KOCH-GLITSCH

INTRODUCTION TO KG-TOWER®

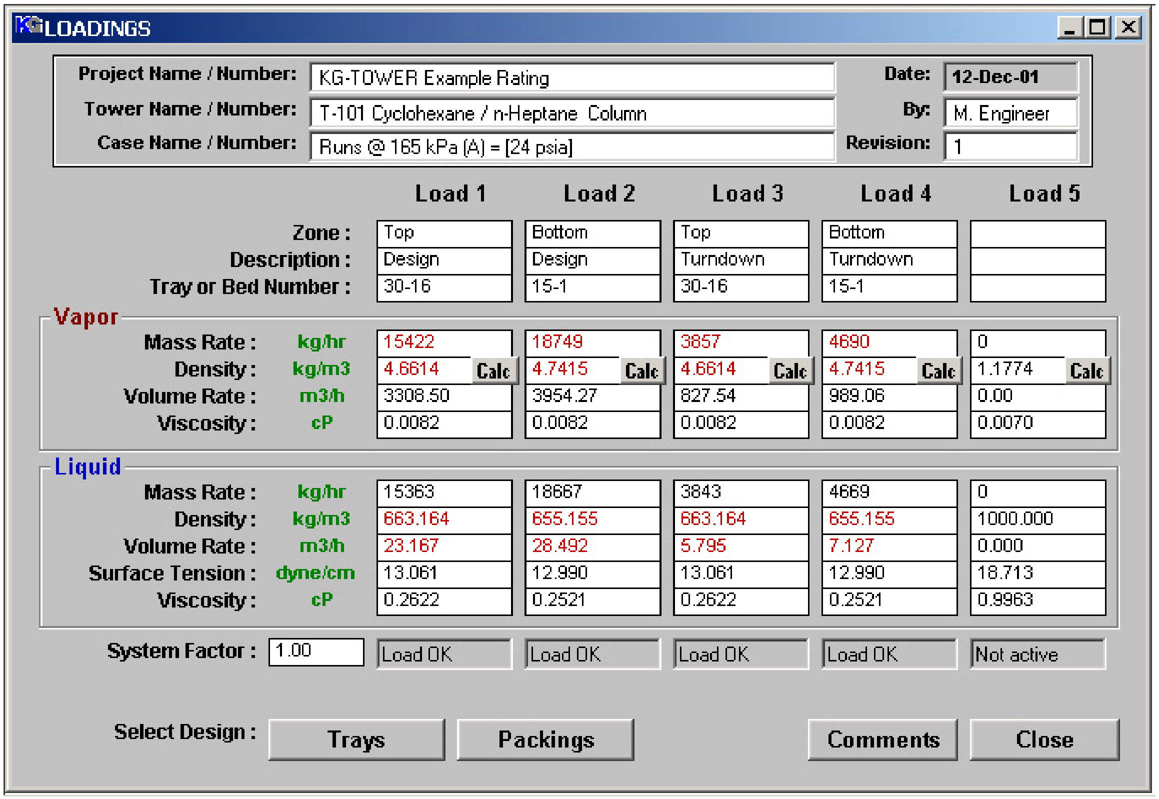
Tray & Packed Tower Sizing Software Program

Version 2.0

Visit our website at www.koch-glitsch.com

Rev 5
4/2006

LOADING INPUT SCREEN



1. *Vapor and Liquid Rates*: Enter internal vapor and liquid rates from process simulation output. Densities are required inputs. Enter either mass rates or volumetric rates and the other value will be calculated based on the density.

   If the gas density in not known, it can be estimated using the gas density calculation module by pressing the “Calc” button. Vapor viscosity, liquid viscosity, and liquid surface tension are optional inputs. The values tend to have a much greater impact on the packing hydraulic calculations than tray calculations and should be entered when known. If no value is entered, these values will be estimated using a correlation derived for hydrocarbon systems.

   The input units can be changed by using the “Units” menu. The loading conditions in each column can be copied, deleted, or scaled by using the “Edit” menu.

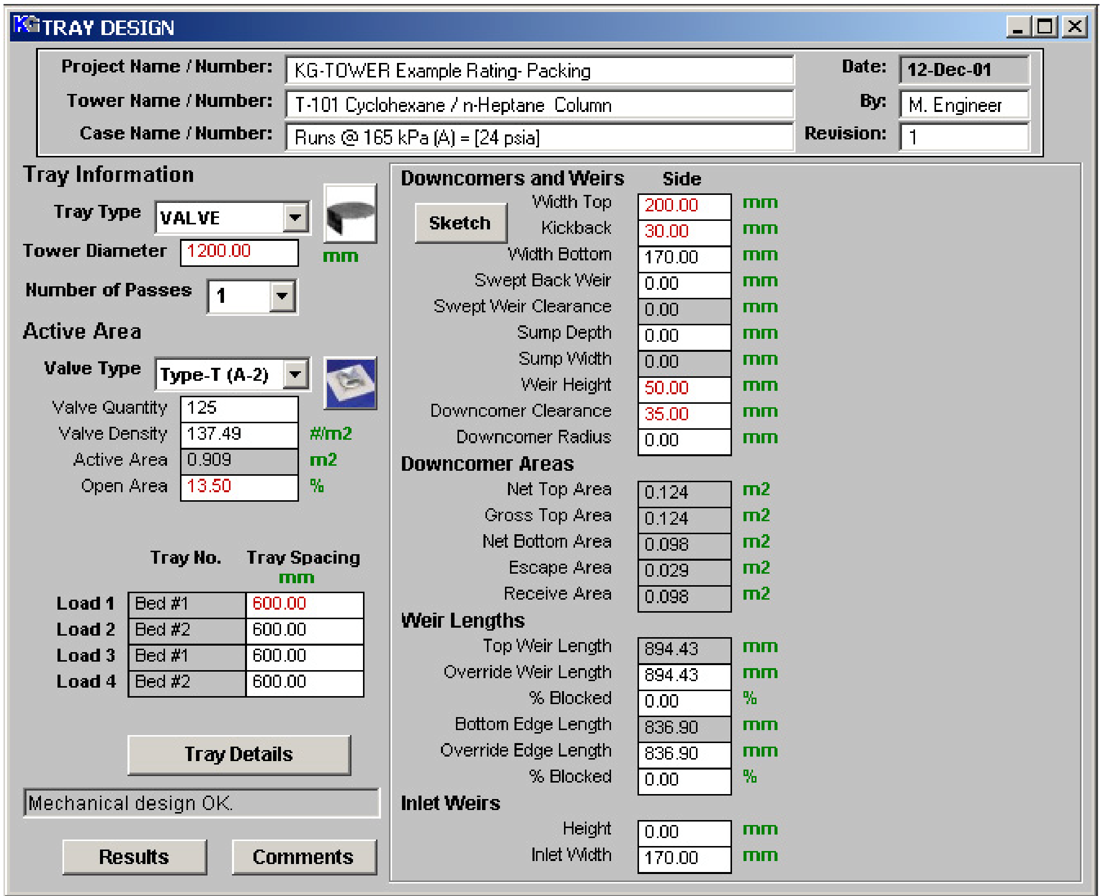
2. *System Factor*: Enter a system factor to derate the tray capacity ratings for foaming or other factors if necessary. For trayed columns, the system factor is used to derate both the jet flood and downcomer flood ratings.

   Severity of foaming can be dependent on a number of different factors and operating experience is the best method for determining the exact system factor for a particular system. Typical system factors used for trayed columns are shown in table 1. These same system factors may not be applicable for use in derating packed column capacity. Consult with your local Koch-Glitsch representative for assistance in selecting the appropriate derating factors for packed systems.

Table 1: Typical System Factors for Trayed Towers

SYSTEM	SYSTEM FACTOR
Absorbers (over 0^oF)	0.85
Absorbers (under 0^oF)	0.80
Amine Contactor	0.80
Vacuum Towers	0.85
Amine Stills (Amine Regenerator)	0.85
Furfural Fractionator	0.85
High Pressure Hydrocarbon Fractionators (Demethanizers & Deethanizers)	0.85
Glycol Contactors	0.60
Glycol Stills &Glycol Contactors in Glycol Synthesis Gas	0.65
$C0_2$ Absorber	0.80
$C0_2$ 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

TRAY DESIGN SCREEN



3. *Tray Type*: KG-TOWER software can be used to provide detailed calculations for Valve, Bi-FRAC®, or MAX-FRAC® trays. Selection of TRITON®, Nye, SUPERFRAC® or ULTRA-FRAC® trays will take the user directly to the Tray Results screen for a display of approximate jet flood and pressure drop parameters. Tray ratings of Koch-Glitsch's other high performance tray – the SUPERFLUX® tray – are not currently available in the KG-TOWER software.

   Proper tray selection can be complex. In many cases, there may be more than one tray type suitable for a particular application, thus making tray selection difficult for engineers who are not tray design experts. In such cases selection is often based on previous application experiences or ease of mechanical revamp. Consult with your local Koch-Glitsch representative if you need assistance with proper tray selection.

4. *Tower Diameter*: The column diameter input units can be set for feet, inches, millimeters or meters by selection of "Custom" under the "Units" pull-down menu.

   When sizing new columns, the tower diameter may be estimated using the tools menu. This will require some specification of the number of passes, tray spacing, and design flooding values.

   Caution should be used when rating tray columns with column diameters less than 2.5 ft [762 mm] as these trays may require special mechanical tray construction (cartridge / post supported trays with envelope downcomers) that may not be accurately accounted for using KG-TOWER software.

5. *Number of Passes*: Select one, two, three or four flow passes. The number of flow passes should be increased as required to provide the necessary liquid handling capacity. When sizing new columns, it is generally desirable to utilize the minimum number of flow passes necessary to meet the capacity requirements as this will result in the highest tray efficiency, greatest operating flexibility, and the lowest cost.

   In some cases, the column diameter may limit the number of flow passes practical in order to avoid the use of trays with very short flow path lengths or trays than can not be designed for man access through the trays.

   Table 2: Minimum Tower Diameter Required For Multipass Trays

No of Passes	Min Tower ID
2	5 ft [1524 mm]
3	8 ft [2438 mm]
4	10 ft [3048 mm]

6. *Valve Type* Select the valve type from the menu. A photo of each valve type can be obtained by clicking on the small photo next to the valve type.

   The type 'A' valve (equivalent to Glitsch V-1 BALLAST® Unit) is recommended for general purpose use. The VG-10 valve is the recommended conventional fixed valve. Its large size and net rise make it particularly suited for dirty or corrosive services. The VG-0 fixed MINIVALVE® valve and the PROVALVE® valve have been added since the previous version.

7. *Valve Quantity, Valve Density, and Open Area*: Enter either the number of valves per tray, the number of valves per square foot of active area, or the tray open area and the remaining two values will be calculated.

   For valve trays, the open area is defined as the smaller of either the horizontal hole area punched in the deck of the trays or the vertical slot/escape area from the valves. Tray open areas typically range from 5 to 14%.

   For VG-10 fixed valves, the slot height of the valve opening is variable and must be provided by the user (indicated as the net rise). A good starting point for the net rise of a VG-10 valve is 10 mm.

Table 3: Typical Valve Densities for Fully Valved Trays
Conventional Type A (V-1) and Type T Valves

Tower Diameter	Single Pass Valves/ft2 [Valves/m2]	Two Pass Valves/ft2 [Valves/m2]	Three & Four Pass Valves/ft2 [Valves/m2]
2.5 - 4.5 ft [762-1372 mm]	10.0 [108]	-	-
5 – 6 ft [1524 –1829 mm]	12.0 [129]	10.0 [108]	-
6.5 – 7.5 ft [1981-2286 mm]	13.5 [145]	12.0 [129]	-
8 – 10 ft [2438 –3048 mm]	14.0 [151]	13.0 [140]	-
10.5 – 12 ft [3200-3658 mm]	14.0 [151]	13.5 [145]	12.0 [129]
12 ft + [3658mm +]	14.0 [151]	14.0 [145]	12.0 [129]

8. *TRAY DETAILS*: The tray details button is used primarily to provide additional information on the valve units and valve layout. For most preliminary design purposes, the default values can be utilized to given adequate estimations of performance. These values may be provided for cases when more detailed design estimates are preferred or when rating existing tray designs.

   The details button includes specification of the valve leg length (or cage height), tray thickness, valve thickness, and valve material.

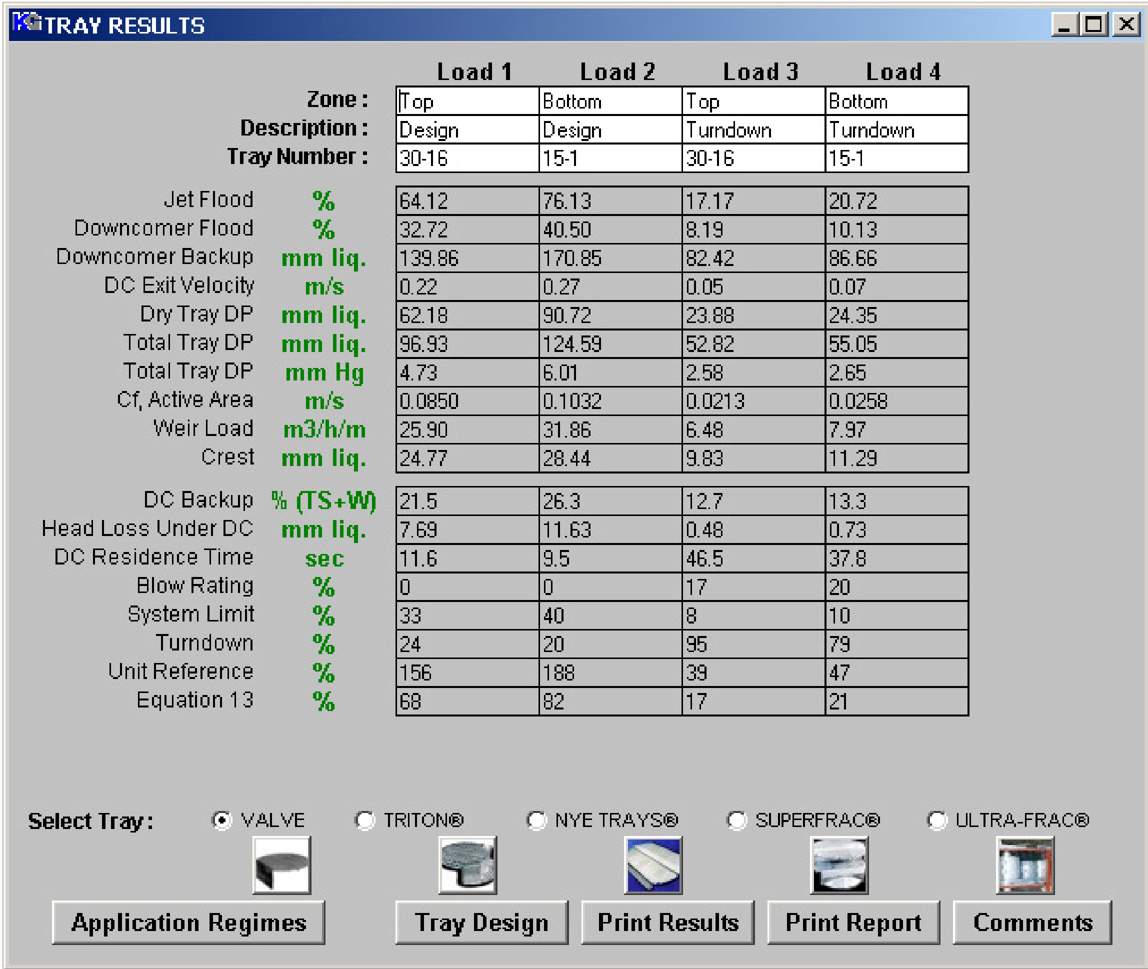
   Of the mechanical details inputs – manway ID, support ring width, and envelope width - are more critical when used in evaluating high performance tray designs.

9. *TRAY GEOMETRY:* Downcomer widths (top and bottom), weir heights, downcomer clearances, and tray spacings must be provided or estimated to complete the tray calculations. Additional tray features such as weir blocks (or picket fence weirs), swept back weirs, radius-tip downcomers, recessed inlet sumps, and inlet weirs are also supported with KG-TOWER software and may be input when applicable. For clarification on the meaning of these provided variables, select the ‘sketch’ button to see a pictorial view of these parameters.

   When sizing new columns, preliminary downcomer sizes can be estimated using the tools menu.

   Proper definition of tray geometry requires some experience to ensure that the design is not only optimized from the process standpoint, but also to ensure that it is mechanically feasible to convert the design on the computer into real metal (for example, is it possible to fit this number of valve units on the tray panels? Or, does this tray design have long enough flow paths to allow for tray manways?, etc). Several detailed tray design guidelines exist that are outside the scope of this training session. Consult your local Koch-Glitsch representative for detailed reviews and evaluations of equipment designs.

TRAY RESULTS SCREEN



		Load 1	Load 2	Load 3	Load 4
Zone:		Top	Bottom	Top	Bottom
Description:		Design	Design	Turndown	Turndown
Tray Number:		30-16	15-1	30-16	15-1
Jet Flood	%	64.12	76.13	17.17	20.72
Downcomer Flood	%	32.72	40.50	8.19	10.13
Downcomer Backup	mm liq.	139.86	170.85	82.42	86.66
DC Exit Velocity	m/s	0.22	0.27	0.05	0.07
Dry Tray DP	mm liq.	62.18	90.72	23.88	24.35
Total Tray DP	mm liq.	96.93	124.59	52.82	55.05
Total Tray DP	mm Hg	4.73	6.01	2.58	2.65
Cf, Active Area	m/s	0.0850	0.1032	0.0213	0.0258
Weir Load	m3/h/m	25.90	31.86	6.48	7.97
Crest	mm liq.	24.77	28.44	9.83	11.29
DC Backup	% (TS+W)	21.5	26.3	12.7	13.3
Head Loss Under DC	mm liq.	7.69	11.63	0.48	0.73
DC Residence Time	sec	11.6	9.5	46.5	37.8
Blow Rating	%	0	0	17	20
System Limit	%	33	40	8	10
Turndown	%	24	20	95	79
Unit Reference	%	156	188	39	47
Equation 13	%	68	82	17	21

9. *Jet Flood*: Jet flood rating should be limited to 85% of flood to avoid the possibility of flooding and/or inefficient operation. Increasing tower diameter, active area and/or tray spacing can be used to reduce the jet flood rating.

10. *Downcomer Flood*: Downcomer rating should be limited to 85% of flood. The downcomer rating is generally set by the size of the downcomer area at the top. For a well balanced tray design, the downcomer and jet flood ratings should be fairly equal.

11. *Downcomer Backup*: The clear liquid downcomer backup is reported in both inches of liquid and as a percentage of the tray spacing plus weir height. The clear liquid backup should be limited to 40% of the tray spacing plus weir height for normal services. For high pressure, light hydrocarbon distillation services, the clear liquid backup should be limited to 30-33% of the tray spacing plus weir height. The downcomer backup is dependent on the tray pressure drop and the clearance under the downcomer.

12. *DC Exit Velocity*: The downcomer exit velocity is the liquid velocity as it flows horizontally through the downcomer clearance. This value should be limited to 1.5 ft/sec [0.46 m/s] for conventional valve tray designs. The downcomer exit velocity is most easily adjusted by changing the downcomer clearance.

13. *Dry Tray DP*: The dry tray pressure drop is an intermediate term in calculating the total tray pressure drop that does not include the effect of the liquid head. It can be used to provide a relative indication of vapor velocity through the valves. A good starting point for many tray designs is a dry tray pressure drop of around 2 inches of hot liquid. As a rule of thumb, the dry tray pressure drop should be limited to 15% of the tray spacing when possible.

14. *Total Tray DP*: Many tray design methods do not set specific limits on the tray pressure drop; however, a tray typically reaches flood at a pressure drop of around 8-10 mm Hg per tray. The tray pressure drop is also a very key component to downcomer hydraulics due to its impact on downcomer backup.

    Note: Consistent with industry standards, the total tray pressure drop calculated by KG-TOWER software is comprised solely of the dry tray drop and the hydrostatic head of liquid that exists on the tray when liquid is flowing across it. The KG-TOWER software-calculated total tray pressure drop does not include the vapor static head in the operating column (i.e. the weight of the vapor is excluded from the calculation). Vapor static head must be estimated by process engineers responsible for the total distillation system including the heat exchangers. Vapor static head can have an appreciable impact on the pressure difference between the top and the bottom of a distillation column. For example, in a demethanizer with a vapor density of 5 lb/ft^3 and 24-inch tray spacings, the inclusion of the vapor static head can cause the calculated top-to-bottom pressure difference to double.

15. *Cf, Active Area*: C_f or capacity factor is a commonly used, density-corrected vapor velocity term on a per unit of active area basis.

16. *Weir Load*: The weir loading is generally used to determine the liquid loading of the tray. Although there is no specific design limit for weir loading, increased number of flow passes should be considered when the weir loading is greater than 100 – 120 gpm/ft [74.5 – 89.4 m^3/h/m] in order to provide increased tray capacity. Trays have been designed in some large-tray-spacing cases with weir loadings greater than 200 gpm/ft [149 m^3/h/m]; however, consultation with a Koch-Glitsch design engineer is recommended when designing trays for weir loadings greater than 140 gpm/ft [104.3 m^3/h/m].

    A minimum weir loading of 5 gpm/ft [3.7 m^3/h/m] is recommended at turndown. Picket fence outlet weirs (or "weir blocks") can be added to increase the weir loading by specifying an override to the calculated outlet weir length or specifying a percentage of the outlet weir to be blocked.

17. *Crest*: The crest is the theoretical height of clear liquid flowing over the outlet weir. It is important to remember that the liquid leaving the tray consists of drops, spray and slugs and not a measurable height of clear liquid as this term might suggest.
    The liquid crest is directly associated with the weir loading. A minimum liquid crest of 0.25 inches [6 mm] is recommended to ensure proper tray performance at low liquid rates.

18. *Head Loss Under DC*: The head loss under the downcomer is based on the downcomer clearance and the shape of the downcomer edge. Typically, the head loss should be designed somewhere between 0.06 to 1.0 inches [1.5 to 25 mm]. The head loss can be adjusted by changing the downcomer clearance or utilizing radius-tip downcomers.

19. *DC Residence Time*: The calculated residence time in the limiting downcomer is based on the liquid flow rate and the available volume of the downcomer. Downcomer residence time is not typically used by Koch-Glitsch to determine proper downcomer sizing; however, this parameter is used by some tray designers to size downcomers in foaming systems.

20. *Blow Rating*: The blow rating indicates the approach to a phase inversion condition, in which the liquid is blown into a fine spray (or "fluidized"), leaving the tray essentially dry (even though the spray is not necessarily carried to the tray above).
    The result is a loss of column efficiency due to gas bypassing and a shift in the limiting mass transfer resistance (from the gas side to the liquid side).

    The blow rating is only applicable to trays operating in the spray regime and thus is reported as zero for moderate to high liquid rate applications.

The blow rating should be held to a maximum of to 85% if possible. It can be reduced by increasing the number of valves, adding weir blocks, and/or raising the outlet weir height.

21. *System Limit*: The system limit represents an ultimate column capacity limit which can not be exceeded by changing the tray design or increasing the tray spacing. It occurs when there is substantial up-flow of liquid entrained relative to the total liquid flow and is a function of the droplet sizes created at a certain surface tension and the terminal velocities of the liquid droplets as determined by Stokes Law.

22. *Turndown*: The turndown is an approximation of the minimum vapor rate required for efficient tray activity (vapor and liquid contacting from movable valve units), expressed as a percent of the loads specified. This term applies only to moveable valves (not fixed valves) and is not to be confused with weepage .

    If possible, valve trays should be designed for a turndown percentage of at least 50% at design rates (allowing a 2:1 turndown from the design rates). For the minimum rate cases, the calculated turndown percentage should be less than or equal to 100%.

23. *Unit Reference*: Unit reference is the percentage of valves open at a given operating condition. This term serves a similar function of the turndown percentage (#24) and is applicable to only moving valve units. The suggested minimum unit references are given in table 4.

Table 4: Recommended Minimum Unit Reference

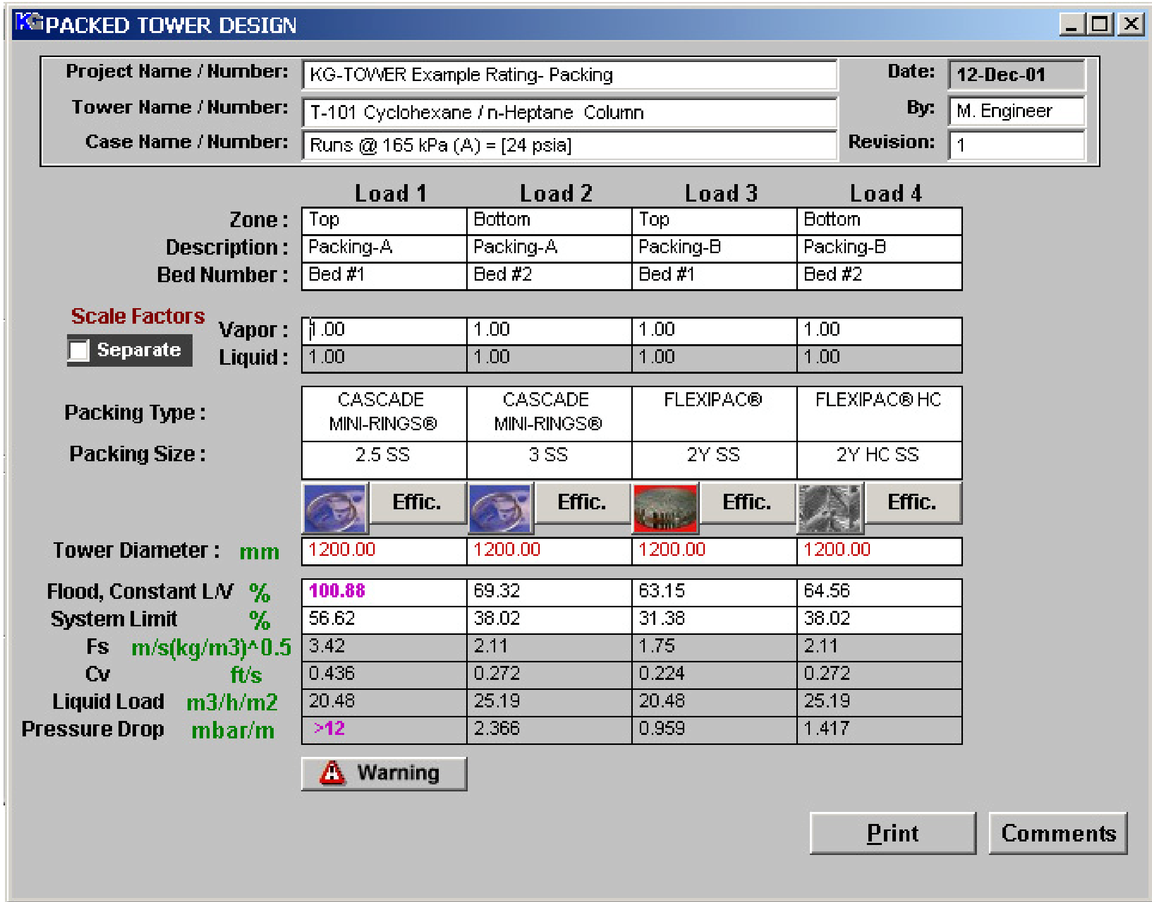
Number of Flow Passes	Minimum Unit Reference
1	40
2	60
3	70
4	80

If the unit reference is less than the minimum recommended, the valve quantity should be reduced or consideration should be given to the use of two weights of valves.

26. *Equation 13*: Equation 13 is the conventional valve tray jet flood capacity model from Glitsch Bulletin 4900. It is reported as a convenience to those users that are familiar with this popular flooding model.

KG-TOWER® Software

PACKED TOWER DESIGN SCREEN



a. *Scale Factors*: Scale factors are used to provide quick adjustment of the vapor and liquid loadings. The vapor and liquid loads can be scaled independently by checking the 'separate' scale factor box.

b. *Packing Type*: Select from a range of Koch-Glitsch random, structured, or grid packings. The full line of Norton packings are not yet available in the program although more have been added since Version 1.0.

c. *Tower Diameter*: Input the inside diameter of the column. It is important to account for any lining, clad, or wall thickness – especially when rating very small packed columns.

When sizing a new column, it is also possible to enter the desired packing flood capacity and have the program calculate the required column diameter (for a given packing size).

d. *Flood, Constant L/V%*: The calculated percentage of flood (based on a constant liquid/vapor ratio) should be limited to 80% for most cases. For those systems where the liquid rate is held constant, the flooding percentage may be reported on a constant liquid rate basis by selecting 'flooding limit' under the options menu.

e. *Fs, Cv, and Liquid Load*: These terms are used to provide a relative indication of the vapor and liquid loads in the tower. These are based on the total cross sectional area of the tower. No general design guidelines exists for these parameters; however, some specific guidelines are used for certain packings and/or for specific applications based on commercial experience.

f. *Pressure Drop*: The packing pressure drop is expressed per unit of vertical distance (feet or meter) of packing height. Again, packing and application specific guidelines are used to determine minimum and maximum acceptable pressure drop limits.

Please note that the pressure drop in packed towers should also take into account the pressure drop across the packed bed internals (distributors, collectors, etc) which are not accounted for in the packing pressure drop. In addition, the packing pressure does not include the vapor static head of vapor (see item #15 under tray hydraulic calculations for additional details).

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