP	0.0130	0.0120	0.0130	0.0070	0.0070
Min. Rate	%	40.00	40.00	40.00	0.00	0.00
Max. Rate	%	110.00	110.00	110.00	0.00	0.00
Liquid						
Mass Rate	kg/hr	460000	359000	406000	0	0
Density	kg/m3	727.000	709.000	751.000	1000.000	1000.000
Volume Rate	m3/hr	632.737	506.347	540.613	0.000	0.000
Surface Tension	dyne/cm	17.000	15.000	20.000	18.713	18.713
Viscosity	cP	0.2210	0.2250	0.2210	0.9963	0.9963
Min. Rate	%	40.00	40.00	40.00	0.00	0.00
Max. Rate	%	110.00	110.00	110.00	0.00	0.00
System Factor	1.00	Load OK	Load OK	Load OK	Load not active	Load not active

Std. Calc

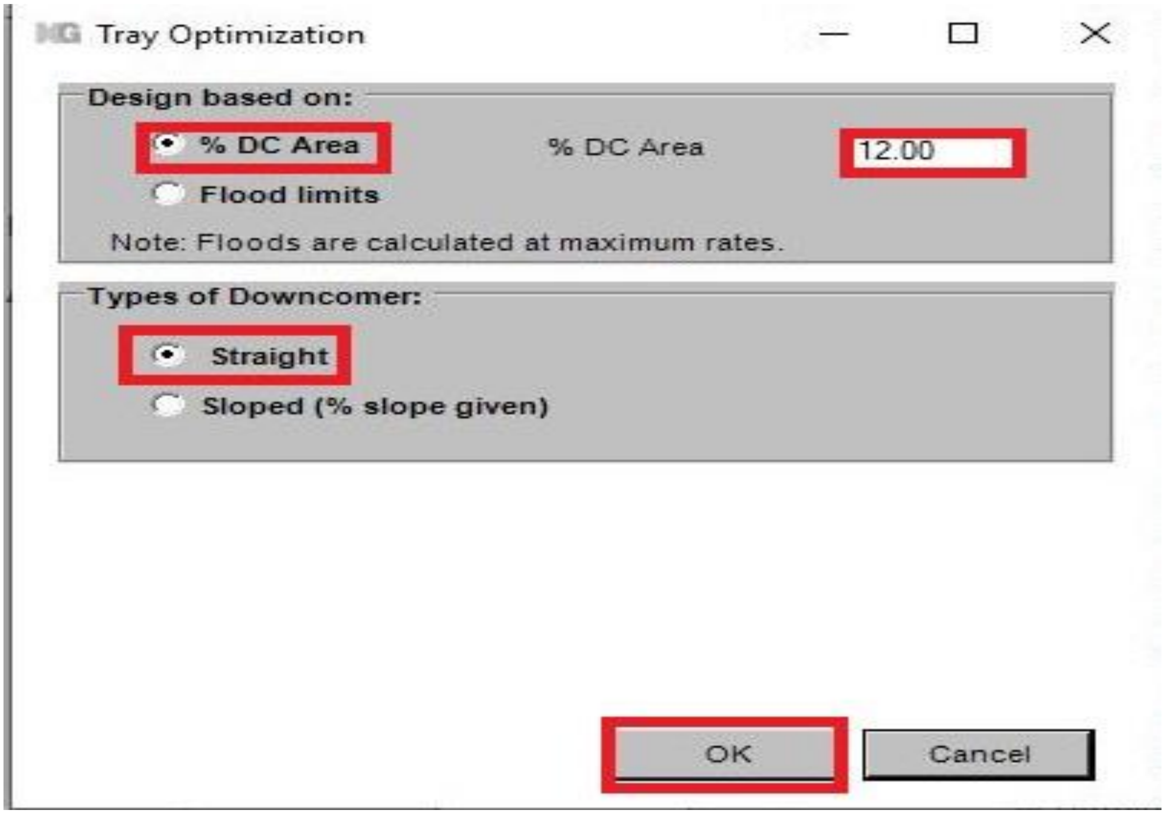
Rates : Min Design Max

Select Design : TRAYS PACKINGS DEMISTER® ME Comments Close

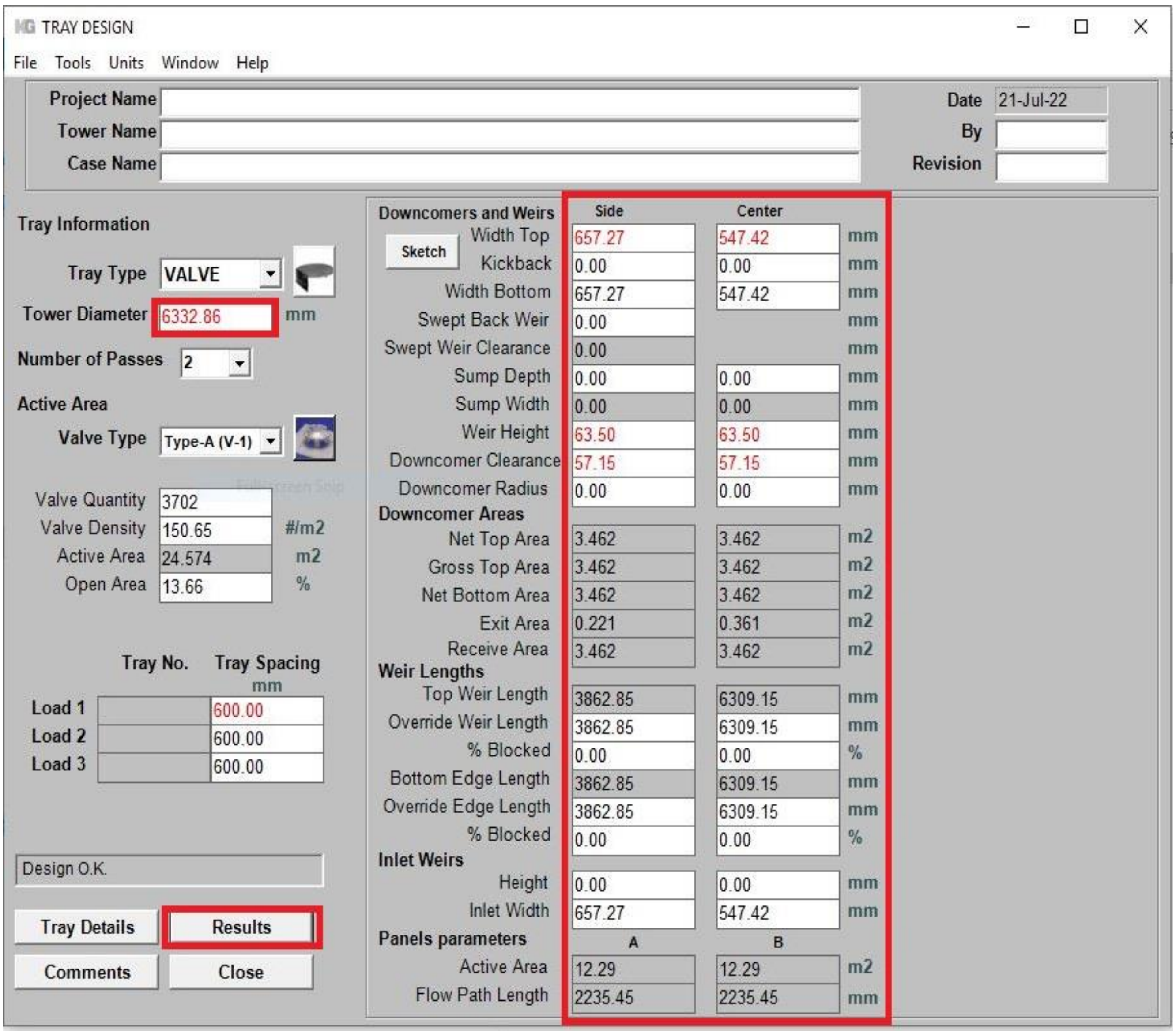
Fill-up tray type, number of passes and Koch valve type



Go to TOOL and select “Estimate Tower Diameter”



Check the Results



TRAY DESIGN

File Tools Units Window Help

Project Name		Date	21-Jul-22
Tower Name		By	
Case Name		Revision	

Tray Information

Tray Type	VALVE	
Tower Diameter	6332.86	mm
Number of Passes	2	

Active Area

Valve Type	Type-A (V-1)	
Valve Quantity	3702	
Valve Density	150.65	#/m2
Active Area	24.574	m2
Open Area	13.66	%

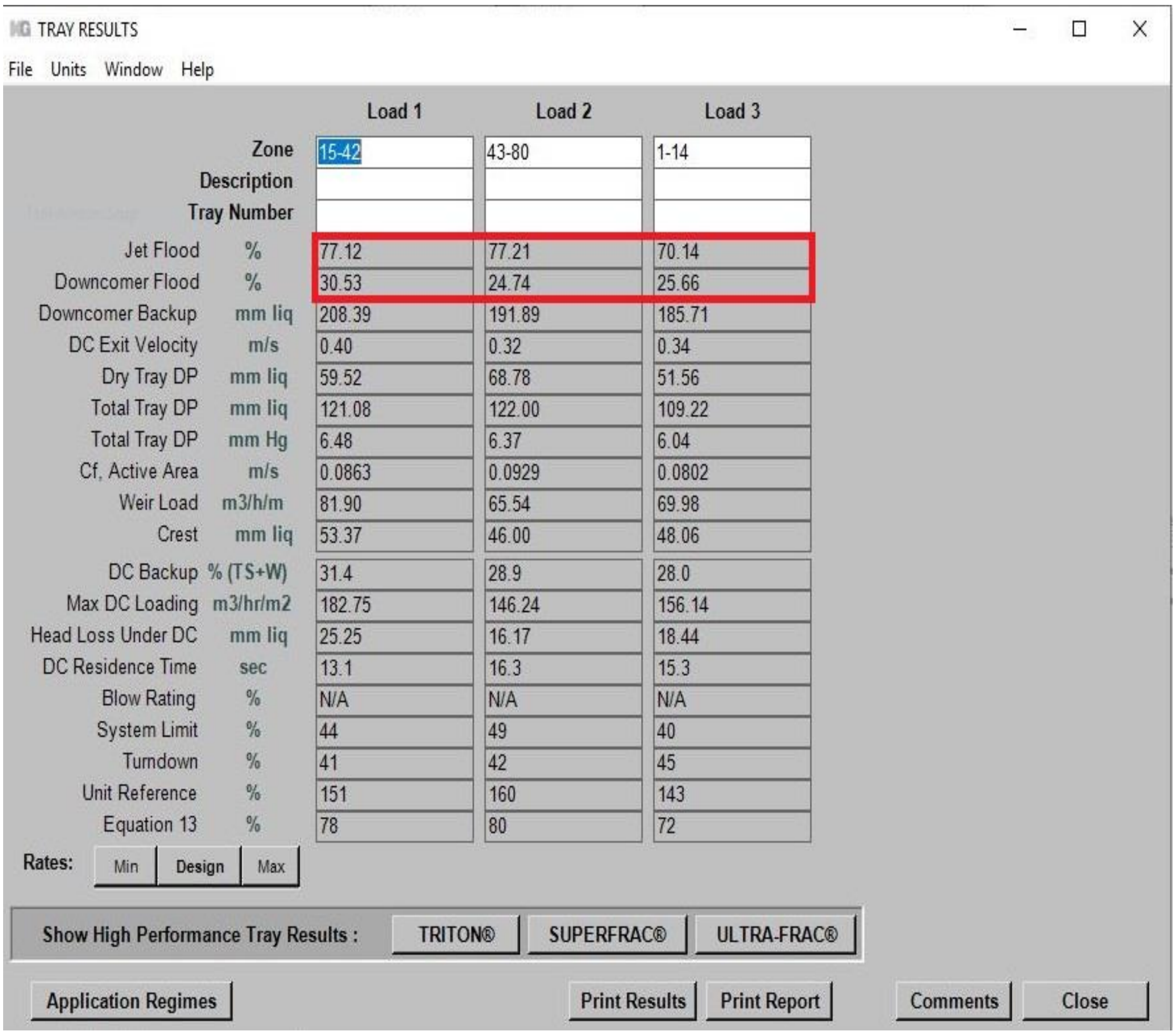
	Tray No.	Tray Spacing mm
Load 1		600.00
Load 2		600.00
Load 3		600.00

Design O.K.

Tray Details | Results | Comments | Close

Downcomers and Weirs	Side	Center	
Width Top	657.27	547.42	mm
Kickback	0.00	0.00	mm
Width Bottom	657.27	547.42	mm
Swept Back Weir	0.00		mm
Swept Weir Clearance	0.00		mm
Sump Depth	0.00	0.00	mm
Sump Width	0.00	0.00	mm
Weir Height	63.50	63.50	mm
Downcomer Clearance	57.15	57.15	mm
Downcomer Radius	0.00	0.00	mm
Downcomer Areas			
Net Top Area	3.462	3.462	m2
Gross Top Area	3.462	3.462	m2
Net Bottom Area	3.462	3.462	m2
Exit Area	0.221	0.361	m2
Receive Area	3.462	3.462	m2
Weir Lengths			
Top Weir Length	3862.85	6309.15	mm
Override Weir Length	3862.85	6309.15	mm
% Blocked	0.00	0.00	%
Bottom Edge Length	3862.85	6309.15	mm
Override Edge Length	3862.85	6309.15	mm
% Blocked	0.00	0.00	%
Inlet Weirs			
Height	0.00	0.00	mm
Inlet Width	657.27	547.42	mm
Panels parameters	A	B	
Active Area	12.29	12.29	m2
Flow Path Length	2235.45	2235.45	mm

Sketch



TRAY RESULTS

File Units Window Help

		Load 1	Load 2	Load 3
Zone		15-42	43-80	1-14
Description				
Tray Number				
Jet Flood	%	77.12	77.21	70.14
Downcomer Flood	%	30.53	24.74	25.66
Downcomer Backup	mm liq	208.39	191.89	185.71
DC Exit Velocity	m/s	0.40	0.32	0.34
Dry Tray DP	mm liq	59.52	68.78	51.56
Total Tray DP	mm liq	121.08	122.00	109.22
Total Tray DP	mm Hg	6.48	6.37	6.04
Cf, Active Area	m/s	0.0863	0.0929	0.0802
Weir Load	m3/h/m	81.90	65.54	69.98
Crest	mm liq	53.37	46.00	48.06
DC Backup	% (TS+W)	31.4	28.9	28.0
Max DC Loading	m3/hr/m2	182.75	146.24	156.14
Head Loss Under DC	mm liq	25.25	16.17	18.44
DC Residence Time	sec	13.1	16.3	15.3
Blow Rating	%	N/A	N/A	N/A
System Limit	%	44	49	40
Turndown	%	41	42	45
Unit Reference	%	151	160	143
Equation 13	%	78	80	72

Comparison

Haldor Topsoe	Koch-Glitsch Excell	KG Tower
6350 mm	6140 mm	6332 mm