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DESIGN OF MULTIPASS

FRACTIONATING TRAYS

BY

PAUL W. BECKER

A THESIS

PRESENTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE

WITH A MAJOR IN

CHEMICAL ENGINEERING

AT

NEWARK COLLEGE OF ENGINEERING

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Newark, New Jersey

May, 1974

ABSTRACT

Multipass fractionating trays are vapor-liquid contacting devices with high liquid handling capabilities which can be economically used in large fractionating towers. However, process design engineers in the chemical and petroleum industries seem to have an aversion to specifying multipass trays for their tower designs. This thesis presents the case for using multipass trays as well as methods for their design.

Because multipass trays are not symmetrical, as one and two pass trays are, the liquid and vapor need not split equally between the three or four passes. Equations are developed which enable the vapor and liquid flowrate for each pass to be determined. A computer program is presented which is capable of either rating existing multipass trays or designing multipass trays for new services. Also, techniques for the optimum design of multipass trays are suggested.

The present energy shortage has provided strong incentive to build larger refineries, which means larger capacity fractionation towers are required. This thesis demonstrates how the use of multipass trays can reduce investment costs for these large towers.

The use of the tools presented in this thesis enable process engineers to design multipass trays without relying on the proprietary techniques and programs of others, not readily available to them. It is hoped that this will enable multipass trays to be specified whenever they are economically justified.

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APPROVAL OF THESIS

DESIGN OF MULTIPASS

FRACTIONATING TRAYS

BY

PAUL W. BECKER

FOR

DEPARTMENT OF CHEMICAL ENGINEERING

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CHAPTER I

INTRODUCTION

What is a Multipass Tray?

Fractionating columns in the chemical and petroleum industries generally utilize perforated metal trays as the contacting devices. These sieve trays facilitate the countercurrent contacting of vapor and liquid. Liquid flows across the tray and contacts the vapor which is bubbling through the perforations. The liquid passes downward from tray to tray via downcomers.

The most common and simplest type of crossflow tray is the single pass tray. On a single pass tray, the liquid travels in only one path, and there is only one contacting or bubble area on each tray. There is also only one downcomer leaving each tray.

Another common type of crossflow tray is the two pass tray. On this type of tray, there are two different paths in which liquid may flow, as well as two distinct bubble areas. Half of the trays have a single center downcomer while every other tray has two outboard downcomers.

Multipass trays, while not used very often, have distinct advantages over single or two pass trays. Multipass trays generally have three or four passes, although five pass trays have at least been considered (1). Three and four pass trays have three or four different liquid paths and distinct bubble areas on each tray. A three pass tray

has two downcomers on each tray: one outboard and one off-center. Half of the four pass trays have two downcomers - both off-center. Every other tray has three downcomers: two outboard and one center.

The liquid and vapor flow patterns on all four types of trays are depicted in Figure 1.

Advantages of Multipass Tray Design

The use of multipass trays becomes economically attractive for large towers. A tower's vapor handling capacity increases proportionately to the tower cross sectional area. Therefore, vapor capacity is proportional to the square of the diameter. However, a tower's liquid handling capacity is proportional to the weir length over which the liquid flows on each tray. Therefore, for a one pass tray, the liquid handling capacity is linearly proportional to the tower diameter.

By increasing the number of passes, the weir length per tray is increased. Therefore, a two pass tray will have almost twice the liquid handling capacity of a one pass tray; a three pass tray will have almost three times the liquid handling capacity; and so on. Therefore, using multiple passes helps the liquid capacity increase as rapidly as the vapor capacity.

For example, a 20 foot diameter tower has roughly four times the vapor capacity of a 10 foot diameter tower. However, if both towers are single pass, the 20 foot diameter tower has only twice the liquid capacity. If the 20 foot tower is made two pass, then it will be able



•



Three Pass





Four Pass

Figure 1 LIQUID AND VAPOR FLOW PATTERNS ON TRAYS

to handle four times the liquid rate, and four times the vapor rate. If the 10 foot tower was already two pass, then the 20 foot tower would have to be four pass in order to handle four times the vapor and liquid. In such a case, if multipass trays are not used, tower diameter would have to be increased to handle the liquid loading, although it would not be necessary to handle the vapor loading.

Another reason for going to multipass trays is that several capacity correlations indicate that <u>vapor</u> capacity is also dependent on the weir length available for liquid flow (7). The explanation for this is that with a larger weir length, the froth height on a tray is lower. This permits more space for vapor disengaging above the tray, and therefore increased vapor capacity. Because increasing the number of liquid passes decreases the liquid height on each tray, it also decreases the tray pressure drop. This, in turn, decreases the liquid backup in the downcomer. Therefore, multipass trays also provide for designs with lower tray spacings.

The one disadvantage to a multipass tray is that it has a shorter flowpath in which the liquid travels on each tray. There is some evidence that shorter flowpaths reduce tray efficiency (4). But most tray efficiency correlations do not take liquid flowpath into account (8), and it is doubtful that this has much of an effect on large diameter towers, which have large flowpath lengths regardless of the number of liquid passes.

Why Multipass Trays Are Important

The previous section has demonstrated how multipass trays are economically attractive for large towers. With the present energy shortage and the world need for economic expansion of petroleum capacity, there is a strong incentive to build larger and larger refineries. Since single train plants are the most economical, larger capacity fractionating towers are required. For example, atmospheric crude distillation towers in large refineries can be over 30 feet in diameter. With the use of multipass trays, these towers can be designed with smaller diameters, and, therefore, at lower cost.

Another attractive use of multipass trays is in superfractionators. These are towers used to separate close boiling mixtures into high purity components. Some examples are propane/propylene splitters and ethane/ethylene splitters. These difficult separations require a high reflux rate, or liquid loading, and a large number of trays, and, therefore, a larger diameter and a high tower height. In fact, depending on the plant's location and local height restrictions (e.g. if it is near an airport), the tower may have to be split into two shells. Because, as mentioned in the previous section, multipass trays can decrease tower height and diameter, tower investment for superfractionators can be reduced.

Another reason the use of multipass trays is economically attractive is that it can eliminate the need for special, high cost fractionating devices in some cases. Proprietary devices have been

developed for use especially in heavily liquid loaded services, such as high pressure light ends towers and absorbers and strippers. These devices are marketed at premium prices because they are patented. In some cases, conventional sieve trays designed for three or four liquid passes may have liquid handling capabilities comparable to such proprietary devices. Because the sieve tray is non-proprietary, no premiums need be paid for patented technology.

What Has Been Done So Far?

It has been noted that, "There seems to be an aversion in the industry to using multipass trays (4).". This is probably because engineers do not know how to design them. The main problem is that unlike one or two pass trays, multipass trays are not absolutely symmetrical. This makes engineers worry about the hydraulic performance of multipass trays, since the liquid and vapor will not necessarily split into three or four <u>equal</u> parts to travel through each of the passes. Therefore, the design of multipass trays requires a little more work (which may be the real reason engineers shy away from such designs).

Actually, engineers who do not work for a tray vendor have no instructional manual in the design of multipass trays. An investigation of the literature has shown no articles or texts which show <u>how to</u> design multipass trays, although Jamison (4) does make some suggestions, and some tray vendors' manuals do give methods of setting up designs (1). However, most tray vendors consider their detailed design techniques

proprietary, and, therefore, do not make them publicly available.

The main drawback to engineers designing multipass trays is that there is no publicly available program for either rating or designing multipass trays. Tray vendors do have their own proprietary programs which utilize their own special design techniques. But there are various methods of designing multipass trays, and, therefore, each vendor's program uses their own technique.

The purpose of this thesis is to present the various methods of designing three and four pass sieve trays, with the appropriate design equations required. In addition, a computer program is presented for the rating of existing multipass trays and for the design of new multipass trays. This program utilizes publicly available correlations for capacity and pressure drop. These equations can be replaced with the user's own proprietary correlations if he wishes. The remainder of this thesis describes the development of these design methods and the program.

A photograph of a four pass tray is shown in Figure 2.

Although the methodology presented in this thesis can be applied to single and double pass trays, their design is not elaborated on in this work. The design of such trays is common knowledge to most process engineers.



FIGURE 2

Photograph of Four Pass Tray. Courtesy of F.W. Glitsch & Sons, Inc.

CHAPTER II

METHODS OF DESIGNING MULTIPASS TRAYS

Background: One and Two Pass Trays

The design of one and two pass trays for fractionating columns is relatively straightforward. Nearly every chemical process design engineer in the petroleum and chemical industries has done at least one such design. Figures 3 and 4 depict the liquid and vapor flow patterns and pressure drop equations for one and two pass trays, respectively.

On a single pass tray, there is only one path or bubble area for the liquid and the vapor to travel from tray to tray. The vapor rate on the single pass obviously equals the total vapor rate, and the liquid rate on the single tray pass obviously equals the total liquid rate.

On a two pass tray, both the vapor and liquid have a choice of two paths to take in traveling from tray to tray. But as can be seen in Figure 4, a two pass tray is completely symmetrical. The vapor and liquid have no preference as to which path to travel and consequently split equally into the two paths.

The only way the fluids will not split equally is if something such as improper shop fabrication upsets the symmetry of the trays. For example, if there are more perforations on one side of the tray than the other, the vapor will preferentially travel through this side. Since the total tray pressure drop across each side of the tray <u>must</u> be equal, the liquid will preferentially travel across the other side. However,







because two pass trays are always designed symmetrically, an unequal split can only occur as a result of holes plugging or improper field construction or shop fabrication.

In determining the vapor and liquid splits on a two pass tray, the four unknowns (V_A , V_B , L_A , L_B) are determined by the following four simple equations:

- (1) $V_A = V_B$
- (2) $V_A + V_B = V_{total}$
- (3) $L_A = L_B$
- (4) $L_A + L_B = L_{total}$

Where VX is the vapor rate in cubic feet per second for pass X, LX is the liquid rate in gallons per minute for pass X. The subscript total refers to rates for the entire tray. Knowing V_{total} and L_{total} , it is obvious that the flowrate through any given pass is equal to one-half the total flowrate.

Three and Four Pass Trays

The design of three and four pass trays, however, is not as straightforward. Although multipass trays are not symmetrical, there are enough equations to solve for the six unknowns in a three pass design, and the eight unknowns in a four pass design. These equations are presented in the next chapter.

There are several methods of setting up multipass tray designs. Because the liquid and vapor do not necessarily have symmetrical paths to choose from, the liquid and vapor do not split equally. That is, unless great care is taken in the design, the liquid and vapor flowrate for each pass of a three or four pass tray is not equal to one-third or one-fourth the total flowrate. In order to prevent possible vapor maldistribution from propogating itself, trays are often designed with passageways for vapor to travel from one pass to another.

The most common method of providing for such vapor crossover is to design the inboard or off-center downcomers (those which are not segmental) as envelope or box downcomers. This is depicted in Figure 5. These downcomers are of almost rectangular shape and are fabricated as two separate downcomers. A space is left between them through which vapor can cross over from one pass to another. If no provision for vapor crossover is desired, the downcomer extends across the entire tray with no separation.

Another method of providing for vapor crossover is to place a horizontal pipe or duct running across the downcomer through which vapor can travel. Jamison (4) has suggested this technique.

Through the use of vapor crossover, the pressure above any tray is equalized. Therefore, trays designed with vapor crossover have a different set of equations than trays designed without vapor crossover. Therefore, four sets of equations for determining liquid and vapor splits are presented in the next chapter: three and four pass trays, with and without vapor crossover.

There are two basic methods of laying out the plan view of three

Figure 5

DESIGN OF CENTER AND OFF-CENTER DOWNCOMERS WITH AND WITHOUT VAPOR CROSSOVER



and four pass trays. The first method consists of designing for equal liquid flow path lengths. That is, equal distances the liquid must travel in its course from downcomer to downcomer. The other method is to design for equal bubbling areas. That is, the perforated area in which vapor-liquid contacting takes place should be the same for each pass. Each of these methods has its own advantages and disadvantages. Neither is generally accepted as the "proper" method because some tray vendors design for equal flowpath length, while others design for equal bubbling areas.

Some vendors probably prefer the equal flowpath length method because it is easy to fabricate. All tray panels can be made of equal widths. Some also claim that since tray efficiency is dependent on flowpath length, such a design provides for equal tray efficiencies. The equal bubble area method is preferred by some because they can then attempt to design for equal liquid and vapor flowrates for each pass. Chapter VI of this thesis describes how the equal bubble area method can be used in the optimum design of multipass trays.

CHAPTER III

EQUATIONS FOR THREE AND FOUR PASS TRAYS

The liquid and vapor splits for a multipass tray are determined by various pressure drop equations. There are enough equations to solve for each of the unknown liquid and vapor flowrates on a multipass tray. Because vapor crossover affects the tray pressure drop relationships, a separate but related set of equations are necessary for tray designs with vapor crossover. The first section of this chapter presents the pressure drop equations for the four types of multipass tray designs (three and four pass, each with and without vapor crossover) which are necessary and sufficient to completely determine the liquid and vapor flowrates in each pass. The next section presents the derivation of the critical equations. Finally, it is shown that through the use of these equations, the calculated downcomer backup of a downcomer which is shared by two passes of a multipass tray, is indeed the same, regardless of which pass it is calculated for.

Equations For Determining Liquid and Vapor Splits

Three pass, no vapor crossover. The vapor and liquid flow patterns and pressure drops of a three pass tray are shown in Figure 6. The following six equations (Al to A6) can be used to determine the three vapor and liquid rates, one for each pass. The first three equations determine the liquid split, and the last three equations determine the vapor split.

THREE-PASS TRAY FLOW PATTERNS AND PRESSURE DROPS



- (A1) $L_A \rightarrow L_C$
- (A2) $HI_C + HDA_C HT_A = HI_B + HDA_B HT_B$
- (A3) $L_A + L_B + L_C = L_{total}$
- (A4) $V_A = V_C$
- (A5) $HT_A + HT_C = 2 \times HT_B$
- (A6) $V_A + V_B + V_C = V_{total}$

Where HIX is the inlet head on pass X, HDAX is the head loss under the downcomer for pass X, and HTX is the total tray pressure drop on pass X.

Three pass with vapor crossover. If provision is made for vapor to crossover through the off-center downcomer, equations (A4) and (A5) above can be replaced with the two equations below (B4 and B5). Note that equation (B5) is merely a simplification of equation (A5) knowing (B4) is true.

(B4) $HT_A = HT_B$

(B5) $HT_B = HT_C$ ($HT_A + HT_C = 2 \times HT_B$)

Four pass, no vapor crossover. The vapor and liquid flow patterns and pressure drops for a four pass tray are shown in Figure 7. The following eight equations (Cl to C8) can be used to determine the four liquid and vapor rates, one for each pass. The first four equations determine the liquid split, and the last four equations determine the vapor split.

- (C1) $L_A = L_C$
- (C2) $L_B = L_D$
- (C3) $HI_C + HDA_C HT_A = HI_D + HDA_D HT_B$



- (C4) $L_A + L_B + L_C = L_{total}$
- (C5) $V_{A} = V_{C}$
- (C6) $V_B = V_D$ (2 x V_A + 2 x $V_B = V_{total}$)
- (C7) $HT_A + HT_C = HT_B HT_D$
- (C8) $V_A + V_B + V_C + V_D = V_{total}$

Four pass with vapor crossover. If provision is made for vapor to crossover through the off-center and center downcomers, equations (D5) to (D8) below replace equations (C5) to (C8) above. Note that equation (D6) is merely a simplification of (C6) once (D5) is true. Also, note that (C6) is a simplification of (D6) once (C5) is true.

- (D5) $HT_A = HT_B$
- (D6) $HT_C = HT_D$ ($HT_A + HT_C = HT_B + HT_D$)
- (D7) $2 \times V_A + 2 \times V_B = V_{total}$
- (D8) $2 \times V_C + 2 \times V_D = V_{total}$

Derivation of Critical Pressure Drop Equations

Upon studying Figures 6 and 7, most of the equations presented above become obvious. However, the four pressure drop equations which determine the critical vapor and liquid splits (A2, A5, C3, C7) are derived below.

Equation (A2). The critical liquid split on a three pass tray occurs at the bottom of the off-center downcomer. The liquid will split such that the pressure drop it must overcome in each possible path is exactly equal. The pressure it must overcome is equal to the sum of the inlet head of liquid (HI) the head loss it undergoes in going through the area under the downcomer (HDA), and the pressure level in the chamber it is entering. Therefore,

(E1) $HI_C + HDA_C + P_A = HI_B + HDA_B + P_B$

Where Px is the pressure level above pass X.

The pressure level in the chamber (P_A, P_B) is equal to the pressure level below that chamber (P'_A, P'_B) minus the tray pressure drop through that pass (HT_A, HT_B). That is

(E2) $P_A = P'_A - HT_A$

(E3) $P_B = P'_B - HT_B$

Where P'_X is the pressure level below pass X. Substituting equations (E2) and (E3) into equation (E1),

(E4) $HI_C + HDA_C + P'_A - HT_A = HI_B + HDA_B + P'_B - HT_B$ Since the pressures P'A and P'_B are for the same chamber,

(E5) $P'_{A} = P'_{B}$

Therefore, substituting (E5) into (E4) gives equation (A2).

(A2) $HI_C + HDA_C - HT_A = HI_B + HDA_B - HT_B$

Equation (A5). For trays without vapor crossover, we must consider a pressure balance across two trays because for any one tray, one vapor flow chamber is completely closed off from the other chamber. The vapor from the chamber above pass C travels through the chamber above pass A before it returns to another chamber above another pass C. It cannot travel through the chamber above pass C, then through the chamber above pass B, because $V_A = V_C$ as defined by equation (A4). Therefore,

(F1) $HT_A + HT_C = HT_B + HT_B$

(A5) $HT_A + HT_C = 2 \times HT_B$

Equation (C3). As with the three pass tray, the critical liquid split occurs at the bottom of the off-center downcomer, and the same type of pressure balance is required:

(G1)
$$HI_C + HDA_C + P_A = HI_D + HDA_D + P_B$$

(G2) $P_A = P_A - HT_A$
(G3) $P_B = P_B - HT_B$
(G4) $HI_C + HDA_C + P_A - HT_A = HI_D + HDA_D + P_B - HT_B$
(G5) $P_A = P_B$
(C3) $HI_C + HDA_C - HT_A = HI_D + HDA_D - HT_B$

Equation (C7). As with the three pass tray, consider the pressure balance across two trays. Vapor from the chambers above passes C and D, must pass through the chambers above passes A and B respectively. Therefore,

(C7) $HT_A + HT_C = HT_B + HT_D$

Proofs That Shared Downcomers Have Equal Backups.

On multipass trays, liquid from two different passes can flow into a single shared downcomer. For example, liquid from passes B and C on a three pass tray share a common downcomer, as does liquid from passes C and D on a four pass tray. Because the liquid in these downcomers blend and actually form one column of liquid, the downcomer backup (the static head equal to the height of this column) must be the same regardless of which pass it is calculated for. That is, for a three pass tray, HDc must equal HD_B ; and for a four pass tray, HD_C must equal HD_D . This is proven below.

<u>Three pass.</u> By definition, the backup in a downcomer is equal to the sum of the total tray pressure drop (HT), plus the head loss under the downcomer (HDA), plus the inlet head (HI). Therefore,

(H1) $HDC_B = HT_B + HDA_B + HI_B$

(H2) $HDC_C = HT_C + HDA_C + HI_C$

Where HDC_X is the downcomer filling in the downcomer from pass X. For HDC_B to be equal to HDC_C , the following must hold,

(H3) $HDC_B - HDC_C = 0 = HT_B + HDA_B + HI_B - HT_C - HDA_C - HI_C$ Now from previous equations,

(A5) $HT_A + HT_C = 2 \times HT_B = HT_B + HT_B$

(H4) $HT_B - HT_C = HT_A - HT_B$

Substituting (H4) into (H3)

(H5) $0 = HT_A + HDA_B + HI_B - HT_B - HDA_C - HI_C$

Rearranging, this equation is the same as the identity of equation (A2),

(A2) $HI_C + HDA_C - HT_A = HI_C + HDA_B - HT_B$

Therefore, (H3) is true, and

(H6) $HDC_B = HDC_C$

Q.E.D.

Four pass. Following the logic used in the derivation for three passes above:

(11) $HDC_C = HT_C + HDA_C + HI_C$ (12) $HDC_D = HT_D + HDA_D + HI_D$ We will prove

(13) $HDC_C - HDC_D = 0 = HT_C + HDA_C + HI_C - HI_D - HDA_D - HI_D$ Using the following equations:

(C7) HTA + $HT_C = HT_B + HT_D$

(14) $HT_C - HT_D = HT_B - HTA$

(15) $O = HT_B - HT_A + HDA_C + HI_C - HDA_D - HI_D$

Now (I5) is the same as the identity (C3) rearranged. Therefore, (I3) is true, and

(16) $HDC_{C} \simeq HDC_{D}$

Q.E.D.

CHAPTER IV

COMPUTER PROGRAM FOR RATING AND DESIGNING MULTIPASS TRAYS

A computer program has been written to rate existing multipass trays and to design three and four pass trays for new services. This program uses the equations presented in the preceding chapter to determine the vapor and liquid loadings for each pass.

Equations Used to Rate Designs

In order to rate or design trays, equations are necessary for the various pressure drops required, as well as for tray capacity and efficiency. This section presents the equations used in this program. Most are published equations although the jet flood capacity equation is not from any single source but is contrived to represent known trends in tower capacity. The equations chosen are not intended to be recommended as the best possible equation available. It is expected that those interested in using this program will substitute some or all of these rating equations with their own proprietary rating equations.

Jet Flood. The jet flood point normally sets the maximum vapor capacity of a sieve tray. Jet flooding is the condition in which liquid entrained from one tray to the next by the vapor jets becomes excessive. Tower pressure drop increases significantly, and the tower may become filled with liquid. Tray efficiency decreases drastically.

Many tower capacity correlations predict the vapor velocity through the bubble area at which jet flooding occurs. This jet flood

point decreases as the liquid rate across the weir increases. This program calculates the percentage of the flood point at which the tray is operating for each pass. A desirable design is generally at about 85 percent of the flood point. This maximizes tower capacity without debiting tower efficiency due to excessive entrainment.

The following equation used in this program to calculate the jet flood point is not taken from any one source. It is a contrived equation based on known trends in tower capacity.

 (V_L/A_B) flood = HFACT1 x 0.55 - 0.035 (GPHFTWEIR/1000) where $V_L = CFS_V$ $\sqrt{\rho V/\rho_L - \rho_V}$ and HFACT1 = $\frac{H/24}{H/24}$

Where V_L is the vapor load in cubic feet per second, A_B is the bubble area, CFS_V is the vapor flowrate in cubic feet per second, ρ_V is the vapor density in pounds per cubic foot, ρ_L is the liquid density in pounds per cubic foot, H the tray spacing in inches, HFACTL is a tray spacing capacity factor, and GPHFTWEIR is the liquid weir loading in gallons per hour per foot of weir length.

Allowable downcomer inlet velocity. As the frothy liquid from the tray enters the downcomer, the froth disengages. The liquid goes down through the downcomer to the next lower tray while the vapor goes up through the vapor space to the next higher tray. There is an upper limit to the velocity at which the froth can enter the downcomer and successfully disengage without carrying vapor downward to be recycled to the tray below.
This allowable downcomer inlet velocity increases as the tray spacing increases. As the tray spacing or downcomer height increases, the disengaging residence time increases, and, therefore, the vapor and liquid separate more easily. The allowable velocity also increases as the difference between the liquid and vapor densities ($\rho_{\rm L} - \rho_{\rm V}$) increases. As the liquid and vapor densities come closer, the two phases are more difficult to separate, and, therefore, a lower downcomer inlet velocity is allowed.

ALLVEL = HFACT2 x RHOFAC

Where HFACT2 = H/24

and RHOFAC = $f(\rho_L - \rho_V)$

Where ALLVEL is the allowable downcomer inlet velocity, HFACT2 is a tray spacing downcomer design factor and RHOFAC is a function of the density difference.

Dry tray pressure drop. The dry tray pressure drop is the pressure drop the vapor would undergo in passing through the tray's perforations if there were no liquid on the tray. This is calculated from a typical velocity head equation. All pressure drop equations used are similar to those presented by Smith (9). To simplify the dry tray pressure drop equation, the constant C_{VO} was set at an average value of 0.70. The literature gives several methods of predicting C_{VO} , including correlating it with the ratio of hole to bubble area (A_O/A_B) and the ratio of hole diameter to tray thickness (D_O/TT).

HH = 0.186 $(1/C_{VO})^2 V_0^2 (\rho_V/\rho_L)$

where $V_0 = CFSV/A_0$

and $C_{VO} = 0.70$

where HH is the dry tray pressure drop, V_0 is the vapor velocity through the open area to feet per second, A0 is the open area in square feet, and CyO is a dry tray pressure drop coefficient.

<u>Clear liquid height</u>. The height of the froth on a tray is given as the sum of the weir height, plus the static head of the crest of liquid overflowing the weir (the Francis weir formula). The static head of this froth, as a clear liquid, is equal to the froth height multiplied by an aeration factor (β). Some texts give β as a function of the weir liquid loading and the ratio of weir length to diameter (9). This program uses average values of 0.70 and 1.00 for β and F_W, respectively.

 $HL = \beta$ (HOW + HWO)

Where $\beta = 0.70$

 $HOW = 0.48 F_W (GPM/LWO)^{2/3}$

and $F_W = 1.00$

Where HL is the clear liquid height on a tray, HOW is the crest over the weir, HWO is the outlet weir height in inches, β is an aeration factor and F_W is a weir factor, GPM is liquid flowrate in gallons per minute, and LWO is the weir length in inches.

<u>Total tray pressure drop.</u> The total pressure drop a vapor undergoes in passing from one tray to another (HT) is generally agreed to be equal to the sum of the dry tray pressure drop plus the clear liquid head on the tray.

HT = HH + HL

Inlet head. The static head of liquid at the tray inlet is used in calculating downcomer filling. It is usually equal to the clear liquid height on a sieve tray (a sieve tray is generally regarded to have no crossflow pressure gradrent) unless there is an inlet weir. If there is an inlet weir, the inlet head is equal to the inlet weir height plus the crest over the inlet weir. Since the liquid at this point is clarified, no aerator factor is necessary (i.e. $\beta = 1.00$).

Without an inlet weir HI = HL

With an inlet weir HI = 0.48 Fw (GPM/LWI)^{2/3} HWI

Where HI is the inlet head, LWI is the inlet weir length in inches and HWI is the inlet weir height in inches.

<u>Head loss under downcomer</u>. As the liquid passes through the area under each downcomer, it changes direction from vertical to horizontal. This requires a pressure loss (HDA) which is predicted by the submerged weir formula.

 $HDA = 0.06 (GPM/A_{ID})^2$

where $A_{UD} = C \times L_{UD}$

where A_{UD} is the area under the downcomer in square inches, C is the downcomer clearance in inches, and L_{UD} is the length under the downcomer in inches.

By curving the outlet lip of the downcomer, this head loss is reduced. If a shaped lip downcomer is used, this program calculates the head loss to be one-half the value calculated by the above equation.

<u>Downcomer filling</u>. A static head of liquid builds up in the downcomer (HDC) to compensate for the pressure drop between trays plus enough head to overcome the tray inlet head and the head loss under the downcomer.

HDC = HT + HI + HDA

If a recessed box or inlet weir is used, HDA is doubled, because the liquid makes two turns in leaving the downcomer.

If downcomer filling is excessive, liquid may back up to the tray above and flood the column. Because the froth in the downcomer is not completely clarified, it is generally recommended that the downcomer clear liquid filling not exceed 50 percent of the tray spacing.

<u>Tray efficiency.</u> There are many tray efficiency equations. This program uses a simple correlation of overall tray efficiency with the liquid fluidity on the tray, as presented by Maxwell (8). The liquid fluidity is defined as the reciprocal of the liquid viscosity in centipoises.

Convergence Techniques.

The equations presented in Chapter III are solved simultaneously to determine the liquid and vapor flowrates in each pass. These convergence techniques are summarized in this section.

Three pass, no vapor crossover.

1. Guess $L_A = L_B = L_C = L_{total}/3$ $V_A = V_B = V_C = V_{total}/3$ 2. Calculate HL, HDA, and HI for each pass

3. Calculate HH and HT for each pass

4. Solve for V_A such that

 $HH_A = HT_B + HI_C + HDA_C - HL_A - HI_B - HDA_B$ which is equivalent to equation (A2)

5. Recalculate
$$V_C = V_A$$

 $V_B = V_{total} - V_A - V_C$

Return to Step 3 until VA is converged.

6. Once V_A is converged, solve for L_A such that HL_A = 2 x HT_B - HT_C - HH_A

which is equivalent to equation (A5)

7. Recalculate $LC = L_A$

 $LB = L_{total} - L_A - L_C$

Return to Step 2 until LA is converged.

Three pass, with vapor crossover.

1. Guess
$$L_A = L_B = L_C = L_{total}/3$$

 $V_A = V_B = V_C = V_{total}/3$

- 2. Calculate HL, HDA, and HI for each pass
- 3. Solve for L_A such that

 $HI_C = HI_B + HDA_B + HDA_C$

which is equivalent to equations (A2) and (B4)

4. Recalculate $L_C = L_A$

 $L_B = L_{total} - L_A - L_C$

Return to Step 2 until LA is converged

5. Solve for V_B such that

 $HH_B = HT_C - HL_B$

6. Solve for V_A such that

 $HH_A = HT_B - HLA$

which is equivalent to equation (B4)

7. If $V_A + V_B + V_C$ does not equal V_{total} , recalculate $V_C = V_{total} - V_A - V_B$

Repeat, starting at Step 5, until $V_A + V_B + V_C$ does equal V_{total}

Four pass, no vapor crossover.

1. Guess $L_A = L_B = L_C = L_D = L_{total}/4$

$$V_A = V_B = V_C = V_C = V_{total}/4$$

- 2. Calculate HL, HDA, and HI for each pass
- 3. Solve for V_A such that

 $HH_A = HT_B + HI_C + HDA_C - HL_A - HI_D - HDA_D$

which is equivalent to equation (C3)

4. Recalculate $V_C = V_A$

 $V_B = V_D = 0.5 V_{total} - V_A$

Return to Step 3 until VA is converged

5. Solve for L_A such that

 $HL_A = HT_B + HT_D - HT_C - HH_A$

- . which is equivalent to equation (C7)
- 6. Recalculate $L_C = L_A$

 $L_B = L_D = 0.5 L_{total} - L_A$

Return to Step 2 until LA is converged

Four pass, with vapor crossover.

1. Guess
$$L_A = L_B = L_C = L_D = L_{total}/4$$

 $V_A = V_C = V_{total}/4$

2. Calculate HL, HDA, and HI for each pass

3. Solve for LC such that

HIC = HID + HDAD - HDAC

which is equivalent to equations (C3) and (D5)

4. Recalculate $L_A = L_C$

 $L_B = L_D = 0.5 L_{total} - L_A$

Return to Step 2 until LA is converged

5. Recalculate
$$V_B = 0.5 V_{total} - V_A$$

6. Solve for V_A such that

 $HH_A = HT_B - HL_A$

which is equivalent to equation (D5)

Return to Step 5 until V_A is converged

- 7. Recalculate $V_D = 0.5 V_{total} V_C$
- 8. Solve for V_C such that $HH_C = HT_D - HL_C$ which is equivalent to equation (D6) Return to Step 5 until V_C is converged

How to Use the Program

This section describes how to fill out the input form for the eight possible options this program is capable of evaluating. These are three and four pass trays, each with or without vapor crossover, and each as either a rating or a design case.

The input form for this program is presented on the next page. The input form is, for the most part, self-explanatory. The following are notes describing the use of this input form, as referenced by the numbers in parentheses on the form. Note that all 14 cards must be submitted for each case. Even if there is no input on a card for a given case, a blank card must still be submitted in its place.

Any alphanumeric titles may be placed on these three cards.
 They will be printed out exactly as submitted.

2. At the present time, this information is not used by the program. It is simply read and printed out as submitted.

3. Omit for a design case. Submit a blank card if entire information on a card is to be omitted.

4. Enter geometry values as described in Figure 8 and Figure9. All geometry values are in inches.

5. Enter 0.0 or a blank card if another case follows. Enter
 1.0 if this is the last case.

Design Logic.

This section describes the logic that this computer program uses to design three and four pass trays. Given the liquid and vapor loadings and the number of tray passes, the program proceeds to develop a tray design in the manner described below.

Tray spacing is set at 24 inches. This is a typical tray spacing

CARD #1 CARD #2

#3

CARD #4

CARD #5

CARD #6

CARD #7

CARD #8 (3,4) CARD #9 (3,4)

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	OUTLET WEIR HT HWO	INLET WEIR HT HWI	DC CLEARANCE C	HOLE AREA AO - SQ FT	SHAPED LIP = 1.0	RECESSED BOX = 1.0	
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	
CARD #10 (3,4)	•	•	•	•	•	•	PASS A
CARD #11 (3,4)	•	•	•	•	•	•	PASS B
CARD #12 (3,4)	•	•	•	•	•	•	PASS C
CARD #13 (3,4)	•	•	•		•	•	PASS D

CARD #14 (5)

1 2 3 4 5 6 7 8 9 10

•

TITLE 1 (1)

TITLE 2 (1)

TITLE 3 (1)



Figure 8 THREE-PASS TRAY GEOMETRY



used in commercial fractionation towers.

A diameter is then selected using double table lookups (see Table 2 and Table 3 in the Fortran computer program presented in the appendix) with vapor load and volumetric liquid rate as parameters. These tables were not developed from any single source, but are based on the data presented by a tray vendor (6). They follow the general trends that vapor capacity increases with tower diameter and decreases with liquid rate.

The minimum diameter for three pass trays is 7 feet, for four pass trays it is 10 feet. This program is incapable of designing three pass trays for liquid rates greater than 5000 GPM, four pass trays for liquid rates greater than 6000 GPM, and all trays for vapor loads (V_L) greater than 100 CFS. These are the limits of the prediction methods used (7).

The program determines the allowable downcomer inlet velocity as described in a previous section (see Table 1 of the program in the appendix). The total downcomer area is then calculated as the area required to maintain the total downcomer inlet velocity exactly at the allowable level. This total downcomer area is then divided into parts for each pass as proposed by a tray vendor (1). All downcomers are straight. That is, the inlet area is equal to the outlet area.

Now the program has a tower cross-sectional area and a total downcomer area. It then splits the remaining bubble area into three

or four segments with equal flow path length. Although this thesis does not propose that equal flow path length designs are the most desirable, it is a common method of designing multipass trays, and is therefore the only method used by this program.

At this point, the program has the entire plan layout (top view) of the tray. Now the program sets the outlet weir height (HWO) so that the average clear liquid height (HL) is 3 inches. It sets the hole area (A_O) so that the average dry tray pressure drop (HH) is 2 inches. These are typical design values which should give good operability and efficiency. It then sets the downcomer clearance (C) so that the average head loss under the downcomer (HDA) is 1 inch. The maximum downcomer clearance is 3 inches, and the program will design a shaped lip downcomer if HDA is greater than 1 inch with a 3 inch straight lip downcomer. This yields an average tray pressure drop (HT) of 5 inches and an average downcomer filling of 9 inches, or 37.5 percent of the 24 inch tray spacing.

The following section describes how these suggested values can be adjusted to obtain a more desirable design than is printed out by the program. For example, if the particular circumstances require a low pressure drop (e.g. a low pressure service), low weir heights and higher open areas will reduce both the clear liquid height and the dry tray pressure drop, which, in turn, reduces the total tray pressure drop.

The program does not design for recessed inlet boxes or inlet weirs. A recessed inlet box is a sump below the downcomer to assure that no vapor can enter the downcomer through the clearance. That is, it is a method of providing a positive seal on the downcomer.

Use of the Program To Improve Initial Design.

It is not proposed that this program will give an optimum design the first time it is run. In fact, the first design the program picks can have several deficiencies. In order to make optimum use of this program as a design tool, the original design case should be altered as necessary and rerun as a rating case. This may have to be done several times until a final optimum design is reached. Several possible deficiencies of a design case are described below.

The program only designs for 24 inch tray spacing. Greater or smaller tray spacings may be chosen to increase tower capacity, reduce downcomer filling or reduce tower height.

The program chooses a tower diameter which can have any value. Very often a company prefers to order tower shells on one foot or half foot diameter increments. Therefore, the diameter chosen by the program should be changed to conform to the specific standard procedures of the user.

Similarly, flow path lengths, downcomer widths, weir heights, and downcomer clearances are often preferred to be specified on some standard increment (say one quarter inch). Since the program chooses any value it needs to meet its design logic, these values should be changed to conform with specific standard procedures of the user.

The program also sets all weir heights and clearances equal. Therefore, clear liquid heights and other pressure drop values can vary greatly for different passes even though the average value conforms with the design logic of the program. Therefore, it is suggested that the original values be altered to equalize pressure drops somewhat. In particular, the outboard downcomer (the shortest downcomer) clearance should usually be increased and the outboard downcomer weir height should usually be decreased.

Also, although the average downcomer velocity is at the allowable limit, the velocity for any one downcomer may exceed this limit. The suggestions in the preceding paragraph should help in balancing the downcomer inlet velocities.

Although this program may not give an optimum design on the first trial, good engineering judgment can be used to obtain an economic and well-balanced design with one or two additional trials.

CHAPTER V

SAMPLE PROBLEMS

This chapter presents sample problems run on the Multipass Tray Design computer program. Included are input forms and two pages of printout for each of the following eight cases:

1. Four pass rating case, no vapor crossover.

2. Four pass rating case, with vapor crossover.

3. Three pass rating case, no vapor crossover.

4. Three pass rating case, with vapor crossover.

5. Four pass design case, no vapor crossover.

6. Four pass design case, with vapor crossover.

7. Three pass design case, no vapor crossover.

8. Three pass design case, with vapor crossover.

The printouts include all inputted information, tray geometry information, vapor and liquid loadings per pass, pressure drops and downcomer backup in inches of hot liquid, percent of jet flood, downcomer inlet velocity, and overall tray efficiency.

Note that for four pass trays, the downcomer for passes C and D are shared, and, for three pass trays the downcomer for passes B and C are shared. Also, for four pass trays, a single downcomer is used for liquid from two individual passes B. On the program printout, these downcomers are split in half, and downcomer inlet velocities per pass are calculated by dividing the liquid flowrate per pass by the area of the "half" downcomer.

	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 6	369 70 71 72 7374 75 76 77 78 79 B	9
CARD #1			NCE TEST C	ASE: FOUR	PASS RATI	NG			TITLE I (I)
CARD #2			DESIGNER:	P.W.BECKER	•				TITLE 2 (1)
CARD #3		<u> </u>	NO VAPOR C	K DS SD VER					J TITLE 3 (1)
	VAPOR RATE MLBS/HR	MIN. YAPOR RATE MLBS/HR (2)	VAPOR DENSITY LB/CU FT	0. = NO VAP 1. = VAPOR	DR CROSSOVER CROSSOVER				
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50				
CARD #4	618.	309.	1.403		0•]			
	LIQUID RATE MLBS/HR	MIN, LIQ. RATE Mlbs/hr (2)	LIQUID DENSITY LB/CU FT	LIQUID VISCOSITY CP	SURFACE TENSION DYNES/CM (2)				
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50		*		
CARD #5	554.6	272•3	31.55	0.113	6.16				
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CARD #6	140.	125.							
					1				
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	WIDTH #1	WIDTH #2	WIDTH #3	WIDTH #4	WIDTH #5				
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50				
CARD #8 (3,4)	19.4375	26 . 56 25	9.25	21.75	4.0				
CARD #9 (3,4)	19 .4 375	26.5625	9.25	21.75	4.0				
		1			r				
	OUTLET WEIR HT HWO	INLET WEIR HT HWI	DC CLEARANCE C	HOLE AREA AO - SQ FT	SHAPED LIP	RECESSED BOX = 1.0			
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60			
CARD #10 (3,4)	1.25	•	1.54	2.39	•	•	PASS A		
CARD #11 (3,4)	2.13	•	1.0	z. 39	•	•	PASS B		
CARD #12 (3,4)	2.0		1.0	2.39	•		PASS C		
CARD #13 (3,4)	2.0	•	1.0	2.34	•		PASS D		
	1 2 3 4 5 6 7 8 9 30								
CARD #14 (5)	•								
	L <u>i, i, i, i i</u> i								

GESIGN AND PATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

NCE TEST CASE: FOUR PASS HATION

DESIGNER: P.W.BECKER

NO VAPOR CROSSOVER

OPERATING CONDITIONS

					· · · ·
MEBSZHR VAPOR MAX		619.000	MLBS/HR LIQUID MAX		544.600
ML857HR VAPOR MIN		309.000	MLBS/HR LIQUID MIN		272.300
LBS/CU ET VAPOR AT COND		1.403	LOSICU FT LIQUID AT COND		31.550
TRAY LIQUID TEMPERATURE	DEG F	140.000	SURFACE TENSION AT COND	DYNES/CM	5.160
OPERATING PRESSURE	PSIA	125.000	VISCOSITY AT COND	CP	0,113
CFS VAPOR AT COND		122,357	LIQUID FLOW RATE	GPM	2151.932
VAPOR LOAD	CES	26.395			

TRAY GEOMETRY

FT	13.50
IN	21.00
	4.00
IN	0.38
SQ FT	143.14
PCT	66.86
	NÜ
	FT IN IN SQ FT PCT

		PASS 4	PASS B	PASS C	PASS D
	•				
DOWNCOMER INLET WIDTH **	IN	19.438	4.000	4.625	4.625
DOWNCOMER OUTLET WIDTH **	IN	19.433	4.000	4.625	4.625
FLOW PATH LENGTH	IN	26,563	21.750	26,563	21.750
CHORD LENGTH AT TUP OF DC	IN	105.285	152,018	145.884	153,568
CHORD LENGTH AT BTM OF DC	IN	105.285	152.018	145.884	153.568
DC INLET AREA	SQ FT	9.703	4.390	4.742	4.879
DC OUTLET AREA	SO FT	9.709	4.390	4.742	4.879
DUTLET WEIR HEIGHT .	IN	1.250	2.130	2.000	2.000
INLET WEIR HEIGHT ON TRAY BELO	W IN	J.O	0.0	0.0	0.0
DC CLEARANCE TO TPAY BELOW	IN	1.540	1.000	1.000	1.000
SHAPED LIP (YES OR NO)		MC.	NÜ	NO CH	NO
RECESSED BOX (YES OR ND)		N.	C/A	NB	NO
BUBBLE AREA	SQ FT	23.001	24.250	23.601	24.250
FREE AREA .	SQ FT	33,308	28.640	28,343	29.128
HOLE AREA	SQ FT	2.190	2.390	2.390	2.390
HOLE/BURBLE AREA	PCT	10.127	9.356	10.127	°.856

HALF WIDTH FOR PASSES B.C.D

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PAGE1

LOADINGS PER PASS		PASS A	PASS B	PASS C	PASS D
GPM LIQUID		549.469	526.497	549.469	526.497
GPH/FT WEIR		3757.569	2339.732	2711.851	2468.471
CES VAPOR		30.994	30.184	30.994	30.184
VAPOR LOAD	CFS	5.685	6.512	6.535	6.512
VLOAD/BUBBLE AREA	FPS	0.283	0.269	0. <u>2</u> °3	0,269
VLOAD/CFS LIQUID		5.461	5.551	5.401	5.551
DOWNCOMER FILLING CALCULA	TIONS				
				· .	
DRY TRAY PRESSURE DROP	(HH) IN	2.839	2.692	2.839	2.692
CLEAR LIQUID HEIGHT	(HL) IN	1.386	2.228	2.214	2.164
TOTAL TRAY PRESSURE DROP	(HT) IN	4.725	4.921	5.053	4.857
INLET HEAD	(HI) IN	2.214	2.164	1.886	2,228
DC HEAD LUSS	(HDA) IN	0.699	0.634	9.851	0.705
DC FILLING	(HDC) IN	7.628	7.719	7.790	7.790
DC FILLING	PCT	36:325	36.756	37.097	37.097
ADDITIONAL CALCULATIONS			· · · ·		· ·
*		· .			· .
PERCENT LET FLOOD		73.979	62-073	67-525	62.727
DC INLET VELOCITY	FPS	0.126	0.257	0,258	0.240
		4	k.	·	
					· · · · ·
ALLOWABLE DC INLET VELOCT	TY FPS	0.341			

OVERALL TRAY EFFICIENCY PCT

98.833

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PAGE 2

		NCE TECT I	ACE EDUD	DAGS PATT	NG		
	·	DECIGNER	P. W. RFCKFY)			
		WITH VAD NP	COALSOVE	5			
				<u>Li</u>	u <u></u>		
VAPOR RATE MLBS/HR	MIN. VAPOR RATE MLBS/HR(2)	VAPOR DENSITY LB/CU FT	0. = NO VAP 1. = VAPOR	OR CROSSOVER CROSSOVER			
1 2 3 4 5 6 7 8 9 1	0 1 1 1 2 1 3 1 4 1 5 1 6 1 7 1 8 1 9 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50			
618.	309.	1.403		1.			
		·····	r	·			
LIQUID RATE MLBS/HR	MIN. LIQ. RATE MLBS/HR (2)	LIQUID DENSITY	LIQUID VISCOSITY	SURFACE TENSION DYNES/CM (2)			
	11 12 12 14 15 14 17 18 10 00	21 22 23 24 25 26 27 28 29 30	31 33 33 34 35 36 37 38 39 40	41 47 43 44 45 46 47 48 49 50			
CAL	777.2	21.50	N-112	Z 16			
	616.2						
TEMPERATURE	PRESSURE	1					
DEG F (2)	PSIA (2)						
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20						
140.	125.						
		-					
NO. OF PASSES	HOLE DIAMETER	TOWER DIAMETER	TRAY SPACING				
	INCHES (2)	FEET (3)					
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40				
	0.38	13.5	2.				
	·····	· · · · · · · · · · · · · · · · · · ·	r	r			
WIDTH #1	WIDTH #2	WIDTH #3	WIDTH #4	WIDTH #5			
WIDEN #6	WIDTH #7	WIDTH #8	WIDIN #9	41 42 43 44 45 46 47 48 49 50	•		
10 4377	26-CA31	a.)	21-75	4.0			
17.73/3	200025	9.25	21.75	4.0			
14 •7 2 N	10.0000						
OUTLET WEIP HT	INI ET WEID HT		HOLE AREA		RECESSED BOX		
HWO	HWI	c	AO - SQ FT	5 1.0	= 1.0		
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60		
1.25	•	1.54	2.39	•	•	PASS A	
2.13	•	1.0	2.39	•	•	PASS B	
		1.0	2.39		•	PASS C	
2.0	j i i i i						

CARD #14 (5)

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DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

NCE TEST CASE: FOUR PASS PATING

DESIGNER: P.W.BECKER

WITH VAPOR CROSSOVER

OPERATING CONDITIONS

MLBSIHR VAPOR MAX		617.000	MEBS/HR LIQUID MAX		544,600
MLBS/HR VAPOR MIN		309.000	MLBS/HR LIQUID MIN	· ·	272.300
LBS/CU FT VAPOR AT COND		1.403	LBS/CU FT LIQUID AT COND		31,550
TRAY LIQUID TEMPERATURE	DEG F	140.000	SURFACE TENSION AT COND	DYNES/CM	6.160
OPERATING PRESSURE	PSIA	125.000	VISCUSITY AT COND	CP	0.113
CFS VAPOR AT CUND		122.357	LIQUID FLOW RATE	GPM .	2151.932
VAPOR LOAD	CFS	26.395			
TRAY GEOMETRY					

DIAMETER	FŤ	13.50	
TRAY SPACING	IN	21.00	
WUMBER OF PASSES		4.00	
HOLE DIAMETER	IN	0.39	
CROSS SECT AREA	SQ FT	143.14	
SUBBLE/CROSS SECT AREA	PCT	66.86	
APOR CROSSOVER (YES OR NO)		YE S	
•			

				and the second	
		PASS 4	PASS B	PASS C	PASS D
DOWNCOMER INLET WIDTH **	IN	19.438	4.000	4.625	4.625
DOWNCOMER OUTLET WIDTH **	IЧ	19.438	4.000	4.625	4.625
FLOW PATH LENGTH	IN	26.563	21.750	26.563	21.750
CHORD LENGTH AT TOP OF DC	14	105.285	162.018	145.884	153.568
CHORD LENGTH AT BTM OF DC	IN	105.235	162.018	145.884	153.568
DC INLET AREA	SQ FT	9.708	4.390	4.742	4.879
DC OUTLET AREA	SQ FT	9.708	4.390	4.742	4.879
OUTLET WEIR HEIGHT	IN	1,250	2.130	2.000	2.000
INLET WEIR HEIGHT ON TRAY BELOW	IN	0.0	0.0	0.0	0.0
DC CLEARANCE TO TRAY BELOW	IN	1.540	1.030	1.000	1.000
SHAPED LIP (YES OR NO)		NG	NO	ND	NO
RECESSED BOX (YES OR NO)		. NO	NU	CΥ	NC
BUBBLE AREA	SQ FT	23.501	24.250	23,601	24.250
FREE AREA	SQ FT	33.308	28.640	28.343	29.128
HOLE AREA	SO FT	2.300	2.390	2.340	2,393
HOLE/BUBBLE AREA	PCT	10.127	9.856	10.127	9.856

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 PAGE1

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				1	
LOADINGS PER PASS		PASS A	PASS B	P288 C	PASS D
GPM LIQUID		574.215	531.750	574.216	501.750
GPH/FT WEIR		3926.804	2229.756	2533.999	2352.444
CES VAPOR		31.387	29.792	30,316	30.862
VAPOR LOAD	* F S	6.771	5.427	e.540	6.658
VLOÁDZBUBBLE AREA	FPS	0.287	9.265	2.277	0,275
VLOAD/CES LIQUID	-	5.292	5.749	5.112	5.955
DOWNCOMER FILLING CALCULA	TIONS				
DRY TRAY PRESSURE DROP	(HH) IN	2.911	2.623	2.716	2.815
CLEAR LIQUID HEIGHT	(HL) IN	1.917	2.205	2.239	2.140
TOTAL TRAY PRESSURE DROP	(HT) IN	4.828	4.828	4.954	4.955
INLET HEAD	(HI) IN	2.238	2.140	1.917	2.205
DC HEAD LOSS	(HDA) IN	0.753	0.575	0,930	0.641
DC FILLING	(HDC) IN	7.818	7.544	7.300	7.801
DC FILLING	PCT	37.230	35.922	37.144	37.145
ADDITIONAL CALCULATIONS				· .	
******			 .		
PERCENT JET FLOOD		76.091	50.727	66.727	63.534
DC INLET VELOCITY	FPS .	0.132	9.255	0,270	0.229
·					
	•				· · · · · ·
ALLOWABLE DC INLET VELOCT	7 9 3 9 1	0.341	•		· · · · ·
			·		
	ос т	00 022	· ·	· .	•
OVERALE INAT EFFICIENCE	PUI	. 70.022			
				•	



CARD #14 (5)

DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

NCE TEST CASE: THREE PASS BATING

DESIGNER: P.W.BECKER

NO VAPOR CROSSOVER

OPERATING CONDITIONS

MLBS/HR VAPOR MAX MLBS/HP VAPOR MIN LBS/CU FT VAPOR AT CONO TRAY LIQUID TEMPERATURE OPERATING PRESSURE CFS VAPOR AT COND VAPOR LOAD	DEG F PSIA CFS	618.000 309.000 1.403 140.000 125.000 122.357 26.396	MLBS/HR LIQUID M/ MLBS/HR LIQUID M/ LBS/CU FT LIQUID SURFACE TENSION / VISCOSITY AT CUNE LIQUID FLOW RATE	AX IN AT COND DT COND DYNES/CM CP GPM	544.600 272.300 31.550 6.160 0.113 2151.932
TRAY GEOMETRY					
DIAMETER TRAY SPACING NUMBER OF PASSES HOLE DIAMETER CROSS SECT AREA BUBBLE/CROSS SECT AREA VAPOR CROSSOVER (YES OR NO)	FT 13 IN 21 3 IN 0 SQ FT 143 PCT 49	• 50 • 00 • 38 • 14 • 30 NO			
		PASS A	PASS B	PASS C	PASS D
DOWNCOMER INLET WIDTH ** DOWNCOMER DUTLET WIDTH ** FLOW PATH LENGTH CHORD LENGTH AT TOP.OF DC CHORD LENGTH AT BIM OF DC DC INLET AREA DC OUTLET AREA OUTLET WEIR HEIGHT INLET WEIR HEIGHT INLET WEIR HEIGHT ON TRAY BE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES OR NO) RECESSED BOX (YES OR NO)	IN IN IN SQ FT SQ FT IN LGW IN IN	24.000 21.000 24.000 115.332 109.019 13.163 10.854 1.250 0.0 1.540 NO	12.000 10.500 24.000 150.273 160.273 13.286 11.662 2.130 0.0 1.030 ND	12.000 10.500 24.000 144.924 147.734 12.506 11.091 2.000 0.0 1.000 ND ND	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
BUBBLE AREA FREE AREA HOLE AREA HOLE/GUBBLE AREA	SQ FT SQ FT SQ FT SQ FT PCT	22.174 32.302 2.390 10.778	25,949 39,612 2,660 9,870	21.449 33.265 2.390 11.143	0.0 0.0 0.0 0.0

** HALF WIDTH FOR PASSES 3,C,D

PAGE1

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PAGE 2

LOADINGS PER PASS PASS A PASS B PASS C PASS D _____ _____ ---------------GPM LIQUID 710.954 718.024 716.954 0.0 GPH/FT WEIR 4475.820 3561.914 0.0 3225.575 CES VAPOR 0.0 39.631 43.094 39.631 VAPOR LOAD CES 8.550 9.297 8.550 0.0 VLOAD/BUBBLE AFEA FPS 0.386 0.345 0.399 0.0 VLOAD/CES LIQUID 5,352 5.352 5.811 0.0 DOWNCOMER FILLING CALCULATIONS ---______ DRY TRAY PRESSURE DROP (HH) IN 4.641 4.430 4.641 0.0 CLEAR LIQUID HEIGHT 2.376 0.0 (HL) IN 2.012 2.435 TOTAL TRAY PRESSURE DROP 7.018 0.0 (HT) ΞN 6.653 6.835 INLET HEAD (HI) IN 2.012 0.0 2.376 2.405 DC HEAD LOSS (HDA) IN 0.0 1.094 1.413 1.204 DC FILLING (HDC) IN 10.123 10.442 0.0 10.444 DC FILLING PC T 48.207 49.732 49.725 0.0 ADDITIONAL CALCULATIONS PERCENT JET FLOUD 107.753 85.901 102.258 0.0 DC INLET VELOCITY FPS 0.121 0.120 0.128 0.0 ALLOWABLE DC INLET VELOCITY FPS 0.341 OVERALL TRAY EFFICIENCY PCT 98.833

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	1 2 3 4 5 6 7 8 9 10	0 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 6	6 67 68 69 70 71 72 7	374 75 76 77 78.79	80
CARD #1 CARD #2			NCE TEST C	ASE: THRE	E PASS RAT	ING				TITLE 1 (1)
CARD #3			WITH VAPOR	C ROSS OVE						TITLE 3 (1)
	VAPOR RATE MLBS/HR	MIN. VAPOR RATE MLBS/HR(2)	VAPOR DENSITY LB/CU FT	0. = NO VAP 1. = VAPOR	OR CROSSOVER CROSSOVER					
	1 2 3 4 5 6 7 8 9 10	0 1 1 1 2 1 3 1 4 1 5 1 6 1 7 1 8 1 9 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50					
CARD #4	618.	309.	1.403							
	LIQUID RATE MLB5/HR	MIN. LIQ. RATE Mlb5/Hr (2)	LIQUID DENSITY LB/CU FT	LIQUID VISCOSITY CP	SURFACE TENSION DYNES/CM (2)					
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50					
CARD #5	554.6	272.3	31.55	0.113	6.16					
	TEMPERATURE DEG F (2)	PRESSURE PSIA (2)								
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	· .							
CARD #6	140.	125.								
	NO. OF PASSES 3 OR 4	HOLE DIAMETER INCHES (2)	TOWER DIAMETER Feet (3)	TRAY SPACING INCHES (3)						
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40						
CARD #7	<u> </u>	0.38	3.5	21•						
	WIDTH #1	WIDTH #2	WIDTH #3	WIDTH #4	WIDTH #5					
	WIDTH #6	WIDTH #7	WIDTH #8	WIDTH #9	WIDTH #10					
CARD #8 (3.4)	74	74.	21 22 23 24 25 26 27 28 24 30	7 4	24.					
CARD #9 (3,4)	24.	21.	•	•	•					
		•			······································					
	OUTLET WEIR HT	INLET WEIR HT HWI	DC CLEARANCE C	HOLE AREA AO - SQ FT	SHAPED LIP	RECESSED BOX = 1.0				
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60				
CARD #10 (3,4)	1.25	•	1.54	• • • • • • • •	2.57	•	PASS A			
CARD #11 $(3,4)$	2.0	•	1.02	•	2.39		PASS B			
CARD #12 (3,4) CARD #13 (3,4)	•	•	•			•	PASS D			
	1 2 3 4 5 6 7 8 9 10									
CARD #14 (5)	•									
										L L

DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

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PAGE1

NCE TEST CASE: THREE PASS RATING

DESIGNER: P.W.BECKER

WITH VAPOR CROSSOVER

OPERATING CONDITIONS

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MLBS/HP VAPOR MAX MLBS/HR VAPOR MIN LBS/CU FT VAPOR AT COND TRAY LIQUID TEMPERATURE OPERATING PRESSURE CFS VAPOR AT COND VAPOR LOAD	DEG F PSIA CFS	613.000 309.000 1.403 140.000 125.000 122.357 26.396	MLBS/HR LIQUID MLBS/HR LIQUID LBS/CU FT LIQUI SURFACE TENSION VISCOSITY AT CO LIQUID FLOW PAT	MAX MIN D AT COND AT COND ND E	DYNES/CM CP GPM	544.600 272.300 31.550 6.160 0.113 2151.932
TRAY GEOMETRY			•			
DIAMETER TRAY SPACING NUMBER OF PASSES HOLE DIAMETER CROSS SECT AREA BUBBLE/CROSS SECT AREA VAPOR CROSSOVER (YES OR NO)	FT 13 IN 21 IN 3 IN 0 SQ FT 143 PCT 49	.50 .00 .39 .14 .30 YE S				•
		PASS 4	PASS B	PASS	<u>с</u>	PASS D
DOWNCOMER INLET WIDTH ** DOWNCOMER OUTLET WIDTH ** FLOW PATH LENGTH CHORD LENGTH AT TOP OF DC CHORD LENGTH AT BIY OF DC DC INLET AREA OUTLET AREA OUTLET WEIR HEIGHT INLET WEIR HEIGHT ON TRAY BE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES DR NO) RECESSED BOX (YES DR NO)	IN IN IN SQ FT SQ FT IN LOW IN IN	24.000 21.000 24.000 115.332 109.019 13.168 10.854 1.250 0.0 1.540 NB ND	12.000 10.500 24.000 160.273 13.286 11.662 2.130 0.0 1.000 NO	12.0 10.5 24.0 144.9 147.7 12.5 11.0 2.0 0.0 1.0 NJ	00 00 24 34 05 91 00	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
BUABLE AREA FREE AREA HOLE AREA HOLE/GUBBLE AREA	50 FT 50 FT 50 FT PCT	22.174 32.302 2.399 10.778	26.949 38.612 2.660 9.870	21.4 33.2 2.3 11.1	48 65 90 43	0.0 0.0 0.0 0.0

** HALF WINTH FOR PASSES B,C,D

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			· · ·			
	LOADINGS PER PASS		PASS A	PASS B	PASS C	PASS D
:	GPM LIQUID		730,921	690.290	730.821	0.0
	GPH/FT WEIR		4552.391	3101.006	3630.805	0.0
	CFS VAPOR		40.347	43.209	38,772	0.0
	VAPOR LOAD	C = S	5.70+	9.321	8+367	0.0
	VECAD/BUSBLE AKEA	FP 5	0.343 5.345	0.346	Us 340 5 130	0.0
	VL040/073 L19010		2.6.2.4.2	5.055	2.137	0.0
	DOWNCOMER FILLING CALCULATIONS					
	DRY TRAY PRESSURE DROP (HH)	IN	4,811	4.454	4,447	0.0
	CLEAR LIQUID HEIGHT (HL)	IN	2.025	2.331	2.389	0.0
	TOTAL TRAY PRESSURE DROP (HT)	IN	6.737	6.835	6.835	0.0
	INLET HEAD (HI)	IN	2.339	2,381	2.026	0 .0
	DC HEAD LOSS (HDA)	IN	1.137	1.113	1.468	0.0
	DC FILLING (HDC)		10.362	10,329	10.330	0.0
	DC FILLING	PCT	44.343	49.185	49.191	0.0
	ADDITIONAL CALCULATIONS			• .		
	DERCENT LET EL COD			05 DD/	100 714	0.0
	AC THEFT VELOCITY	505	110+830	0 116	0 130	0.0
	DC INCLI VELOCIIV	1.5	~3267	0.110		
		•				· .
	ALLOWABLE DC INLET VELOCITY	FPS	0.341			



CARD #14 (5)

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PESION AND PATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

NCE TEST CASE: FOUR PASS DESIGN

DESIGNER: P.W.BECKER

NO VAPOR CROSSOVER

OPERATING CONDITIONS						
		•				· · ·
MEBS/HR VAPIR MAX		619,000	MURSZER LTOUTO MA	x		544.600
MEBS/HR VAPOR MIN		309.000	MLBSZHR LIQUID MT	N		272.300
LBS/CU FT VAPOR AT COND		1.403	IBS/CULET I TOUTO	AT COND		31-550
TRAY LIQUID TEMPERATURE	DEG F	140.000	SURFACE TENSION A	T COND	DYNESZCH	6-160
OPERATING PRESSURE	PSIA	125.000	VISCOSITY AT COND		CP	0.113
CES VAPOR AT COND		122,357	LIQUID FLOW RATE		GPM	2151.932
VAPOR LUAD	CFS	25.395				
TRAY GEOMETRY						
DIAMETER	FT	11.80			1	
TRAY SPACING	IN	24.00				
NUMBER OF PASSES		4.00				
HOLE DIAMETER	IN	0.38				
CROSS SECT AREA	SQ FT	109-45				
BUBBLE/CROSS SECT AREA	PCT	77.40				
VAPOR CROSSOVER (YES OR NO)		NO				k.
		PASS 4	PASS B	PASS	с	PASS D
DOWNCOMER INLET WIDTH **	TN	8.395	3.593	3,53	1	3.531
DOWNCOMER OUTLET WIDTH **	IN	3.395	3.593	3,53	1	3.531
FLOW PATH LENGTH	IN	25.889	25.839	25.88	9	25.889
CHORD LENGTH AT TOP DF DC	IN	59+07Z	141.665	121.32	0	128.612
CHORD LENGTH AT BTM OF DC	IN	69.072	141.665	121.32	0	128.612
DC INLET AREA	SQ F	T 2.804	3.452	3.00	19	3.101
DC DUTLET AREA	FA F	7 0 0 0 /				~
- MUTLET WEIR HEIGHT	. SQ F	1 4.504	3.452	3.00	9.	3.101
	IN SU F	2.944	3.452 2.944	3.00 2.94	.4	3.101 2.944
INLET WEIR HEIGHT ON TRAY RE	IN LOW IN	2 • 504 2 • 944 2 • 0	3•452 2•944 0•0	3.00 2.94 0.0	.4	2.944 0.0
INLET WEIR HEIGHT ON TRAY BE DC CLEARANCE TO TRAY BELOW	IN LOW IN IN	2.944 2.944 0.0 1.144	3.452 2.944 0.0 1.144	3.00 2.94 0.0 1.14	19 -4 -4	3.101 2.944 0.0 1.144
INLET WEIR HEIGHT ON TRAY RE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO)	IN IN LOW IN IN	2.504 2.5944 0.0 1.144 NU	3.452 2.944 0.0 1.144 NU	3.00 2.94 0.0 1.14 N3	.4 .4	3.101 2.944 0.0 1.144 NO
INLET WEIR HEIGHT ON TRAY RE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO) RECESSED BOX (YES OR NO)	IN IN LOW IN IN	2.504 2.944 0.0 1.144 NU NU	3.452 2.944 0.0 1.144 NO NO	3.00 2.94 0.0 1.14 N3 N0	99 - 4 - 4	3.101 2.944 0.0 1.144 ND ND
INLET WEIR HEIGHT ON TRAY BE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO) RECESSED BOX (YES OR NO) BUBBLE AREA	SU F LOW IN IN SO F	1 2.504 2.944 0.0 1.144 NU NU NU 1.7.549	3.452 2.944 0.0 1.144 NO NO 24.807	3.00 2.94 0.0 1.14 NJ NO 17.54	9 -4 -9	3.101 2.944 0.0 1.144 ND ND 24.807
INLET WEIR HEIGHT ON TRAY RE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO) RECESSED BOX (YES OR NO) BUBBLE AREA FREE AREA	SU F IN LOW IN IN SO F SQ F	1 2.504 2.944 0.0 1.144 NU NU NU 1 17.549 1 20.353	3.452 2.944 0.0 1.144 NO NO 24.807 28.259	3.00 2.94 0.0 1.14 NO NO 17.54 20.55	99 -4 -9 -8	2.944 0.0 1.144 ND NO 24.807 27.909
INLET WEIR HEIGHT ON TRAY RE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO) RECESSED BOX (YES OR NO) BURBLE AREA FREE AREA HOLE AREA	SO F LOW IN IN SO F SQ F SQ F	1 2.504 2.944 0.0 1.144 NU NU T 17.549 T 20.553 T 2.361	3.452 2.944 0.0 1.144 ND NO 24.807 28.259 3.250	3.00 2.94 0.0 1.14 NU NU 17.54 20.55 2.36	99 -4 -9 -9 -1	2.944 0.0 1.144 ND ND 24.807 27.909 3.250

** HALF WIRTH FOR PASSES 3,C,D

PAGE1

LOADINGS PE- PASS			PASS A	PASS B	PASS C	PASS D
GPN LIGHD			495.924	590.042	495.924	580.042
GPH/FT REIR R			5169.500	2948.019	2943.169	3247.218
CFS VAPTA			25.075	36.104	25.075	36.104
VAP 34 1.40		CFS	5.409	7.789	5.409	7.789
VLCADZE FRELE AREA		FPS	0.308	0.314	0,308	0,314
CIUCIL Z=TVCAD/V.			4.805	6.026	4,895	5.026
DOWNCIMER FILLING CALCULAT	TIONS					
				a 071	1 205	2 071
DRY THAY PRESSURE DROP	(HH)	IN	1.905	2.071	· 1,905	2,074
CLEAK BIQUID HEIGHT	(HL)	IN	3.312	2.921	2.920	2.9/0
TOTAL TRAY PRESSURE DROP	(HT)	IN	5.215	4.991	4.423	2.045
INLET HEAD	(HI)	IN	2.920	2.978	3.312	2. 921
DC HEAD LOSS	(HDA)	IN	2.363	0.769	U. 705	0.933
DC FILLING	(HDC)	IN	10.500	8 - 138	8.903	3.902
DC FILLING		PCT	43.749	36.410	37-094	37.093
ADDITIONAL CALCULATIONS						
PERCENT JET FLOOD			83.518	70.266	68.959	71.953
DC INLET VELOCITY		FPS	0.394	0.374	0.367	0.417
ALLERABLE DC INLET VELOCIT	ſY	FPS	0.390		•	·

OVERALL TRAY EFFICIENCY

PCT

98.833

PAGE 2

	1 2 3 4 5 6 7 8 9 1	01112 13 14 15 16 17 18 19 2	0 21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	4142 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65	66 67 6869 7	0 71 72 737	4 75 76 77 78	79 80
D #1			NCE TELT 1	ASE' EQUE	DACS DEGS	AN					TITLE 1
D #2			DEST CHER:	P.W. BECKE	R	N	• • • • • • • • • • • • • • • • • • •				TITLE 2
D #3			WITH VAPOR	CRASSOVE	§	4					TITLE 3
					<u> </u>	<u>,</u>	<u></u>				
	VAPOR RATE MLBS/HR	MIN. VAPOR RATE MLBS/HR (2)	VAPOR DENSITY LB/CU FT	0. = NO VAP 1. = VAPOR	OR CROSSOVER CROSSOVER						
	1 2 3 4 5 6 7 8 9 1	0 11 12 13 14 15 16 17 18 19 2	0 21 22 23 24 25 26 27 28 29 34	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50						
D #4	618.	309.	1.403		1.						
		• · · · · · · · · · · · · · · · · · · ·	·	• ••••••••••••••••••••••••••••••••••••		· ·					
	LIQUID RATE MLBS/HR	MIN. LIQ. RATE MLBS/HR (2)	LIQUID DENSITY LB/CU FT	LIQUID VISCOSITY CP	SURFACE TENSION DYNES/CM (2)						
	1 2 3 4 5 6 7 8 9 1	0 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50						
) #5	554.6	272.3	31.55	0.113	6.16						
			_								
	TEMPERATURE DEG F (2)	PRESSURE PSIA (2)									
	1 2 3 4 5 6 7 8 9 1	0 1 1 12 13 14 15 16 17 18 19 20									
)#6	140.	125.	J								
	NO. OF PASSES 3 OR 4	HOLE DIAMETER INCHES (2)	TOWER DIAMETER FEET (3)	TRAY SPACING INCHES (3)							
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40							
# 7	4.	0.38	•	•							
				• <u>•••••••••••••••••••••••••••••••••••</u> ••••	,						
	WIDTH #1	WIDTH #2	WIDTH #3		WIDTH #5						
	WIDTH #6	WIDTH #7	WIDTH #8	WIDTH #9	WIDTH #10						
	1 2 3 4 5 6 7 8 9 10	0 1 1 1 2 1 3 1 4 1 5 1 6 1 7 1 8 1 9 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50						
#8 (3,4)	•	•	•	•	•						
#9 (3,4)	•	•	•	•	•		,				
				-							
	OUTLET WEIR HT HWO	INLET WEIR HT HWI	DC CLEARANCE C	HOLE AREA AO - SQ FT	SHAPED LIP = 1.0	RECESSED BOX = 1.0					
	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60					
#10 (3,4)	•	•	•	•	•	•	PASS A				
#11 (3,4)	•	•	•	•	•	•	PASS B				
#12 (3,4)	•	•	•	•	•	•	PASS C				
#13 (3.4)	•	•	•	•	•	•	PASS D				
	- Kaning in the second se				**************************************	terrates of the strength of the	•				
	1 2 3 4 5 6 7 8 9 10	1									

DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

PAGE1

NCF TEST CASE: FOUR PASS DESIGN

DESIGNER: P.W. BECKER

WITH VAPOR CROSSOVER

ΟP	ΞP	AT	I.	IG	(50	N	0	I	T	I	J	Ŋ	S	

OPERATING PRESSURE

CFS VAPOR AT COND

MLAS/HR VAPOR MAX		613.
MEBS/HR VAPOR MIN		309.
LBS/CU FT VAPOR AT COND		1.
TRAY LIDUID TEMPERATURE	DEG F	140.

PSIA

CFS

613.000	MEBS/HR LIQUID MAX		544.600
309.000	MLBS/HR LIQUID MIN		272.300
1.403	LBS/CU FT LIQUID AT COND	*	31.550
140.000	SURFACE TENSION AT COND	DYNES/CM	6.160
125.000	VISCOSITY AT COND	CP	0.113
122.357	LIQUID FLOW RATE	GPM	2151.932
25.396			

ŤF	2 4 Y	G	ЕЭ	ME	TRY	,
	_					

VAPOR LOAD

DIAMETER	FT	11.80
TRAY SPACING	IN	24.00
NUMBER OF PASSES		4.00
HOLE DIAMETER	IN	0.38
CROSS SECT AREA	SQ FT	109.45
BUBBLE/CROSS SECT AREA	PCT	77.40
VAPOR CROSSOVER (YES OR NO)		YE S

	·	

	· · ·	PASS A	PASS B.	PASS C	PASS D
		**********			*******
DOWNCOMER INLET WIDTH **	IN	\$.396	3,593	3.531	3,531
DOWNCOMER OUTLET WIDTH **	IN	3.396	3.593	3.531	3.531
FLOW PATH LENGTH	IN	25.889	25.889	25.899	25.889
CHORD LENGTH AT TOP OF DC	IN .	69.072	141.665	121.320	128.612
CHORD LENGTH AT BIM OF DC	IN	69.072	141.665	121.320	128,612
DC INLET AREA	SQ FT	2.804	3.452	3.009	3.101
DC JUTLET AREA	SQ FT	2.804	3.452	3.009	3.101
OUTLET WEIR HEIGHT	IN	2.944	2,944	2.944	2.944
INLET WEIR HEIGHT ON TRAY BELOW	IN	0.0	0.0	0.0	0.0
OC CLEARANCE TO TRAY BELOW	IN	1.144	1.144	1.144	1.144
SHAPED LIP (YES OR NO)		NO	NО	C/V	ND
RECESSED BOX (YES OP NO)		NO	- NO	Υ?	NO
91331= 19E4	SO FT	17.549	24.807	17.549	24.807
FREE AREA	SQ FT	20.353	28.259	20.558	27,909
HOLE AREA	SU FT	2.361	3.250	2.361	3.260
HOLF/ BUBBLE APEA	PC T	13.451	13.141	13.451	13.141

			· · · ·	PAGE Z	· · ·
			·		
LOADINGS PER PASS		PASS A	PASS B	PASS C	PASS D
GPM LIQUID GPH/FT WEIR CES VAPOR VAPOR LIQAD VLOAD/BUBBLE AREA VLOAD/CES LIQUID	C F S FP S	470.938 4909.558 24.430 5.291 1.301 5.032	604.953 3074.705 36.698 7.917 0.319 5.873	.470.998 2795.239 26.119 5.635 0.321 5.369	604.968 3386.761 35.060 7.563 0.305 5.411
DOWNCOMER FILLING CALCULA	TICNS				· · ·
DRY TRAY PRESSURE DROP CLEAR LIQUID HEIGHT FOTAL TRAY PRESSURE DROP INLET HEAD DC HEAD LOSS DC FILLING DC FILLING	(HH) IN (HL) IN (HT) IN (HT) IN (HDA) IN (HDC) IN PCT	1.315 3.270 5.085 2.891 2.132 10.108 42.115	2.139 2.945 5.085 3.004 0.836 8.925 37.188	2.067 2.891 4.957 3.270 0.691 8.918 37.158	1.953 3.004 4.957 2.945 1.014 8.917 37.153
ADDITIONAL CALCULATIONS			· · ·		
PERCENT JET FLOOD DC INLET VELOCITY	FPS	79.577 0.374	72.139 0.391	71.008 0.349	70.663 0.435
		· .			
LLGWARLE DC INLET VELOCI	TY FPS	0.390			
VERALL TRAY EFFICIENCY	PCT	98.833			
			• •	·	·

10.4 NCE TEST CASE: THEEE PASE DESTENT THEET THEEE 20 NCE TEST CASE: THEEE PASE DESTENT THEET THEET 21 NCE TEST CASE: THEEE PASE DESTENT THEET THEET 22 NCE TEST CASE: THEEE PASE DESTENT THEET THEET 23 NCE TEST CASE: THEEE PASE DESTENT THEET THEET 24 NELSARE NELSARE TESTENT 25 TESTERT NELSARE TESTERT 24 NELSARE NELSARE TESTERT 25 TESTERT NELSARE TESTERT 26 NELSARE NELSARE TESTERT 26 NELSARE NELSARE TESTERT 27 TESTERT NELSARE TESTERT 28 TESTERT TESTERT TESTERT 29 TESTERT TESTERT TESTERT 20 TESTERT TESTERT TESTERT 20 TESTERT TESTERT TESTERT 20 TESTERT TESTERT TESTERT 21 TESTERT TESTERT TESTERT 21 TESTERT TESTERT TESTER		1 2 3 4 5 6 7 8 9 1	0 1 1 12 13 14 15 16 17 18 19 2	0 21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	1 41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68	9 70 71 72 7374 75 76 77 78 79	80
9 DESTRICT P. W. BECKER TTTLE 1 DESTRICT P. W. BECKER TTTLE 1 TTTLE	#1			NCF TEST (ACF: THRE	E PASS DES	16N			TITLE
$\frac{1}{12} \frac{1}{12} \frac$	2			DESTANEN	P W DEL KE					TITLE 2
$\frac{1}{12} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} = \frac{1}{12} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\$	2	_		NA VADAD (PALLANED	•				TITLE 1
$ \frac{1}{12} \frac{1}{2} \frac{1}{4} \frac{1}{5} $	5			NO VATER C	LYSSOV CA		<u>iiiiii.</u>			
$\frac{1}{12} \frac{1}{2} 1$		VAPOR RATE MLBS/HR	MIN. VAPOR RATE MLBS/HR (2)	VAPOR DENSITY LB/CU FT	0. = NO VAP 1. = VAPOR	OR CROSSOVER CROSSOVER				
$\frac{4}{12} \frac{1}{2} \frac{1}{3} \frac{1}{6} \frac{1}{6} \frac{1}{6} \frac{1}{9} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{16} \frac{1}{9} \frac{1}{16} \frac{1}{16}$		1 2 3 4 5 6 7 8 9 1	0 11 12 13 14 15 16 17 18 19 2	0 21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	·			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	4	618.	309.	1.403		0.				
$\frac{1}{12} \frac{1}{2} \frac{1}{4} \frac{1}{5} \frac{1}{6} \frac{1}{7} \frac{1}{6} \frac{1}{9} \frac{1}{10} \frac{1}{112} \frac{1}{12} \frac{1}{12} \frac{1}{2} \frac{1}{2$			······································			· · ·				
$ \frac{1}{2} 1$		LIQUID RATE MLBS/HR	MIN. LIQ. RATE MLBS/HR (2)	LIQUID DENSITY LB/CU FT	LIQUID VISCOSITY CP	SURFACE TENSION DYNES/CM (2)	•			
$\frac{1}{3} \frac{1}{3} \frac{1}{3} \frac{1}{4} \frac{1}{4} \frac{1}{6} \frac{1}{6} \frac{1}{2} \frac{1}{72} \frac{1}{2} \frac{3}{3} \frac{3}{3} \frac{1}{4} \frac{1}{5} 1$		1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50				
$\frac{1}{2} = \frac{1}{2} = \frac{1}$	5	554.6	272.3	21.55	0.113	6.16				
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$			<u></u>	ta de la construcción de la constru	\$		1			
$\frac{1}{12} \frac{1}{2} \frac{1}{4} \frac{1}{5} \frac{1}{6} \frac{7}{16} \frac{1}{9} \frac{1001132}{1011213} \frac{11}{12} \frac{1}{16} \frac{1}{16} \frac{1}{19} \frac{1}{10} \frac{1}{19} \frac{1}{12} \frac{1}{12} \frac{1}{2} \frac{1}{5} \frac{1}{5} \frac{1}{6} \frac{1}{16} \frac{1}{10} \frac{1}{19} \frac{1}{19} \frac{1}{16} \frac{1}{19} \frac{1}{10} \frac{1}{19} \frac{1}{19$		TEMPERATURE DEG F (2)	PRESSURE PSIA (2)]				×		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20							
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	5	140.	125.	1						
NO. OF PASSES HOLE DIAMETER INCRES (3) TOWER DIAMETER FEET (3) TAXY SPACING INCRES (3) 1 2 3 6 7 0 0 12 2 5 6 7 0 12 2 3 5 6 7 0 0 12 2 3 4 15 16 17 16 10 12 2 <td></td> <td></td> <td></td> <td>-</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>				-						
$\begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 1112 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 120 & 22 & 22 & 22 & 22 & 22 & 22 & 2$		NO. OF PASSES 3 OR 4	HOLE DIAMETER INCHES (2)	TOWER DIAMETER FEET (3)	TRAY SPACING INCHES (3)					
$ \frac{1}{2} \frac{3}{3} \frac{1}{1} \frac{1}{2} \frac{1}{3} \frac{1}{4} \frac{1}{5} \frac{1}{6} \frac{1}{7} \frac{1}{1} 1$	5	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40					
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WIDTH #1 WIDTH #2 WIDTH #3 WIDTH #4 WIDTH #5 WIDTH #6 WIDTH #6 WIDTH #6 WIDTH #6 WIDTH #6 1 2 3 4 5 6 7 8 9 101112 13 14 1516 17 18 19 20 21 22 23 2425 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 4142 43 44 4546 47 48 49 50 • • 0 (3,4) • • • • • • 1 2 3 4 5 6 7 8 9 101112 13 14 1516 17 18 19 20 21 22 23 2425 26 27 28 29 30 31 32 33 44 35 46 47 48 49 50 • • • • 0 (3,4) • • • • • • • • 1 2 3 4 5 6 7 8 9 101112 13 14 1516 17 18 19 20 12 22 12 23 2425 26 17 (28 29 10 13 22 33 34 35 36 37 38 39 40 4142 43 44 4546 47 48 49 50 51 52 53 54 555 55 57 59 159 160 PASS A 0 (3,4) • <td></td>										
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3 (3,4) • </td <td></td> <td>1 2 2 4 5 4 7 8 9 10</td> <td>11 12 12 14 15 16 17 18 19 20</td> <td>21 22 22 24:25 26 27 28:29 30</td> <td>31 32 33 34 35 36 37 38 39 40</td> <td>41 42 43 44 45 46 47 48 49 50</td> <td></td> <td></td> <td></td> <td></td>		1 2 2 4 5 4 7 8 9 10	11 12 12 14 15 16 17 18 19 20	21 22 22 24:25 26 27 28:29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50				
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OUTLET WEIR HT INLET WEIR HT DC CLEARANCE HOLE AREA AO - SQ FT SHAPED LIP RECESSED BOX = 1.0 1 2 3 4 5 6 7 8 9 10 13 10 13 </td <td>D (3,4)</td> <td>la inter l'Andrea a</td> <td>a da ga a sur sur sur da da ga ga ga</td> <td>l.,</td> <td></td> <td>· · · · · · · · · · · · · · · · · · ·</td> <td></td> <td></td> <td></td> <td></td>	D (3,4)	la inter l'Andrea a	a da ga a sur sur sur da da ga ga ga	l.,		· · · · · · · · · · · · · · · · · · ·				
OUTLET WEIR HT HWO INLET WEIR HT HWU INLET WEIR HT HWU DC CLEARANCE C HOLE AREA AO - SQ FT SHAPED LIP 1.0 RECESSED BOX 1.0 1 2.3.4.5.6 7 8.9 101112 13 14.1536 17 18 19 20 21 22 23 24/25 26 27 28/29 30 31/32 33 34 35 36 37 38/39 44 45/46 47 48 49.50 51 52 53 54 55 57 59 50 0 (3,4) • • • • • • • • PASS A 2 (3,4) • • • • • • • • PASS C 1 2 3 4 5 6 7 8 9 10 • PASS C 2 3 4 5 6 7 8 9 10 • •	9 (3,4)	•		•	•					
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1 2 3 4 5 6 7 8 9 10[11]2 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 23 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 [51 52 53 54 55 55 57 58 59 60] 0 (3,4) 1 (3,4) 2 (3,4) 3 (3,4) 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10										
10 (3,4) • • • • • PASS A 1 (3,4) • • • • • PASS B 2 (3,4) • • • • • PASS C 3 (3,4) • • • • • PASS D		1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60			
1 (3,4) • </td <td>10 (3,4)</td> <td>•</td> <td>•</td> <td>•</td> <td>•</td> <td>•</td> <td></td> <td>PASS A</td> <td></td> <td></td>	10 (3,4)	•	•	•	•	•		PASS A		
2 (3,4) 3 (3,4) 1 2 3 4 5 6 7 8 9 10 1 (1) 1 2 3 4 5 6 7 8 9 10	11 (3,4)	•	•	•	•	•	•	PASS B		
3 (3,4) • PASS D	12 (3,4)	•	•	•	•	•	•	PASS C		
	3 (3,4)		•			•	•	PASS D		
				• · · · · · · · · · · · · · · · · · · ·		K +				
		1 2 3 4 5 6 7 8 9 10								

DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS-SIEVE TRAYS

NCE TEST CASE: THREE PASS DESIGN

DESIGNER: P.W.BECKEP

NO VAPOR CROSSOVER

OPERATING CONDITIONS

MLBS/HE VAPOR MAX MLBS/HE VAPOR MIN LBS/CU ET VAPOR AT COND TRAY LIQUID TEMPERATURE OPERATING PRESSURE CFS VAPOR AT COND VAPOR LOAD	DEG F PSIA CFS	613.000 309.000 1.403 140.000 125.000 122.357 26.395	ML957H3 LIQUID ML857HR LIQUID L857CU FT LIQUI SURFACE TENSION VISCOSITY AT CO LIQUID FLOW RAT	MAX MIN D AT COND D DYNES/CM ND CP E GPM	5+4,600 272.300 31.550 6.160 0.113 2151.932
TRAY GERMETRY					
DIAMETER	FT 11	. 94		· · · · · · · · · · · · · · · · · · ·	
NUMBER OF PASSES	1% 24	.00		·	
HOLE DIAMETER	IN O	.38		-	
CROSS SECT AREA	SQ FT 111	. 89			
BUBBLE/CROSS SECT AREA	PC-T 77	.71			
VAPOR CROSSOVER (YES OR NO)		NO			
		PASS 4	PASS B	PASS C	PASS D
BOUNCONED IN ST DIOTH AN	• • •				
DOWNCOMER INLET WIDTH **	· IN TN	10 + 24	4.447) 4.445	4.445	0.0
EDW DATH I SNGTH	1.0	10.000	27 655	27 455	0.0
CHORD JENGTH AT TOP DE DC	1.59	75.693	140.414	135.412	0.0
CHORD LENGTH AT BIM GE DC	T N	75.693	140.414	135.412	0.0
DC INLET AREA	SO FT	3.887	4.342	4.242	0.0
DC OUTLET AREA	SO FT	3.887	4.342	4.242	0.0
OUTLET WEIR HEIGHT	IΝ	2.678	2,678	2,678	0.0
INLET WEIR HEIGHT ON TRAY BE	LUW IN	0.0	0.0	0.0	0.0
DC CLEARANCE TO TRAY BELOW	ΓV	1.499	1.499	1.499	0.0
SHAPED LIP (YES OR NO)		NG	N-3	NO CA	NO
RECESSED BOX (YES OR NU)		N.7	GA	NO .	ON
BUBBLE AREA	SO FT	29,192	28,551	29.192	0.0
FREE AREA	SO FT	33.079	32,903	33.434	0.0
	SO FT	3.485	4-272	3,485	0.0

** HALE STOTH FOR PASSES 3.0.0

HOLE/BUBBLE APEN POT

11,977

14.956

11.937

0.0

62

PAGE1
					PAGE 2	
÷	LOADINGS PER PASS		PASS A	PASS B	PASS C	PASS D
	GPM LIQUID GPH/FT WEIR CFS VAPOR VAPOR LOAD VLOAD/BURBLE AREA VLOAD/BURBLE AREA VLOAD/CFS LIQUID	CFS FPS	692.473 6491.785 37.353 3.059 0.276 5.299	786.957 4035.438 47.651 10.230 0.350 5.852	632.473 3628.785 37.353 9.353 3.276 5.299	0. C 0. 0 0. 0 0. 0 0. 0 0. 0 0. 0
	DOWNCOMER FILLING CALCULA	TIDAS	· ·			
	DRY TRAY PRESSURE DROP CLEAR LIQUID HEIGHT TOTAL TRAY PRESSURE DROP INLET HEAD DC HEAD LOSS DC FILLING DC FILLING	(HH) IN (HL) IN (HT) IN (HT) IN (HD4) IN (HD6) IN PCT	1.940 3.332 5.271 2.863 2.170 10.304 42.934	2.101 2.936 5.036 2.936 0.839 8.811 36.711	1.940 2.963 4.803 3.332 0.678 8.912 36.718	0.0 0.0 0.0 0.0 0.0 0.0 0.0
	ADDITIONAL CALCULATIONS					· .
	PERCENT JET FLOOD DC INLET VELOCITY	FPS	85•516 0•391	88•051 0•404	65+258 0+358	0.0 0.0
	ALLOWABLE DC INLET VELOCI	TY FPS	0.390			·
	OVERALL TRAY EFFICIENCY	PCT	98.833		· · · ·	

Ś

HULTIPASS TRAY DESIGN PROGRAM

	10 11 12 13 14 15 10 1/ 18 19 2			41 42 43 44 45 46 47 48 49 50	- 1 22 23 34 33 30 37 38 39 80	61 62 63 64 63 66 67 68 87 70 71 72 73 74 73 76 77 78 7
		NCE TEST C	ASE THEE	t page des	26N	
		DESIGNER	PIWIBECKEN			
		WITH VAPOR	CROSSOVER			
VAPOR RATE	MIN. VAPOR RATE	VAPOR DENSITY	0. = NO VAP	OR CROSSOVER]	
MLB5/MR	MLB5/HR (2)	LB/CU FT	I. = VAPOR	CROSSOVER		
1 2 3 4 5 6 7 8 9 1	10 11 12 13 14 15 16 17 18 19 2	0 21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	4	
610.	1 209.	1.703]	
	MIN. LIQ. RATE			SURFACE TENSION	}	
MLBS/HR	MLBS/HR (2)	LB/CU FT	CP	DYNES/CM (2)		
1 2 3 4 5 6 7 8 9 1	0 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50		
554.6	272.3	31.55	0.113	6.16		
r		1				
TEMPERATURE DEG F (2)	PRESSURE PSIA (2)					
1 2 3 4 5 6 7 8 9 1	011 12 13 14 15 16 17 18 19 20	t				
140.	125.	1				
na an a		•				
NO. OF PASSES	HOLE DIAMETER	TOWER DIAMETER	TRAY SPACING			
	INCRES (2)	FEEI (3)	INCHES (3)			
1 2 3 4 5 6 7 8 9 10	0 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40			
9 •	1 V•28	•				
WIDTH #1	T					
WIDTH #6	WIDTH #7	WIDTH #8	WIDTH #9	WIDTH #10		
1 2 3 4 5 6 7 8 9 10	011 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50		
•		•	•	•		
•	•	•	•	•		
	T	p	· · · · · · · · · · · · · · · · · · ·	r		}
OUTLET WEIR HT HWO	INLET WEIR HT	DC CLEARANCE C	HOLE AREA AO - SQ FT	SHAPED LIP	RECESSED BOX = 1.0	
1 2 3 4 5 6 7 8 9 10	0 11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	
•	•	•	•	•	•	PASS A
•	•	•	•	•	•	PASS B
•	•	•	•	•	•	PASS C
•	•	•	•	•	•	PASS D
	1	and a long out of the second s				
1 2 3 4 5 6 7 8 9 10	2					
1.0	1					

\$

DESIGN AND RATING PROGRAM FOR THREE AND FOUR PASS SIEVE TRAYS

NCE TEST CASE: THREE PASS DESIGN

DESIGNER: P.W. BECKER

WITH VAPOR CROSSOVER

OPERATING CONDITIONS

MLBS/HR VAPOR MAX MLBS/HR VAPOR MIN LBS/CU FT VAPOR AT COND TRAY LIQUID TEMPEPATURE OPERATING PRESSURE CFS VAPOR AT COND VAPOR LOAD	DEG F PSIA CES	618.000 309.000 1.403 140.000 125.000 122.357 26.395	MLBS/HR LIQUID M MLBS/HR LIQUID M LBS/CU FT LIQUID SURFACE TENSION VISCOSITY AT CON LIQUID FLOW RATE	AX IIN AT COND AT COND D	DYVES/CM CP GPM	544.600 272.300 31.550 6.160 0.113 2151.932
TRAY GEOMETRY	01.5		·			
DIAMETER TRAY SPACING NUMBER OF PASSES HOLE DIAMETER CROSS SECT AREA BUBBLE/CROSS SECT AREA VAPOR CROSSOVER (YES OR NO)	FT 1 IN 2 IN 5 SQ FT 111 PCT 7	94 00 38 89 71 YES			· · · · · · · · · · · · · · · · · · ·	
		PASS A	PASS B	PASS (PASS D
DOWNCOMER INLET WIDTH ** DOWNCOMER OUTLET WIDTH ** FLOA PATH LENGTH CHORD LENGTH AT TOP OF DC CHORD LENGTH AT BTM OF DC DC INLET AREA DC OUTLET AREA OUTLET WEIR HEIGHT INLET WEIR HEIGHT INLET WEIR HEIGHT ON TRAY BE DC CLEARANCE TO TRAY BELOW SHAPED LIP (YES UR NO) RECESSED BOX (YES UR NO)	IN IN IN SQ FT SQ FT IN LOW IN	10.686 10.686 37.655 75.693 75.693 3.887 3.887 2.673 0.0 1.499 NO	4.445 4.445 37.655 140.414 140.414 4.342 4.342 2.678 0.0 1.499 NO NO	4.445 4.445 37.655 135.412 135.412 4.242 4.242 2.678 0.0 1.499 NU NO		0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
BUBBLE AREA FREE AREA HOLE AREA HOLE/BUBBLE AREA	SQ FT SQ FT SQ FT PCT	29.192 33.079 3.485 11.937	28.561 32.903 4.272 14.956	29.192 33.434 3.485 11.037		0.0 0.0 0.0 0.0

** HALF WIDTH FUR PASSES B,C,D

PAGE1

		PASS A	PASS B	PASS C	PASS D
PM LIQUID		657.953	836.015	657,958	0.0
PH/FT WEIP		6253.598	4286,844	3498.439	0.0
FS VAPOR		35.404	47.175	39.776	0.C
APOR LOAD	CFS	7.633	10.177	8.581	0.0
LOADZBUBBLE ARFA	FPS.	0.252	3,355	0.294	0.0
LOAD/CES LIQUID		5.210	5.463	5.853	0.0
DWNCOMER FILLING CALCUL	ATIONS				
TOAN DRESSIDE DOOD		1.742	2.059	2,199	0.0
LEAR LIGHTS HEIGHT		3,296	2.979	2.839	0.0
TAL TRAY PRESSURE DOOP	(HT) TN	5.039	5-038	5.039	0.0
NIET HEAD	(HT) IN	2-839	2,979	3,296	0.0
C HEAD LOSS	(HDA) IN	2.017	0.946	0.630	0.0
C FILLING	(HDC) IN	9,895	8,964	8.965	. 0.0
FILLING	PCT	41.230	37.350	37.356	0.0
DOITIONAL CALCULATIONS					
RCENT JET FLOOD		79-056	89.091	68.751	0.0
INLET VELOCITY	FPS	0.377	0.429	0.346	0.0
				9 a.	
				· · · ·	
LOWABLE DC INLET VELOCI	TY FPS	0.390			•

OVERALL TRAY EFFICIENCY PCT 98.833

PAGE 2

99

Discussion of Sample Problem Output

The output for the first two sample problems (four pass rating cases) show that these trays should have no problems operating under the conditions inputted. The highest downcomer filling is about 37 percent, the highest percentage of jet flood is about 76, and the downcomer velocity for each downcomer is below the allowable value of 0.341 feet per second.

The three pass rating cases do show some potential problems, For both cases, the vapor velocities for passes A and C exceed 100 percent jet flood. This indicates that if the tower were run under these conditions, it is likely to flood. Note, however, that the downcomer velocities are well below the allowable level. Therefore, this tower could be made operable by changing the tray geometry so that the downcomers are smaller (this will increase the downcomer inlet velocities) and the bubbling areas greater. (This will reduce the percentages of jet flood.)

The three and four pass designs are, of course, workable, although downcomer velocities for some individual downcomers are slightly higher than allowable. Methods of balancing and improving such designs are discussed in Chapter IV.

CHAPTER VI

RECOMMENDATIONS FOR THE OPTIMUM DESIGN OF MULTIPASS TRAYS

This chapter presents the techniques recommended for the optimum design of multipass trays. The use of these techniques should provide designs with maximum flexibility and should eliminate those potential problems which have made engineers apprehensive about specifying multipass trays. In summary, the following rules are proposed for the design of multipass trays. They guarantee equal vapor and liquid flow rates for each pass.

- Design for equal bubble areas and equal hole areas for each tray pass. This will enable each pass to accommodate equal vapor loadings. Equal downcomer areas are not necessary, and downcomers should be designed to meet the other criteria recommended.
- 2. Equalize weir lengths and lengths under downcomers for each pass, using the techniques depicted in Figure 10. Also, specify equal downcomer clearances and weir lengths for each pass. This will make the resistance to liquid flow the same for each pass.
- 3. Provide for vapor crossover through the downcomers using either pipes, ducts, or box-type downcomers, depicted in Figure 5. The box-type downcomer may be preferred by tray vendors as it is easier to fabricate. Also, the box-type downcomer provides another means of reducing downcomer weir

Figure 10

METHODS OF PROVIDING FOR EQUAL DOWNCOMER LENGTHS



length, as in recommendation 2. Vapor crossover will make the total tray pressure drop across each pass equal, and will provide a means of any vapor maldistribution (e.g. due to poor distribution at vapor inlet nozzles) to be corrected.

The first recommendation provides for equal dry tray pressure drops (HH) for each pass. The second recommendation provides for equal clear liquid heights (HL) and equal downcomer head losses (HDA) for each pass. If no inlet weirs or equal inlet weir heights and lengths are used, the tray inlet head (HI) will also be equal for each pass. Therefore, the total tray pressure drop (HT) will be equal for each pass. This is guaranteed by the third recommendation. Based on the equations presented in Chapters III and IV, these three recommendations guarantee equal vapor and liquid flowrates for each pass.

Although such a design may be slightly more difficult to fabricate than an equal flowpath length design (which can utilize tray panels of the same width), it has distinct advantages. An equal flowpath design, or, for that matter, any design, <u>can</u> be specified to provide any desired vapor and liquid split between the three or four passes. However, the desired split will <u>only</u> occur at the design vapor and liquid loadings. If the total vapor and liquid rates vary at all from the design values, the split will vary.

This variation is due to the fact that the clear liquid height equation is dependent on a term which includes the liquid rate, plus

a constant term dependent on the weir height:

 $HL = \beta (HOW \tau HWO)$

Where HWO = $0.48 \times F_W (GPM/LWO)^{2/3}$

The head over the weir (HOW) depends on the liquid rate (GPM), but the weir height (HWO) is a constant.

For example, suppose the total liquid flowrate is 4000 GPM on a four pass tray. If the tray is designed for equal weir length and height, the clear liquid height for each pass will be equal. With weir height set at 2 inches and every weir length set at 200 inches, the clear liquid height for each pass with 1000 GPM is 2.38 inches $(F_W = 1.0, \beta = 0.7)$.

HL = 0.7
$$\left[0.48 \times 1.0 \times (1000/200)^{2/3} + 2.0\right]$$

= 2.38 inches

If one weir length is 240 inches, and another 120 inches, the two clear liquid heights can still be made equal for an equal liquid split by making the longer weir 2.16 inches high and the shorter weir only 1.43 inches high.

$$HL_{A} = 0.7 \left[0.48 \times 1.0 \times (1000/240)^{2/3} + 2.16 \right]$$

= 2.38 inches
$$HL_{B} = 0.7 \left[0.48 \times 1.0 \times (1000/120)^{2/3} + 1.43 \right]$$

= 2.38 inches

This example shows how even designs with unequal weir lengths <u>can</u> be made to have equal clear liquid heights for any given set of loadings. Only the weir height need be varied.

Suppose, however, that during the course of a tower's life, it must be operated at less than design rates. Suppose half rates, or a total liquid rate of 2000 GPM, were run through the tower. The equal weir length design would <u>still</u> have equal clear liquid heights for each pass.

HL =
$$0.7 \left[0.48 \times 1.0 \times (500/200)^{2/3} + 2.0 \right]$$

= 2.02 inches

However, the unequal weir length design, which gave equal clear liquid heights for the design rates, does <u>not</u> give equal clear liquid heights for half rates.

$$HL_{A} = 0.7 \left[0.48 \times 1.0 \times (500/240)^{2/3} + 2.16 \right]$$

= 2.06 inches
$$HL_{B} = 0.7 \left[0.48 \times 1.0 \times (500/120)^{2/3} + 1.43 \right]$$

= 1.87 inches

For this reason, if both designs were specified to provide for equal vapor and liquid rates to each pass for the design conditions, only the equal weir length design would have equal splits under <u>all</u> conditions. Only the equal weir length design provides for equal clear liquid heights for all conditions, which, combined with the other recommendations, guarantees equal vapor and liquid splits for each pass. Tray vendors have revealed that equal flowpath length designs have had operability problems due to imbalanced flowrates at other than design conditions (2).

The procedures presented in this chapter guarantee symmetrical multipass tray designs. Therefore, using these recommendations, engineers should have no "aversion" to specifying multipass trays in fractionating towers.

CHAPTER VII

CONCLUSIONS

This thesis has presented the case for the usefulness of multipass trays for large fractionating towers. An example will demonstrate how multipass trays are economically attractive.

Holland, et al (3) have stated that the cost of a tower of constant height increases linearly with capacity.

$$C_2/C_1 = Q_2/Q_1$$

Where C_2 and C_1 are costs for 2 towers and Q_1 and Q_2 are their respective capacities. Because capacity increases linearly with tower cross sectional area, it increases proportionately to the square of the diameter.

$$Q_2/Q_1 = (D_2/D_1)^2$$

Where D_2 and D_1 are the required tower diameters for the two towers. Therefore, tower cost increases with the square of tower diameter.

$$C_2/C_1 = (D_2/D_1)^2$$

Using this relationship we can compare the costs of towers using trays of varying number of liquid passes for a given service. For a system with a liquid load of 2000 GPM and a vapor load (V_L) of 37 cubic feet per second, one tray vendor (7) suggests the diameters given below for a typical column with 24 inch tray spacing. If the cost of the four pass design is set at 100, the relative costs of each of the other designs is given below.

No. of passes	Diameter (ft)	Relative Cost
1	18	192
2	14.5	124
3	13.5	108
4	13.0	100 (Base)

As shown in the table above, one, two and three pass designs are 92, 24 and 8 percent more costly than a four pass design. With the cost of large towers running in the six and seven figure range, substantial savings can be realized if multipass trays are used.

Through the use of the equations, recommendations, and computer program presented in this thesis, multipass fractionating tray design should be made easier to those engineers in the chemical and petroleum industries who do not have access to proprietary procedures. Although multipass trays sometimes have slightly lower tray efficiencies than trays with longer flowpath lengths, this effect becomes negligible for large size towers. Therefore, multipass trays are economical for many large tower designs, and should be specified more frequently by process design engineers.

APPENDIX

Fortran IV Computer Program for Rating and Designing Three and Four Pass Sieve Trays

Εύστκαν ΙΛ	31 RELEASE	?•0	MAIN	DATE =	74100	1+/52/38	PAGE 0001
	C .	FOUR PASS SI	EVE TRAY RATIN	G PROGRAM			
0001		REAL LEP, LT	UT, L, LIQDES,	LIQMIN, LBGAL	,L₩0,L∀1,LU	D.LFP.LIQCON,	
0002		REAL LWOTOT,	LUDTOT				
,00° s		DIMENSION #1	14),HW7(4),HWI	(4),C(4),AD(4)	TITLE(60),	ADC1(4), ADCD(4)	
		L ,LH 2 HI 3 ,L(4), 4VLAR(4),S{4)	10(4),LWI(4),LU (4),HUD(4),HD(XKHP(4),XKGP(4 ,GPHFTW(4),A(4	D(4),LFP(4),AB 4),SHAPE(4),RE),V(4),VD(4),H),B(4),ALPHA(2	(4),AF(4),H CBOX(4),AOA F(4),PCTHD(),TÅBLE1(11	ED(4),HC(4), B(4) 4),VL(4),)	
2,004		CIMENSION HC	KHL(4),VBJET(4), PCT JET (4), CFS	SL(4), DCV EL	(4),GPHETD(4)	
0.005		DIMENSION TA	BLE2(72), TABL	E3 (72) , TABL	E4 (18)		
0006		DATA ALPHA/	NOT, YEST	•			
0007	. 1	DATA TARLET D	/ 8.0, 16.0, 2. 0.156, 0.232	.0, , 0.285, 0.314, , 0.375, 0.390	, ,		
0009	~	DATA TABLEZ	/ 11.0. 0.0. 10	0.0.510, 0.590	,		
	1		4.0, 0.0, 20	000.,			
· · · ·	2	2 10.0,10.	0,10.0,10.5,12	.0,13.3,14.4,19	.7,16.9,18	.2,19.4,	
	3	10,0,10,	0,10,5,12,3,13,	.5,14.9,16.2,17	•5,18,9,20	.2,21.5,	
	4	10.0,10.	6,12.5,14.0,15.	.4,16.7,18.0,19	.4,20.7,22	•0•23•3•	
0.009		0 10+0+12+ 0ATA TABLES	0,14,4,10,2,10,	i/,18+2,19+/,21 D D-	• 2 9 2 2 • 1 9 2 4	•2,25.1 /	
.0007	1	DATA TABLES	6.0.0.0.0.10	000			
	2	7.0, 7.	0, 8.5,10.2,11.	5,12,7,13,7,14	.7.15.7.16	.7.17.7.	
	· .3	7.0,7.	4, 9.4,11.1,12.	5,13.8,14.8,15	.8,17.0,18	.1,19.2,	
	4	7.0,8.	6,10.6,12.3,13.	7,14.9,16.2,17	.4,18.6,19	.8,21.0,	
	. 5	7.4, 9.	9,12.2,13.8,15.	3,16.5,17.9,19	.2,20.5,21	.8,23.0,	
	C 7		8 : 13 : 9 : 17 : 4 : 10 : 0 : 15 : 7 : 17 : 3 : 19	0 10 5 31 1 33	1.8,22.1,23	•4, Z4. / +	
0010		DATA TABIE4				*7+21+2 /	
	1		10.0.36.2.50	0.60.4.68.6.76	.).82.4.		
	2		88.5,94.3,99.	6,104.5,109.3,	113.4,117.	0,120.0 /	
0011		CALL RELOC					
0012	1000	VAPCON = 0.0					
0013	c	LIQUEN = 0.0					
	C C	USES FULLOWI	NG TYPICAL VALU	JES FOR 'FW' AN	D BETA	· .	
2014		FW = 1,00			•	· .	
0015		BETA = 0.70					
	c ·	USES FOLLOWI	NG TYPICAL VALU	JE OF CVO	·		
1016	L	CVD - 0 70				•	
1017		$V_{0} = 0.186$	*()_/(VD)**2.			•	
	Ċ						
	00	READ INPUT DA	ΑΤΑ				
0013		READ 1001, TH	TTLE				
2010	1001	FREMAT(2044)					
0020	1	SEVU 1005° A.	PDES, VAPMIN.	RHOV,CROSS,			
	1	L	DOES, LIGHIN,	PHOL, VISC, SU	9F •		

Elbin70 IA GI	RELEASE	2.0	MAIN	DATE = 74100	14/32/39	P438 0002
		2 3 4 5	TEMP, PSIA, NP, DHOLE, DT, TS (W(I),I=1,5), (W(K),K=5,10), NBO(I) = DU(I) - C(, 	2nv(1)	
		о 7 3 9 А	HWO(1), HWI(1), C(HWO(2), HWI(2), C(HWO(3), HWI(3), C(HWO(4), HWI(4), C(ASAIN	<pre>2), AO(2),SHAPE(2),REC 3), AO(3),SHAPE(3),REC 3), AO(3),SHAPE(3),REC 4), AO(4),SHAPE(4),REC</pre>	55X(2), 85X(2), 85X(3), 85X(4) ,	•
0021	1002	EARMAT (1	2F10.3,F10.5,10X,F10.4 2F10,3,F10.5,2F10,4,/	· , / , ,		
		2 .	2F10.3,/, F10.3,3F10.5,/,			
		4 5 6	2(5+10,4,/), 4(6F10,4,/), F10(4)			
	C C	INTERMED	IATE CALCULATIONS: LO	DINGS AND GEOMETRY		
3372	ĉ	7520 - 0	0			
0022 0023 0024		DRHOL = VTOT = V	.0 RHOL / (RHOL - RHOV) APDES /(RHOV * 3.6) TODES /(RHOL * 3.6)			
0025 0027 0028		LTOT = C DRHOV = VLTOT =	FSLL* 448.8 RHOV / (RHOL - RHOV) VTOT * SQRT(DRHOV)			
0029	C	IF (TS.E	Q.0.0) TS = 24.			
	Č C	DOWNCOME	R INLET VELOCITY: A TY	PICAL EQUATION		
0030 0031		HFACT2 = RHOFAC =	TS/24. (RHOL - RHOV)			
0032 0033 0034		IF (RHOF ALLVEL =	AC.GT.30.)RHOFAC = 30. STLU(PHOFAC,TABLE1)			
2035 2035 2037		ALLVEL = TOTOCA = TE LDT.G	ALLVEL * HFACT2 CFSLL/ALLVEL T.O.O. GG TO 1003			
0039 0039	_	IF(VLTOT IF (NP.E	•GT•100•) GD TO 2154 Q.3•0) GD TO 1004			•
	с С	DESIGN -	FOUR PASS			
0040 0041	L.	IF(LTOT. OT = DTL	GT.6000.) GO TO 2162 U(VLTOT,LTOT,TABLE2)			
CC→2	Ċ	ACS = .7	A5 ≠ (DT**2.)			
	с. С	4-2433 J	JE 313N			
0043 0044		40C1(1) 40C0(1)	= .21 * TOTDCA = ADCI(1)			
20045 20459 2047		w(1) w(6) w(8)	= MISE(100,*A001(1)/A0 = W(1) = 5.78 * TOISEA/ST	8) * 0.12 * 01 1		

FORTRAN IV 31	° EL EASE	2.0	1 A I N	CATE = 74100	14/52/39	PAGE 0003
0049		w(3) = w(3)				
2049		W25. = 6.9 *TOT	CALDE			
1051		w(f) = w25 /2				
1051		A(10) = W(5)				
2052		$XEPI = (12.50)^{-1}$	(2. *#(1)+2 *#(18)	+42511 / NP		
1053		w(2) = xEP1	2	- 12 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2		
0.054		w(A) = xEQt				
1055		d(7) = YED				
2055		1(1) = 1(2)				
0057						
V U V I	c	00 10 1005				
	Č	DESIGN - THREE PA	SS			
0.023	ິ ເ	TELLIOT OF EDOO N	C . T			
0 0 5 5 5	L304	1F(L+3F.54.5000.)	GU 19 2165			x
0057		UI = UILU(VLIUI)L	IUI + TABLES			
1060	c	405 = • 185 # (DI*	<i>₹∠•</i> }	•		
	č	3-PASS DC DESIGN				
	С					
0061		4DCI(1) = .31 * T	UTDCA			
0062		ADCO(1) = ADCI(1)				
0063		W(1) = RISE (1)	00.*ADCI(1)/ACS) = 3.12 = DT		
0064		w(7) = w(1)				
0065		W(5) = 8.63 *	TOTOCA / DT			
0065		W(3) = W(5)				
0067		XFPL = (12.*DT)	-(2.*W(1)+W(5)))/NP		
0068		W(2) = XFPL				
0064		A(4) = XFPL				
0070		W(6) = XFPL				· · · ·
0071	1.003	CUNTINUE				
0072		$AUS = 0.7854 \times 01$	**()	T))+400 + 0 01		
0073		AUCI(I) = REA((I))	0. #NDCI/11/12.#U	$1)1 \neq \Delta CS = 0.01$		
0074		LWU(I) =CHRD (IO	U. #AUCICI// AUSI	= ') ≠ 0•12		
0.075		XWI = W(I) + W(Z)	A + YU1) (11) +0	T) 1 3 4 C C + 0 0 1		
0073		AB(1) = XAI	0.*XW1) /(12.**)	1)1*AUS * 0.01		
0079		AB(1) = AA1 -		+ 07 + 0 10		
0078		100(3) = 000(1)	UU. MAAL /ACSI	* 01 * 0012		
0014		$L_{min}(3) = L_{min}(3)$				
0000		LEFETII = W(Z) ¥⊎2 = ¥⊎1 i u(2)/	2			
0.092		YA2 - DEA((100 **	ム) レクト / /12 まつていい			
0022		ABCD(2) = ABC(100 + A	NZF 7 (12+~07)7	~AUS ~ 0.01		
0095		$\begin{array}{c} \mathbf{A} \mathbf{D} \mathbf{C} \left[\mathbf{A} \right] \mathbf{D} \mathbf{J} = \mathbf{A} \mathbf{A} \mathbf{Z} = \mathbf{A} \\ \mathbf{Y} \mathbf{U} \mathbf{Z} = \mathbf{Y} \mathbf{U} \mathbf{Z} = \mathbf{U} \mathbf{I} \mathbf{Z} \mathbf{J} \mathbf{J} \end{array}$	A1 2			
3085		$YA3 = DEA(11)0 \pm Y$	4. ₩ 3) / (12 ±ΩΤ))	*********		
0.085		164NP-50.3.1 CO T	0 500	- AC3 - 0401		
0000		ADCC(4) = XAR - X	A 2			
2.384		H(0)(4) = CH(0, 1)	00. * YAA / ACS)	× 0T * 0.12		
0.044		1 (0, 1, -) = 0 (1, 0) (1, 1)	004 . 140 / 400/	// · · · · · · · · · · · · · · · · · ·		
3320		XW4 = XW3 + w(4)				
2001		XA4 = REA((100-*X))	₩4)/(12,×0T)) ÷	ACS # 3.31		
0092		$\Delta is(2) = X\Delta 4 - X\Delta$	3			
0001		= (2) = st(4)	-			
3394		$E_{RO}(Z) = CHPO((1))$	00.#XA4/4C5)) *	0T · # 3.12		
<u>,)04</u>		1001(2) = (105/2.)	- X14			

0096 ADCD(1) =REA((100,*W(6)) /(12,*近ず)) キ ACS キ 0097 LWI(1) =CHRD (100,*ADCU(1)/ACS) キ DT * 0093 LU0(1) = LWI(1) 0093 LU0(1) = LWI(1) 0099 ズ水5 = W(5) + W(7)	3.91
0097 LWI(1) =CHRP (100.*ADCO(1)/ACS) * 9T * 0093 LUO(1) = LWI(1) 0099 Xx5 = W(5) + W(7)	
0093 EUD(1) = EWT(1) 3399 Xx5 = W(6) + W(7)	0.12
0.399 Xx5 = W(5) + W(7)	
2100 X45 = REA((100.*XW5)/(12.*DT)) * ACS *	0.01
AB(3) = XA5 - ADCO(1)	
5102 LFP(3) = $*(7)$	
0103 LW0(3) = CHRD (100.*XA5/ACS) * OT *	0.12
3104 XW6 = XW5 + W(9)/2.	
0105 XA6 = RE4((100.*Xx6)/(12.*DT)) * ACS *	0.01
4001(3) = XA6 - XA5	
3137 XW7 = XW6 + $w(8)/2_{\bullet}$	
$2109 \qquad XA7 = 9F3((100.*XW7)/(12.*DT)) * ACS *$	0.01
$109 \qquad 10CI(4) = XA7 - XA6$	
0110 LW0(4) = CHRD(160,*XA7/ACS) * DT *	0.12
3111 XW8 = XW7 + W(9)	
0112 XA8 = REA((100.*XW3)/(12.*DT)) * ACS *	0.01
AB(4) = XAB - XA7	
0114 LFP(4) = W(9)	
0115 LWI(2) = CHRD(100,*XA8/ACS) * DT *	0.12
UD(2) = LwI(2)	
2117 ADCO(2) = (ACS/2.) - XA8	
0113 WW3 = W(3)/2.	
0119 WW8 = W(8)/2.	
0120 GO TO 501	
0121 500 ADCO(2) = $XA3 - XA2$	
0122 $UUD(2) = CHRD (100.*XA3 / ACS) * DT * 0.12$	•
0123 LWI(2) = LUD(2)	
D124 ADCO(1) = REA((100.*W(7))/(12.*DT))*ACS * 0.0	1
0125 LUD(1) = CHRD(100.*ADCO(1)/ACS) * DT * 0.12	
126 LWI(1) = LUD(1)	
0127 XW4 = W(7) + w(6)	
0128 $XA4 = REA\{(100.*XW4)/(12.*DT)\}*ACS * 0.01$	
0129 AB(3) = XA4 - ADCO(1)	
0130 $LWO(3) = CHRD (1C0.*XA4 / ACS) * DT * 0.12$	
0131 $LFP(3) = W(6)$	
0132 $XW5 = XW4 + W(5)/2$.	
0133 XA5 = REA((100.*XW5)/(12.*DT))*ACS * 0.01	
ADCI(3) = XA5 - XA4	
3135 XW6 = XW5 + W(5)/2.	
0135 $XAb = REA((100.*XW6)/(12.*DT))*ACS * 0.01$	
D137 ADCI(2) = XA5 - XA5	
D138 LWO(2) =CHRD(10C.*XA6 / ACS) * DT * 0.12	
0139 $AB(2) = ACS - XA6 - XA3$	
140 LFP(2) = W(4)	
D141 LFP(4) = 0.0	
2142 AB(4) = 0.0	
2143 $LID(4) = C_0 O$	
0.144 LWI(4) = 0.0	•
0145 I WO(4) = 0.0	
$\Delta IUC I(4) = 0.0$	
2147 (10.7)(4) = 0.0	
)143 $k_{3} = N(3)/2$.	

	EDATELS IV G1	RELEASE	2.0 MAIN	DATE = 7	4106	1+/52/33	PAGE 000
:	2150	501	CONTINUE				an an
		C C	CALCULATING MINIMUM P	PEE AREAS			
	2151	1,	$\Delta F(1) =$	$\Delta B(3) + ADCO$	1(1)		
	0152		IF(NP.F9.3.)30 TO 502				
	0173		4F{2} =	AB(4) + ADCO	(2)		
	2154		AF(3) =	AB(1) + ADCO	1(3)		
	0155		ΔF(4) =	A8(2) + ADCO	(4)		
	215-		$\Delta B \Delta S = \Delta M I N I ((2 * \Delta B (1)))$	+ 2#48(2))/ACS ,(2*A	B(3)+2# AB(4))/ACS}≠100.	
	2157		GO TO 503				
	3153	502	AF(2) = AF(2) + ADCO(2)	2)			
	0153		$\Delta F(3) = \Delta B(1) + \Delta D C D(3)$	3)			
	0140		AF(4) = 0.0				
	0161		ABAS= ((AB(1)+AB(2)+AF	3(3))/ACS)*100.			
	0102	503	CONTINUE				
	0153		IF(C(1).NE.0.0) GO TO	5503			
		С					
		C C	DESIGN OF CLEARANCE,W	EIR HEIGHT, AND HOLE	AREA .		
		č	SET HWO SUCH THAT HC =	= 3 INCHES			
	2364	U U	1 = 1 = 1 = 1 = 1 = 1 = 1 = 1 = 1 = 1 =	+1 40 (3) +1 40 (4)			
	0165		HWTX = (3, -, 48 + 8 + 74 + 74 + 74 + 74 + 74 + 74 +	*[[[TOT/]WOTOT]##0.66	711/8FTA		
	7165		DP = 901 I = 1.4		1110218		
	0167	901	HWD(1) = HWDX				
	0168		1E(NP_E0.3.0) HWP(4)=(0.0			
	0105	ſ	SET C SICH THAT HID =	1 TNCH			
		č	CMAX = 3 INCHES	1 1100			
		č	CMIN = 1 INCH				
	0153		UDTDT=UD(1)+UD(2)+1	(D(3)+(UD(4)))			
	0170		00.902 I=1.4				
	0171		SHAPE(I) = 0.0	· · ·			
	G172	902	C(I)= 2449* LTOT/LUDTO	٦T			
	3173		IF(C(1),(E.3.0) GO TO	903			
	0174		DO 904 I=1.4				
	3175		SHAPF(I) = 1.0				
	0176		C(I)=, 1732* I TOT/I UDTO	T			
	2177	9:04	C(T) = AMINI(C(T), 3, 0)				
	2178	903	DO 906 I=1.4				
	2179	906	C(I) = AMAX1 (C(I).1.0)))			
	3193		IF (NP.EQ.3.0) C(4)	= 0.0			
		С	SET AD SUCH THAT HED =	2 INCHES			
	5131		ADTOT = (SQRT ((XCVD*RH	ICV)/(2.*RHOL))) * \	TOT		
	5182		IF(NP.EQ.4.0)GD TO 905			· .	
	3143		40(1) = 0.31 * A0TOT		· .	1 .	
	0194 -		AO(2) = 0.38 = AOTOT				
	0135		$40(3) = 0.31 \pm AOTOT$				
	314-		AD(4) = 0.0				
	- 2137		GD TO 5503				
	2124	905	47(1) = 0.21 *AOTOT				
	01ea		40(2) = 3.23 *AUTOT				
	1111		AD(3) = 0.21 #40TOT				
			A0(4) = 3.29 #A0TOT				

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+3KIK70 IV :	ગા ⊴ા	. 2435	2 • J	MAIN	0A1E = 74100	14752738	PAGE 0005
0193			M≡VP				
2194			00 2 I=1,	м			
0195		2	ADAB(I) = (AU(I)/AB(I))*100.			
0196			IF(NP.EQ.3	•) ABAB(+)=C.3			
	(<u> </u>
	(DUDALE IKI	AL AND ERROR LJ D	ADED CODESCUES	VAPUR FLOW SPLIT	3
			PER PASSA	FUUR PASS - NE V	A PUR URUSSUVER.	51 A 1	
			F1531 9033	S VADOD SDITTEON	JITUIN DO LOOD ELO	FLUMA E TAUTO COLTTEROS	1
			OU LOUP PD	R VAPOR SPLITTOUT	ATTAIN DO LOOP FOR	LIVUID SPLINIUD	· •
0197	,	/	TEINP.FO.3	-) 60 TO 504		¥	
0194			1(1) = 110	T/4-			
0199			DELTAL = -	03 × 1 TOT			
0200			07 100 JL =	1.40		x	
0201		•	1(2) = 0	50 * 1707 - 1(1)		· .	
0202	,		(3) = (1)			
0203			L(4) = L(2)		· ·	
0204			DO 16 T=1,	4			
0205			HC(I) = 0.	48*BETA*Fw*(L(I)/	LWO(I))**0.667 + BET	A≃HWO(I)	
0206			IF(SHAPE(I)) 11,11,12			
0207		11	HUD(I) = 0	.06 * (L(I) / (C	(I)*LUD(I))) ** 2.		
0208			GO TO 13				
0209		12	HUD(I) = 0	•03 * (L(1) / (C	(I)*LUD(I))) ** 2.		
0210		13	HI(I) =0.	48*(L(I)/LWI(I))**0.667 + HWI(I)		
0211			IF(HWI(I).	GE.C(I).OR.RECBOX	(I).GT.0.0) HUD $(I) =$	2*HUD(I)	
0212		16	CONTINUE				
0213			IF(HWI(I).	GT.0.0) GU TO 14	*		
0214			HI(1) = HC(3))			
J215			H1(2)=HC(4)	•		
0216			H1(3)=HC(1				
0217-		14	H1(4)=H(12)			
0210		14	LUNIINUE				
0219	<u>ر</u>		1-10-03-5+14	E+1+0760 10 13			
	r			PROR TO DETERMIN	- LOADTNES - FOUR PAS		AUCCUVES
	č		SOLVE EOR I	15 AND V1/V2. V3	V4 INDEPENDENTLY		
	č				1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		
220	-		HI3 = HI(4)) + HUD(4) - HUD(3	3) .		
0221			IF(HWI(3).	LE.0.0) GO TO 303			
0222		,	QUTERM =(H	13-HWI(3))/0.48			
0223			QLT = QLTER	RM##1.5		· · ·	
0224			OLI = QLT*I	LWI(3)			
0225			IF (ABS(QL1-	-L(1)).LT.0.01) G	TO 107		
0226			IF(QL1.GT.	L(1).AND.DELTAL.LE	$E.0.0$ DELTAL = -0.4^{*}	*DELTAL ·	
0227			IF(QL1.LT.	L(1).AND.DELTAL.GE	.0.0) DELTAL = -0.44	*DELTAL	
0223		1	L(1) = L(1)) + DELTAL			
0229		,	GO TO 100				
0230		303 (UTERM = (H)	L3-BETA*HWU(1))/(0].48≠F6×3ETA]		
J231 .		(ULT= OLTERA	**1.5			
0232		ſ	161= QLT#L	NU(1)			
0233			LETAR STOLI-	-LUL)].LT.0.01) G6		- 7 - 1 7 - 1	
12234 3012			LET GLIB STAT	ATTA AND DELTAL LE	(,C,J) USLIAL = →C,4* A 31 001744 =	S JELFAL ANDERAL	
073-			2514L1+L1+L (1) = (1)	しんエチゅう 140 m しつ & FAL # 55 トーム・カロト エムト	● ジ● ノナー いたしてみし ニューニューマ	STELEAR PL	
16.20		1	(1) = 1(1)	I ∓ 066'46			

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FURTRAN	I√ G1	RELEASE	2.0	MAIN	DATE = 74100	14/52/38	PAGE 0007
3237			GC TO 100			•	
		С					
		C C	TRIAL AND FR	ROP FOR VAPOR S	SPLIT		
0.239		15	V(1) = VTOT/	4.			
0239			00 50 IV =1;	50			
32.49			V(2) = 0.5 * V	TOT - V(1)			
0241			V(3) = V(1)				
0242			V(4) = V(2)				
J243 0244			$V_{0}(1) = V(1)$	/ 40/11			
12+5			HED(I) = XCVC	* + /	((VO(I))**2.)* RHOV /	PHOL	
2240			HT(I) = HC(I)) + HED(I)	· · · · ·		
0247	1 · · ·	20	CONTINUE				
0248			HED3 = HT(4)	+HUD(4) + HI(4	4) -HC(3) -HJD(3) -HI(3)	
0249			V03 = SORT((HED3*RHUL)/(RF	HUV*XCVU))		
0250			V3 = VU3 =	AU(3) - V(3)) (T.O. 0))	1 GO TO 55		
0.252		50	V(1) = AMIN1	((V(3)+V3)/2.	• 0.49*VTOT)		
0253			VAPCON=1.0				
0254		55	HC1 = HT(2)	+HT(4) - HT(3)	- HED(1)		
0255			QLTERM = (HC	1-BETA#HwO(1))	/ (0.48*FW*8ETA)		
0256			QLT = QLT	2RM ** 1.5			
0257		1.01	QLI = QLI	- ▼ LWU(L) /1)) /T.0 01) 6	N TO 107		
0259		101	TE(0) LGT_L	11. AND. DELTAL.C	$S_{-0.0}$ DELTAL = $-0.4*$	DELTAL	
0260			IF(QL1.LT.L(1). AND. DELTAL.L	E.0.0 DELTAL = $-0.4*$	DELTAL	
0261			L(1) = L(1)	+ DELTAL			
0262		100	L(1) = AMIN1	(L(1),0.49*LTOT	F)		
0263			LIQCON=1.0	1 ALAO TO 135			
0264		107	IFICKUSS.NE.	1.0160 10 105			
		C	VAPOR SPLIT	- FOUR PASS - W	ITH VAPOR CROSSOVER		
0265			V(1)=VTOT/4.				
0266			DO 400 I1=1,	50			
0267			V(2) = 0.50	* VTOT - V(1)			
0268			VU(2) = V(2)/	4U121 * ((VD121)++2	1 * PHOV / PHO		
0269			HEU(2) = HE(2)	+ ((VU(2//~~2+)+HED(2)	A T KHOV / KHOL		
0271			HED1 = HT(2)) - HC(1)			
0272			VD1 = SORT	((HED1*RHOL)/(R	8H①V*XCVO))		
0273			V1 = V01	4 AO(1)			
0274			IF (ABS(V1-V	(1)).LT.0.01) G	50 TO 401		
0275		400	V(1) = AMINI	1(V(1)+V1)/2.,0),49*VIUI)		
J216 0277		4.01	$VAPLUM = I_{\bullet}U$ $V(A) = VINTA$	4.			
0278			00 402 I2=1.	50			
0279			V(4) = 0.50*	VT0T-V(3)			
2230			VO(4) = V(4) /	10(4)			
)281			HFD(4)=XCVO*	((VO(4)) **2,) ⇒	* PHOV/RHOL		
3282			HT(4) =HC(4)	+HED(4)			
0233			112173 = HIL4	I = HU(3)			

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	Fritsde IV	G1 RELEASE 2.0	NUTV	DATE = 74100	1+/52/38	PAGE 0008	
	3795	V3 = V(1	3 × A(1(3)				
	3236	TELABSEV3-	V(3)). (T. 0. 01) G3	TC 403			
	5247	-02 VI31=AMINT	((V(3)+V3)/2,.0.4)	TCTT			
	1298	VAPCON =1.	0				
	1222	AND CONTINUE	5				
	1221	00 TO 506					
	12+1	eru e u e e					
		C THREE PASS	•				
	1211	5201401-0.0					
	J 2 4 L	5.4 L(4)=0.9					
	1292	V(4) = 0.0	-				
	0273	L(1)=L(UT/	3.				
	2294	DELTAL=.03	*LTOT				
	0295	ND 600 JL=	1,40				
•	0296	L(3)=L(1)					
	3297	L(2)=LTOT	-L(3) - L(1)				
	0298	D0 616 I=1	,3				
	3299	$HC(T) = O_{a}$	48*BETA*FW*(L(1)/	LWO(I))##0.567 + BETA*H	WO(I)		
	רסינ	TE(SHAPE(I	1)611.611.612			•	
	0.501	511 HUD(1) = 0	-06 * (1(1) / (C))	(I)*LUD(I))) ** 2.			
	1302	GD TD 613					
	3302	412 + 400(1) = 0	03 * (111) / 10	(T)*(UD(T))) ** 2.			
	2000	413 HI(I) = 0	49±1 1 (1) /1 w1 (1)	$1 \times 10^{-67} + H \times 11^{-1}$			
	3304	212 HILL -0.	CE C(T) ON DECODY	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	NUD(T)		
	0000		GC.U(I).UK.KEUDUA	$(1) \cdot 6(1) \cdot 6(1) = 2^{-1}$			
	0306	515 CUNTINUE					
	0307	IF(HWI(I).	G1.0.0) GU 10 814				
	2308	HI(1) = HC	(3)				
	0309	HI(2) = HC	(2)				
	0310	HI(3) = HC	(1)				
	0311	614 CONTINUE					
	0312	IF(CROSS.N	E.1.0) GO TO 615				
			- I/V SPITT - 1	STTH VADOR CROSSIVER		,	
		C INCE PASS	- L/V SFLIT - 1	ATH AREA CROSSOVER			
	0313	нта = нт	(2) + HID(2) - HII	(3)			
	0314	TELHWILS).	LE. 0. 01 GO TO 703				
	0214	OLTERM - (HT3-HHT(3))/0.48				
	2214		1 TCD M##1 5				
	1310		1 741 41/21				
	0.017		-1(1) $+1$ $+1$ $+1$ $+1$ $+1$ $+1$ $+1$ $+1$	TO (07			
	0313		$- \left[\left(1 \right) \right] \circ \left[1 + 0 + 0 \right] = 0$	= 0 0 0 0 0 0 0 0 0 0	ETAL .		
	.1.319		LILIAND DELTAL LO	-0.01 DELCAL = -0.4+00			
	0320	LPN QLL+L1+1	LILI AND DELIAL G	$c_{\bullet}()_{\bullet}()$ DELIAL = -0.4×0.6	LIAL		
	0321	L(1) = L(1)) + DELTAL				
	0.322	GD TC 600					
	3323	. 703 QLTERM ={H	13-8ETA*HW0(1))/($) \cdot 48 \neq F \neq B \in T \land \}$			
	0324	0LT =0L	TERM##1.5				
	0325	9L1 =9L1	T * LWO(1)				
	0326	IF(ABS(QL1-	-L(1)).LT.Ò.01) G(D TO 607			
	0327	IF(QL1.GT.L	L(1).AND.UELTAL.LE	5.0.0) DELTAL = -0.4*08	LTAL		
	0328	TF(QL1.LT.	L(1).AND.DELTAL.G	5.C.O) DELTAL = -0.64DE	LTAL		
	9329	L(1) = L(1)) + DELTAL				
	2332	30 70 600					
		(
		C VARAR SOLT	т				· · · · · · · · · · · · · · · · · · ·
		1 9447 DF 07 6 1	•				
		•			•		

ETRIPAN IV 31	PPLEASE 2.0	MAIN	EATE = 74100	1+/52/33	PAGE 0009
•	С	·			
3351	615 V(1) = VT(JT/3.			
0332 -	່ <u></u> ີ ວິ ∋50 IV=	=1,50			
2333	. V(3)= V(1)	j -			
3334	V(2)= VT1	(-V(2) - V(3))			
0335	DD 620 I=1	1,3	,		
0336	V0(I)=V(I)	(AD(I)			
3337	HEO(T) = XCV	/:) = ((VO(1))*=2.)*	RHCV/RHOL		
7738	$H^{T}(T) = HC$	T)+HED(T)			
3339	520 CONTINUE				
0340	$\frac{32000311032}{1001} = 171$	2) + HT(3) + HUD/2	h = H(1) = H(2) = H(1)	n(2)	
1341			Y (((1)) (1)2) (0)		
2247	VUX - 396	······································			
0342	VI = V01	$\mathcal{P} = \mathcal{P}(1)$	C() TO : 55		
2266	15 14031N	$(1 - V(1)) \cdot (1 - 0) \cdot (1)$			
2044	UNDOU VILL = AMI	NITIVILI+VII/2	0*+++A101 1		
0345	VAPLUN =]		••		
0345	555 HC1 =2. *H1	(2) - HI(3) - HED(
0347	QLIERM = 0	HC1-BETA*HWU(1)) /	(0.48*FW*BETA)		
0348	QLT = 6	/LTERM ** 1.5			
0349	QL1 = Q	LT * LWO(1)			
0350	601 IF(ABS(QL)	L(1)).LT.0.01) GO	I TO 607		
0351	IF(QL1.LT.	L(1).AND.DELTAL.GE	.0.0) DELTAL=-0.4*DELT/	AL	
3352	IFEQL1.GT.	L(1).AND.DELTAL.LE	.0.0) DELTAL=-0.4*DELTA	AL	
0353	L(1) = L(1)) +DELTAL			
0354	600 L(1) = AMI	N1(L(1),0.49*LTOT)			
0355	LIQCON = 1	• 0			
0356	607 IF(CROSS.N	E.1.0)60 TO 105			
	c				
	C VAPOR SPLI	T - THREE PASS - W	ITH VAPOR CROSSOVER		
	C '				
3357	V(1) = VTC	T/3.			
0358	V(2) = V(1)	.)			
0359	799 DO 800 13	= 1,50	•		
0360	V(3) = VTO	T = V(1) = V(2)			
0361	DO 801 I=2	• 3			
0362	$v_0(T) = v_0$			·	
3363	HED(I) = X	CV0*((V0(I))**2.)*	RHUV/RHUI		
0366	801 HT[1] - H	$e_1(1) + e_1(1)$	intervention in the second sec		
0365		31 = 40/21	· · · ·		
3346		37 - 10121 T/105324000111//000	V*Y (VO1)		
13CU- 1247		+ A0121	V TAUVUV		
0207	$VZ = V^{i}Z$	* AU(2)	TO 0/ D		
U355	IF TABSTV2	-V(2)).L[.9,01) GO	10 802		
0369	800 V(2) =AMIN	1((V(2)+V2)/2.,0.5	(≠VIOT)		
0370	VAPCON = 1	• 0			
0371	305 CUALINGE	·			
0372	0∩ 903 I4≠	1,50			
0373	$\forall \cap (1) = \forall ($	1)/AO(1)			
0374	HED(1)= XC	VO*((VG(1))**2.)*R	HCV/RHOL		
0375	HT(1) = HE	D(1) + HC(1)			
0375	- HFD1 = HT	(2) - HC(1)			
3377	V01 = S0	RT((HE)1#RHOL)/(PH	OV*XCVC))		
0379	V1 = V01	40(1)			
· · · ·	TC (S)CON	- 4(1) 17 2 211 24	ΤΟ 364		
037-	✓ [► [A](* (V))	- VI a a a a a			
037-		$1 \{ \{ V(1) \} + V(1) / 2 = 0 \}$.57 ×VI(T)		
0372	AIM = (1)V 60F	1((V(1) + V1)/2.,0)	.57 ×VI(T)		

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	FORTRAN IV GI	RELEASE 2.0	MAIN	CATE = 74100	14/52/38	PAGE 001	0
	0391	VAPCON =	1.0				
	0382	804 TRYVT = V	V(1)+V(2)+V(3)				
	0383	IF (ABS()	TRYVT - VTOT) .ST. 0.	01) 3C TO 799			
	0394	505 CONTINUE			· ·		
	3395	DN 404 I	=1, M				
	0386	V0(I)=V(I	(I) / AN(I)				
+ *	0337	HED(I)= >	XCVO * ((VO(I))**2.)	* RHCV / RHOL			
	0388	404 HT(I) = 4	HED(I) + HC(I)			1	
		C	- FILLING CALCULATION	- -			
	•		< FILLING CALCULATION	15			
	1221		~1 M				
	7384	1.05 (1) 1.05 (2)	-1,4			*	
			S LIGHTS CRASTENT ACC	OSS TEAY			
		C 433040 40	S EIGOLY DARDIE I HEA				
	0300	GRAD = 0	- 0				
	0391	HD(1) =(H	+T(I)++UD(I)) +	HI(I) + GRAD			
	0397	105 CONTINUE					
	0393	NO 3 I=1,	• M				
	0394	PCTHO(I)	=(HD(I)/TS)*100,				
	0395	VL(I) = V	V(I) * SQRT(DRHOV)		•		
	0396	VL(I) = V	V(I) * SQRT(DRHOV)				
	0397	VLA3(I) =	= VL(I) / AB(I)				
	0393	S(I) =	= VL(I) /(L(I)/448.8)				
	0 399	GPHFTW(I)	=(L(I)*60)/(LWO(I))	/12.)			
	7400	3 CONTINUE		4 - 4			
		C					
		C ADDITIONA	IL CALCULATIONS	· · · · · · · · · · · · · · · · · · ·			
		Ĺ					
			. A TYPICAL FOUNTION				*
		C 311 (2000	. A CHAICAE EQUATION				
	0401	HEACT1 =	SORT(TS/24.)				
	0402	DO 203 I=	=1.M				
	0403	VBJET(I)	= HFACT1 * 0.55 - 0.	035 * (GPHFT#(I)/1000).)		
	3404	203 PCTJET(I)	<pre>/=(VLAB(I)/VBJET(I))</pre>	* 100.			
	0405	DD 204 I=	=1,M				
	0406	CFSL(I) =	= L(1)/448.8				
	0407	204 DCVEL(I)	= CFSL(I)/ADCI(I)	1			
		с					
		C					
		C TRAY SEFT	CIENCY				
		с <u>-</u>		•	· · · · · · · · · · · · · · · · · · ·		
	0408						
	0410	1 - COIS+					
	0410	C 90 INTING	DECHATE				
		C -NINHING	NE JUEI J				
	2411	00 1 1=1.	. 4				
	0412	Δ(I)=ΔI PH	(A(1)				
	2613	IF(SHAPE([].3T.).0) A([)=ALPH	A(2)			
	0414	3(1)=ALPH	(A(1)				
	J 7 I T						
	3415	IFLAECARX	((1).GT.0.0) H(I)=4LP	HA (2)	·	4	

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0417 0419 0419 0421 0422 0421 0422 0423 0424 0425 0425 0425 0426 0425 0426 0427 0431 0431 0432 0433 0434 0433 0434 0435 0436 0437 0438 0439 0444 0442 0444 0445 0444	CROSSI = A IF (CROSS. PRINT 2001 2001 FORMAT(1H1 ISS SIEVE T PRINT 2002 2002 FORMAT(2) 2003 FORMAT(1X, PRINT 2003 2005 FORMAT(1X, 122X,FI0.3) PRINT 2006 2006 FORMAT(1X, 122X,FI0.3) PRINT 2007 2007 FORMAT(1X, 122X,FI0.3) PRINT 2008 2008 FORMAT(1X, 1 SURFACE TE PRINT 2009 2009 FORMAT(1X, 1 'VISCOSITY PRINT 2017 2009 FORMAT(1X, 1 'VISCOSITY PRINT 2017	LPHA(1) .GT.0,0) CROSSI = AL .//,34%,'DESIGN AND RAYS',25%,'PAGE1',// . TITEE .4%,2044,//),24% ,00A 'OPEPATING CONDITION 	PHA(2) RATING PROGRAM FOP (4,/) S') -',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB COND',16X,F10.3,100 COND',16X,F10 COND',17X,F10 COND',17X,F10 COND',17X,F10 COND',17X,F10 COND',17X,F10 COND',1	THRES AND FOUN S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X,	⊃3	
9413 0419 0421 0422 0423 0423 0425 0425 0425 0426 0425 0426 0427 0431 0431 0433 0433 0433 0434 0437 0433 0439 0444 0442 0444 0444 0444	IF (CROSS PRINT 2001 2001 FORMAT(141 ISS SIFVE T PRINT 2002 2002 FORMAT(?(2 PRINT 2003 2003 FORMAT(1X, PRINT 2005 2004 FORMAT(1X, PRINT 2005 2005 FORMAT(1X, 122X,FI0.3) PRINT 2006 2008 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1 PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2019	.ST.9.7) CRESSI = AL .//,34X,'DESIGN AND RAYS',25X,'PAGE1',// .TITLE 4X,2°A4,//),24X ,20A 'OPEPATING CONDITION '	PHA(2) RATING PROGRAM FOP 4,/) 5') -',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB COND',16X,F10.3,10 COND',16X,F10.3,10 FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	THPES AND FOUN S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X,	23	
0419 0421 0421 0422 0423 0424 0425 0424 0425 0424 0425 0426 0427 0428 0431 0431 0432 0433 0434 0433 0434 0435 0436 0437 0439 0440 0441 0442 0443 0444 0445	PRINT 2001 2001 FORMAT(141 ISS SIEVE T PRINT 2002 2002 FORMAT(7(2) PRINT 2003 2003 FORMAT(1X, PRINT 2005 2005 FORMAT(1X, 122X,FI0.3) PRINT 2006 2006 FORMAT(1X, 122X,FI0.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1 PRINT 2009 2009 FORMAT(1X, 1 * SUFFACE TI PRINT 2009 2009 FORMAT(1X, 1 * VISCOSITY PRINT 2019	<pre>//,34%,'DESIGN AND RAYS',25%,'PAGE1',// TITLE 4%,27A4,//),24% ,20A 'DPEPATING CONDITION '</pre>	RATING PROGRAM FOP (4,/) (4,	THREE AND FOUN S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X,	>∆	
0421 0422 0423 0424 0425 0425 0426 0426 0427 0426 0431 0431 0432 0433 0433 0434 0435 0436 0437 0433 0439 0443 0444 0442 0444 0444	2001 FORMAT(1H1 1SS SIFVE T PRINT 2002 2002 FORMAT(2) 2003 FORMAT(1X, PRINT 2003 2003 FORMAT(1X, PRINT 2004 2004 FORMAT(1X, PPINT 2005 2005 FORMAT(1X, 122X,FI0.3) PRINT 2007 2007 FORMAT(1X, 1208 2008 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1 SUBFACE TE PRINT 2009 2009 FORMAT(1X, 1 * SUFFACE TE PRINT 2009 2009 FORMAT(1X, 1 * SUFFACE TE PRINT 2009 2009 FORMAT(1X, 1 * SUFFACE TE PRINT 2001	<pre>.//,34X,'DESIGN AND RAYS',25X,'PAGE1',// . TITLE (4X,2°A4,//),24X ,?0A 'OPEPATING CONDITION '</pre>	RATING PROGRAM FOP (4,/) S') -',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB 20ND',16X,F10.3,10 COND',16X,F10.3) FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	S/HR LIQUID MAX S/HR LIQUID MAX X, X,F10.3,10X,	24	
0421 0422 0423 0424 0425 0425 0426 0426 0427 0428 0429 0430 0431 0433 0433 0433 0433 0434 0433 0436 0437 0433 0449 0443 0444 0444 0444	PRINT 2002 2002 FORMAT(?(2 PRINT 2003 2003 FORMAT(1X, PRINT 2005 2005 FORMAT(1X, PPINT 2005 2005 FORMAT(1X, 122X,FI0.3) PRINT 2006 2006 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1 PRINT 2009 2009 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	<pre>TITLE 4X,2^A4,//),24X ,30A 'OPEPATING CONDITION 'UPES, LIDDES 'MLBS/HR VAPOR MAX', 'VAPMIN, LIDMIN 'MLBS/HR VAPOR MIN', 'RHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT TEMP,SURF 'TRAY LIDUID TEMPERA' ENSION AT COND',7X,'I PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)</pre>	<pre>/ / / / / / / / / / / / / / / / / / /</pre>	S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X, }	• • •	
0422 0423 0424 0425 0425 0427 0427 0427 0428 0431 0431 0432 0433 0434 0433 0434 0435 0436 0437 0438 0439 0440 0441 0442 0443 0444 0444	2002 F RAMAT(7(2 PRINT 2003 2003 F RAMAT(1X, PRINT 2004 2004 F RAMAT(1X, PPINT 2005 2005 F DR MAT(1X, 122X,F10.3) PRINT 2006 2006 F RAMAT(1X, 122X,F10.3) PRINT 2007 2007 F RAMAT(1X, 1 PRINT 2008 2008 F RAMAT(1X, 1 PRINT 2009 2009 F RAMAT(1X, 1 * SURFACE TI PRINT 2009 2009 F RAMAT(1X, 1 * VISCOSITY PRINT 2010	4X,27A4,//),24X,20A 'OPEPATING CONDITION 'VAPDES, LIDDES 'MLBS/HR VAPOR MAX', VAPMIN, LIDMIN 'MLBS/HR VAPOR MIN', 'RHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT TEMP,SURF 'TRAY LIDUID TEMPERA' ENSION AT COND',7X,' PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	<pre>%,/) S') -',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB 20ND',16X,F10.3,100 C0ND',16X,F10.3) FURE',6X,'DEG F',52 OYNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10</pre>	S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X, }	• • • •	
0423 0424 0425 0426 0427 0428 0431 0431 0432 0433 0433 0433 0434 0435 0435 0436 0437 0438 0439 0443 0444 0442 0444 0444 0444	PRINT 2003 PRINT 2004 PRINT 2004 2004 FORMAT(1X, PPINT 2005 2005 FORMAT(1X, 122X,F10.3) PRINT 2006 2006 FORMAT(1X, 122X,F10.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1 SURFACE TE PRINT 2009 2009 FORMAT(1X, 1'SURFACE TE PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2017	'OPEPATING CONDITION ,VAPDES, LIDDES 'MLBS/HR VAPOR MAX', 'MLBS/HR VAPOR MIN', 'MLBS/HR VAPOR MIN', 'RHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT TEMP,SURF 'TRAY LIQUID TEMPERAT ENSION AT COND',7X,' PSIA,VISC 'OPERATING PRESSURE'	S') -',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X,	• • •	
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0425 0425 0427 0428 0431 0433 0433 0433 0434 0435 0436 0437 0438 0437 0438 0443 0444 0444 0444 0444 0444	2009 FORMAT(1X, PRINT 2005 2005 FORMAT(1X, PPINT 2005 2005 FORMAT(1X, 122X,FID.3) PRINT 2006 2006 FORMAT(1X, 122X,FIC.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	VAPDES, LIDDES 'MLBS/HR VAPDR MAX', VAPMIN, LIDMIN 'MLBS/HR VAPDR MIN', 'RHDV, RHOL 'LBS/CU FT VAPDR AT ('LBS/CU FT LIQUID AT ,TEMP, SURF 'TRAY LIDUID TEMPERA' ENSION AT COND',7X,'I ,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	-',/) 22X,F10.3,10X,'MLB 22X,F10.3,10X,'MLB COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA'.6X.F10	S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X, }	• • • • • • • • • • • • • • • • • • • •	
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)427)428)429)430)431)432)433)434)435)436)436)437)436)437)438)439)440)441)442)442)444)444)444	2004 HILK, PPINT 2005 2005 FORMAT(1X, 122X,F13.3) PRINT 2036 2006 FORMAT(1X, 122X,F10.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'YISCOSITY PRINT 2010	VAPDES, LIDDES 'MLBS/HR VAPDR MAX', 'MLBS/HR VAPDR MIN', 'MLBS/UF VAPDR MIN', 'RHDV, RHOL 'LBS/CU FT VAPDR AT ('LBS/CU FT LIDUID AT ,TEMP, SURF 'TRAY LIDUID TEMPERAT ENSION AT COND',7X, ' PSIA,VISC 'OPERATING PRESSURE', AT COND',13X, 'CP',8)	22X,F10.3,10X, MLB 22X,F10.3,10X, MLB 20ND',16X,F10.3,10 COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X, DEG F',5 DYNES/CM',2X,F10.3 11X,'PSIA',6X.F10	S/HR LIQUID MAX S/HR LIQUID MIN X, X,F10.3,10X,	• • • • • • • • • • • • • • • • • • • •	
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0429 0430 0431 0433 0433 0433 0434 0435 0436 0437 0433 0439 0443 0441 0442 0444 0444 0445 0445	2009 FORMAT(1X, 122X,F10.3) PRINT 2006 2006 FORMAT(1X, 122X,F10.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	VAPMIN, LIOMIN 'MLBS/HR VAPOR MIN'; 'RHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT ,TEMP, SURF 'TRAY LIQUID TEMPERA' ENSION AT COND',7X,' ,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	22X,F10.3,10X, MLB 22X,F10.3,10X, MLB COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X, DEG F',5 YNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	S/HR LIQUID MIN X, X,F10.3,10X,		
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0431 0433 0433 0434 0435 0435 0436 0437 0433 0433 0433 0441 0441 0442 0444 0444 0444	2006 FORMAT(1X, 122X,F10.3) PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	*REBSYER VAPOR MIN', *RHOV, RHOL *LBS/CU FT VAPOR AT (*LBS/CU FT LIQUID AT *TEMP,SURF *TRAY LIQUID TEMPERA' ENSION AT COND',7X,' *OPERATING PRESSURE AT COND',13X,*CP',8)	222,F10.3,10X,*MLB COND',16X,F10.3,10 COND',16X,F10.3} FURE',6X,*DEG F',5 DYNES/CM',2X,F10.3 ,11X,*PSIA',6X.F10	X, X, X,F10.3,10X, }	*	
0431 0432 0433 0434 0435 0436 0437 0433 0439 0440 0441 0442 0444 0445 0445	122X,F10-3) PRINT 2007 2:007 FORMAT(1X, 1 PRINT 2:008 2:008 FORMAT(1X, 1*SURFACE TI PRINT 2:009 2:009 FORMAT(1X, 1*VISCOSITY PRINT 2:010	AHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT ,TEMP,SURF 'TRAY LIQUID TEMPERA' ENSION AT COND',7X,' ,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA'.6X.F10	X, X,F10.3,10X, }		
0431)432 0433)434)435)436)436)437)438)449)449)449)441)442)442)444)442)444)442)444	PRINT 2007 2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TH PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	<pre>RHOV, RHOL 'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT ,TEMP,SURF 'TRAY LIQUID TEMPERA' ENSION AT COND',7X,'I ,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)</pre>	COND',16X,F10.3,10 COND',16X,F10.3) FURE',6X,'DEG F',5 YNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	X, X,F10.3,10X, }		
)432 0433 0434 0435 0436 0437 0433 0433 0433 0440 0441 0441 0442 0444 0444 0445 0445	2007 FORMAT(1X, 1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TE PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	'LBS/CU FT VAPOR AT ('LBS/CU FT LIQUID AT TEMP,SURF 'TRAY LIQUID TEMPERA' ENSION AT COND',7X," 'PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,"CP',8)	COND',16X,F10.3,10. COND',16X,F10.3) FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 ,11X,'PSIA',6X.F10	X, X,F10.3,10X, }		•
0433 0434 0435 0436 0437 0433 0433 0433 0440 0441 0442 0442 0444 0444 0444	1 PRINT 2008 2008 FORMAT(1X, 1'SURFACE TI PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	'LBS/CU FT LIQUID AT ,TEMP,SURF 'TRAY LIQUID TEMPERA' ENSION AT COND',7X,'(PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	COND',16X,F10.3) [URE',6X,'DEG F',5] DYNES/CM',2X,F10.3 11X,'PSIA',6X.F10	X,F10.3,10X,)		
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0434 0435 0436 0437 0433 0433 0433 0443 0441 0442 0441 0442 0444 0444 0445 0444	2008 FORMAT(1X, 1'SURFACE TI PRINT 2009, 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010.	'TRAY LIQUID TEMPERA' ENSION AT COND',7X,' PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)	<pre>FURE',6X,'DEG F',5 DYNES/CM',2X,F10.3 11X,'PSIA',6X,F10</pre>	X,F10.3,10X,)		,
2435 0436 0437 0433 0433 0440 0441 0441 0442 0444 0444 0444 0444	1'SURFACE T PRINT 2009 2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	ENSION AT COND',7X," ,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,"CP',8)	DYNES/CM',2X,F10.3	• • •		
2435 2436 2437 2433 2440 2441 2442 2442 2443 0444 2445 2445	PRINT 2009 2009 FORMAT(1X) 1*VISCOSITY PRINT 2010	<pre>,PSIA,VISC 'OPERATING PRESSURE' AT COND',13X,'CP',8)</pre>	11X. PSIA .6X. F10			
0436 0437 0433 0449 0440 0441 0442 0444 0444 0445 0445	2009 FORMAT(1X, 1'VISCOSITY PRINT 2010	OPERATING PRESSURE AT COND: 13X, CP: 8	11X. PSIA'.6X. F10			
0437 0433 0440 0441 0442 0443 0444 0445 0445	1 VISCOSITY PRINT 2010	AT COND + 13X + CP + 8		.3,10X,		
0437 0433 0439 0440 0441 0441 0442 0443 0444 0445 0445	PRINT 2010.		(,F10.3)			· .
0433 0439 0440 0441 0442 0443 0444 0444 0445 0445		•VTOT,LTOT				
0439 0440 0441 0442 0443 0444 0444 0444	2010 FORMAT(1X,	CES VAPOR AT COND .	2X,F10.3.10X.			
0439 0440 0441 0442 0443 04443 0444 0445 0445	1'LIQUID FLO	OW RATE .14X, GPM .7)	(,F10.3)			
0440 0441 0442 0443 0445 0445 0445	PRINT 2011,	, VLTOT				· · · · · · · · · · · · · · · · · · ·
0441 0442 0443 0444 0445 0445	2011 FORMAT(1X,	VAPOR LOAD', 19X. CFS		· · · ·		
0442 0443 0444 0445 0445	PRINT 2012	,		÷		
0443 0444 0445 0445	2012 FORMAT(1X,	TRAY GEDMETRY!)				·
0444 0445 0445	PRINT 2013					
0445 0445	2013 FORMAT(1X.	!!./}		•		
3445	PRINT 2014.	. т.				
	2014 FORMAT(1X.	DIAMETER .21X. FT	X.F6.21			
0447	PRINT 2015.	. TS				
3448	2015 FORMAT(1X.	TRAY SPACING	N1.5X.F6.21			
3443	PRINT 2016	NP	1 15X 1 5 1 2 1			
3453	2016 ED8MAT(1X-	INTIMBER OF PASSEST.20	X. F6. 21		,	`
3451	PRINT 2017.	DHOI =				
1452	2017 E18MAT(1X.)	HOLE DIAMETERI, 168.4	IN1-57-64 21			
1-53	2011 POINT 2018	ACS	11. 192 1. 0.21			
3454	2010 COLON	FREDERE REPT ADEAN JAY	ICO ETH ON EA ON			
7455	2010 C RAAMINA.	ABAC SEU: AREATJIAA	1.20 L1.1541L0.51			
0473 3756	2010 COLUNT 1	PADAS Pubble/Cooper rect au		()		
2723	2014 F03444 (1X)	COOCCE ARUSS SEUL AR	EA. 1/X 1 PCI. 4X FC	0.21		
0477		NAROD FREEDOMEN INTO				
1.400 5.20	212" FORMAHIX.	WARGK LKUSSCVER (YES	UK NUIT,12X,A3,/1	1		
ى بى	PREMI 2020					
Útře Divisional Alexandria de Carlos de C	2020 HORMAT(42X, 11 PASS D	,* PASS 5 *,20X,* *}	PASS B 1,10X,1 P	PASS C ', 10X,		
	DB141 5051	5			,	
24-7	シリウキ 日白マダムで142米。	,'',10X,'	',10X,'	*,10X,		

	1'',/)
0463	IFLNP+EQ.4) 60 TO 2122
3454	PRINT 2022,W(1),WW5,WW5,ZERD
0455	PRINT 2023;w(7);wW3;WW3;ZER0
0468	GO TO 2124
2467	2122 PRINT 2022,W(1),W(5),WW8,WW8
2468	2022 #DRMAT(1X, DOWNCOMER INLET WIDTH ##*,8X, 'IN',5X,4(F10,3,1CX))
0469	PRINT 2023, W(6), W(10), WW3, WW3
0470	2023 #0RMAT(1X,'DOWNCOMER OUTLET WIDTH ##",7X,'IN',5X,4(F10.3,10X))
0471	2124 PFINT 2024,(LFP(I),I=1,4)
0472	2024 F3RMAT(1X, FLOW PATH LENGTH', 16X, 'IN', 5X, 4(F10.3, 10X))
0473	PRINT 2025,(LW0(I),I=1,4)
0474	2025 FORMAT(1X, CHORD LENGTH AT TOP OF DC',7X, 'IN',5X,4(F10,3,10X))
0475	PRINT 2026, (LUD(I), I=1,4)
0476	2026 FORMAT(1X, CHORD LENGTH AT BIM OF DC',7X, 'IN',5X,4(F10.3,10X))
0477	PRINT 2027, (ADCI(I), I=1,4)
0478	2027 FORMAT(1X, DC INLET AREA', 19X, 'SQ FT', 2X, 4(F10, 3, 10X))
0479	PRINT 2028, (ADCO(I), I=1,4)
3480	2028 FORMAT(1X, 'OC OUTLET AREA', 18X, 'SQ FT', 2X, 4(F10, 3, 10X))
0481	PRINT 2029, (HWO(1), I=1, 4)
7482	2029 FJRMAT(1X, OUTLET WEIR HEIGHT +, 14X, 'IN', 5X, 4(F10, 3, 10X))
0483	PRINT 2030, $(HWI(I), I=1, 4)$
0484	2030 FORMAT(1X, INLET WEIR HEIGHT ON TRAY BELOW IN', 5X, 4(F10, 3, 10X))
0485	PRINT 2031, (C(I), I=1, 4)
2486	2031 FORMAT(1X, DC CLEARANCE TO TRAY BELOW', 6X, 'IN', 5X, 4(F10, 3, 10X))
0497	PRINT 2032, $(A(I), I=1, 4)$
0489	2032 FORMAT(1X, SHAPED LIP (YES OR NO) ,21X,4(A3,17X))
0489	PRINT 2033, $(B(I), I=1, 4)$
0490	2033 FORMAT(1X, 'RECESSED BOX (YES OR NO)', 19X, 4(A3, 17X),/)
0491	PRINT 2034 (4B(I) I = 1, 4)
0492	2034 FORMAT(1X, 'BURBLE AREA', 21X, 'SQ FT', 2X, 4(f10, 3, 10X))
0493	PRINT 2035, (AF(I), I=1, 4)
0494	2035 FORMAT(1X, FREE AREA, 23X, SQ FT, 2X, 4(F10, 3, 10X))
0495	PRINT 2036, (AD(I), I=1,4)
0495	2036 FORMAT(1X, HOLE AREA', 23X, 'SQ FT', 2X, 4(F10, 3, 10X))
0497	PRINT 2037, (AOAB(I), I=1, 4)
0498	2037 FORMAT(1X, 'HOLE/BUBBLE AREA', 16X, 'PCT', 4X, 4 (F10, 3, 10X), //)
0499	PRINT 2038
0 50 0	2038 FORMAT(1X, *** HALF WIDTH FOR PASSES B,C,D')
0501	PRINT 2135
0502	2135 FORMAT(1H1,90X, 'PAGE 2')
0503	IF(VAPCON.ST.0.0)G0 T0 3001
0504	PRINT 2136
0505	2136 FORMAT(//)
0506	GO TO 3002
0507	3001 PRINT 2137
0508	2137 FORMAT('NOTE: VAPOR SPLIT UID NOT CONVERGE IN 50 TRIALS - VAPOR SP
	LLIT OF SOTH TRIAL IS USED .//
0509	3062 IF(LIDE-N.ST.A.D)SO T 3007
0510	PPINT 2136
0511	50 TO 3004
0512	3003 PRINT 2138
2513	2139 FORMAT(INGTE: LIQUID SPLIT DID NUT CONVERSE IN 43 TRIALS - LIQUID
	ISPUIT OF 40TH TRIAL IS JSED .//

0) 60

FORTRAN IV 51	PELEASE 2.0 MAIN DATE = 74100 14/52/33 PAGE 0013
0514	3004 CONTINUE
2515	
0514	
0.010	ZJ39 FURMA (LIA, LIAU) 45 PER PASS () ZZA, PRSS A (, LUA,
0517	1' PASS 3', 10X, ' PASS C', 10X, ' PASS C')
0517	PF1N1 2040
0513	$234) + 18MA \{ \{ 1x, ', ', 22x, ', ', 10x, ', ', ', ', ', ', ', ', ', ', ', '', ', ', '', ', '$
	1'',12X,'',10X,'')
0519	IF(NP.EQ.4.) GD TC 2141
0.520	GPHFTW(4) = 0.0
0521	VL(4) = 0.0
0522	VLA8(4)=0.0
0523	S(4) =0.0
0524	HED(4) = 0.0
3525	HC(4) = 2.0
0526	HT(4) = 0.0
0527	HI(4) = 0.0
0528	
0529	
0530	
0521	
0.021	
0532	
0533	2141 Print 2041, (211), 1=1, 4)
0534	2041 FURMAT(IX, 'GPM LIQUD', 29X, 4(F10.3, 10X))
0535	PRINT 2042, (GPHFTW(I), I=1,4)
0536	2042 FORMAT(1X, "GPH/FT WEIR", 28X, 4(F10, 3, 10X))
0537	PRINT 2043, (V(I), I=1,4)
0538	2043 FDRMAT(1x,*CFS VAPOR*,30X,4(F10,3,10X))
0539	PRINT 2044, (VL(I), I=1,4)
0540	2044 FORMAT(1X, *VAPOR LOAD+,22X, *CFS*,4X,4(F10.3,10X))
0541	PRINT 2045, (VLAB(I), I=1,4)
0.542	2045 FORMAT(1X,'VLOAD/BUBBLE AREA',15X,'FPS',4X,4(F10.3,10X))
0543	PRINT 2046, (S(I), I=1,4)
3 5 4 4	2046 FORMAT(1X, VLOAD/CFS LIQUID', 23X, 4(F10, 3, 10X), /)
0545	PRINT 2047
0546	2047 FORMAT(1X+'DOWNCOMER FILLING CALCULATIONS')
0547	PRINT 2048
3548	2248 FORMAT(1X
0549	PRINT 2049-(HEDII)-(=1-4)
3550	2049 FORMAT(1X, 1089 TRAY DESSURE DROPLAY, 1(HH) IN1.5X,4(F10.3,10X))
0551	
1552	2050 EDDWATELY FILERA LINUS ALTOUTE 77 FLUEN INF EV ALENA 2.10713
0582	CODE COMMENTING OF AN LINULD RELEDITING AN TURE IN 1204440100310411 - ODINE 2005 DETENDED AN AN
3554	$\frac{1}{2} \sum_{i=1}^{n} \frac{1}{2} \sum_{i=1}^{n} \frac{1}$
J=34 0555	2001 FORMATILA, TOTAL RAT PRESSURE DROP (HI) IN', 5X, 4(FI0.3, IOX))
V 922	$PR[N] = 2052 \cdot (H1 (1), 1=1, 4)$
3556	2052 FURMAT(IX, 'INLET HEAD', 16X, '(HI) IN', 5X, 4(F10, 3, 19X))
0557	PRINT 2053, (HUD(I), I=1,4)
0.558	2053 FORMAT(1X,+02 HEAD LOSS+,14X,+(HDA) IN+,5X,4(F10,3,10X))
3559	PRINT 2054, (HD(1),1=1,4)
2563	2054 FORMAT(1X, DC FIELING', 15X, '(HDC) IN', 5X, 4(F10, 3, 10X))
0551	PRINT 2055,(PCTHP(I),I=1,4)
3502	2055 FORMAT(1X, DC FILLING', 22X, PCT', 4X, 4(F10, 3, 10X),/)
3553	DRINT 2056

FORTRAN IV G1	RELEASE R.O	MAIN	DATE = 74100	14/52/38
3565	2057 FORMAT(1X."		!,/)	
2557	PRINT 2058.	(PCTJET(I),I=1,4)		
2569	2258 FORMATLIX.	PERCENT JET FLOOD	*.22X.4(F10.3.10X))	
0569	PRINT 2059.	()CVEL(I),I=1.4)		
0570	2059 FORMAT(1X.	DC INLET VELOCITY	1.15X. FPS+.4X.4(E10.3	10X))
0571	PRINT 2161.	ALLVEL		
3572	2151 FORMAT(////	/.IX. ALLOWABLE DO	C INLET VELOCITY'.5X."	FPS*,4X,F10.3)
0573	24197 2251.	EFECY		
3574	2341 = 72917(//,1	X, POVERAEL TRAY EN	FFICIENCY*,9X,*PCT*,4X	,F10.3)
0575	60 TT 0200			
357 6	2142 PKTHT P143			
0577	2163 PREMAT(141,	THIS PROGRAM CAN	NUT DESIGN 4-PASS TRAY	S FOR LIQUID RAT
	155 GPEATER	THAN 5000 GPM. 1)		
0578	GT TE 2200			
0579	2164 PRINT 2165			
0580	2165 FOPMAT(1H1,	THIS PROGRAM CAN	NOT DESIGN TRAYS FOR V	APOR LOADS GREAT
	1ER THAN 100	CFS. 1)		
0581	GO TO 2200			
0582	2166 PRINT 2167			
0583	2167 FORMAT(1H1,	THIS PROGRAM CAN!	NOT DESIGN 3-PASS TRAY	S FOR LIQUID RAT
	1ES GREATER	THAN 5000 GPM. 1)		
0584	SU TO 2200			· · · ·
0585	ELNITING OUSS			
0586	IF (NGNIN.E.	Q.0.01 30 TO 1000		
0597	STOP			
0588	END			· · · · · · · · · · · · · · · · · · ·
			·	
1. 1 ¹				

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PASE 0014

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Paul Becker was born in New York City in 1948. He attended public schools and the Bronx High School of Science. In 1970, he obtained a Bachelor of Science in Chemical Engineering from Columbia University School of Engineering and Applied Science in New York. At Columbia, Paul was student chapter president of the American Institute of Chemical Engineers, Editor of the <u>Columbia Engineering Quarterly</u>, an officer of Tau Beta Pi (national engineering honor society), and a member of Phi Upsilon Lambda (national chemistry honor society). As an undergraduate he was the recipient of the AICHE Scholarship award and the George Vincent Wendell medal for scholarship, character, and service.

Since 1970 Paul has been employed by Esso Research and Engineering Company in Florham Park, New Jersey. Until 1974 he worked in the Technology Department conducting R & D projects in the area of fractionation, and served as tower design consultant for engineers in the company. He is currently working in the Special Projects Design Division as a process design engineer.

Paul entered Newark College of Engineering in the Fall of 1971 as a part-time evening student and began working on this thesis in the Spring of 1973. The computer program presented in this thesis was developed through the use of the IBM 370 computer facilities of the Exxon Corporation Mathematics Computing and Systems Department in Florham Park.

VITA

NOMENCLATURE

AB	Bubbling area, square feet. Perforated area in which vapor and liquid contact each other.
ALLVEL	Allowable downcomer inlet velocity, feet per second.
A _O	Open area or hole area, square feet.
AUD	Area under downcomer, square inches.
C	Downcomer clearance, inches.
cfsv	Vapor rate, cubic feet per second at conditions.
c _{vo}	Dry tray pressure drop coefficient, dimensionless.
D _O	Hole diameter, inches.
F _W	Weir factor used in clear liquid height equation, dimensionless.
GPHFTWEIR	Liquid weir loading, gallons per hour per foot of weir length.
GPM	Liquid rate, gallons per minute.
H	Tray spacing, inches.
HDA	Head loss under the downcomer, inches of liquid at con- ditions.
HDC = HD	Downcomer static backup, inches of liquid at conditions.
HFACT1	Tray spacing capacity factor used in jet flood equation, dimensionless.
HFACT2	Tray spacing capacity factor used in allowable downcomer inlet velocity equation, dimensionless.
нн	Dry tray pressure drop, inches of liquid at conditions.
HI	Inlet head, inches of liquid at conditions.
HL.	Clear liquid height, inches of liquid at conditions.
HOW	Head of crest over weir, inches of liquid at conditions.
HT	Total tray pressure drop, inches of liquid at conditions.
HWI	Inlet weir height, inches.

HWO	Outlet weir height, inches.
L.	Liquid rate, gallons per minute
LUD	Length of chord at bottom of downcomer, inches.
LWI	Length of inlet weir, inches
LWO	Length of outlet weir, inches.
P	Pressure level in chamber above pass, any pressure dimension.
P '	Pressure level in chamber below pass, any pressure dimension.
RHOFAC	Density difference capacity factor used in calculating allowable downcomer inlet velocity. A function of $(\rho_{\rm L} - \rho_{\rm V})$, dimensionless.
TT	Tray thickness, inches
v	Vapor rate, cubic feet per second.
vL	Vapor load = CFSy $\sqrt{\rho_V/\rho_L - \rho_V}$, cubic feet per second.
v _o	Vapor velocity through the perforations = CFSy/A ₀ , feet per second.
β	Aeration faction used in clear liquid height equation, dimensionless.
ρ _v	Vapor density at conditions, pounds per cubic foot.
ρ _L	Liquid density at conditions, pounds per cubic foot.
Subscripts	
A,B,C,D	Identify variable with one of the tray passes.

total Identifies variable as total value for all passes.