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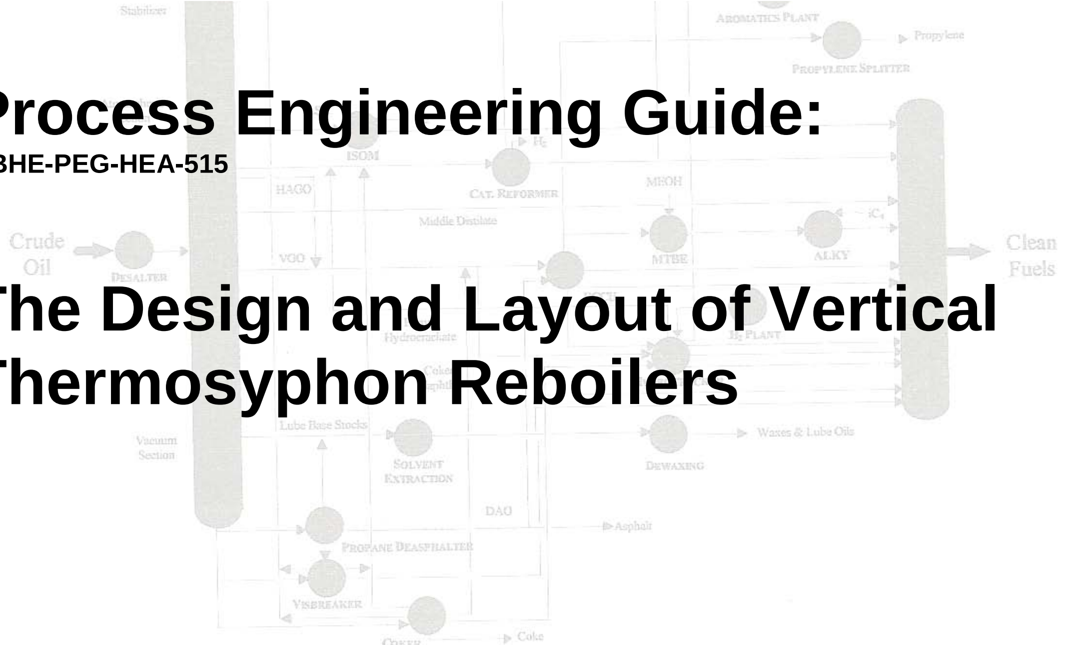

Process Engineering Guide:

GBHE-PEG-HEA-515

The Design and Layout of Vertical Thermosyphon Reboilers

Process Engineering Guide: The Design and Layout of Vertical Thermosyphon Reboilers

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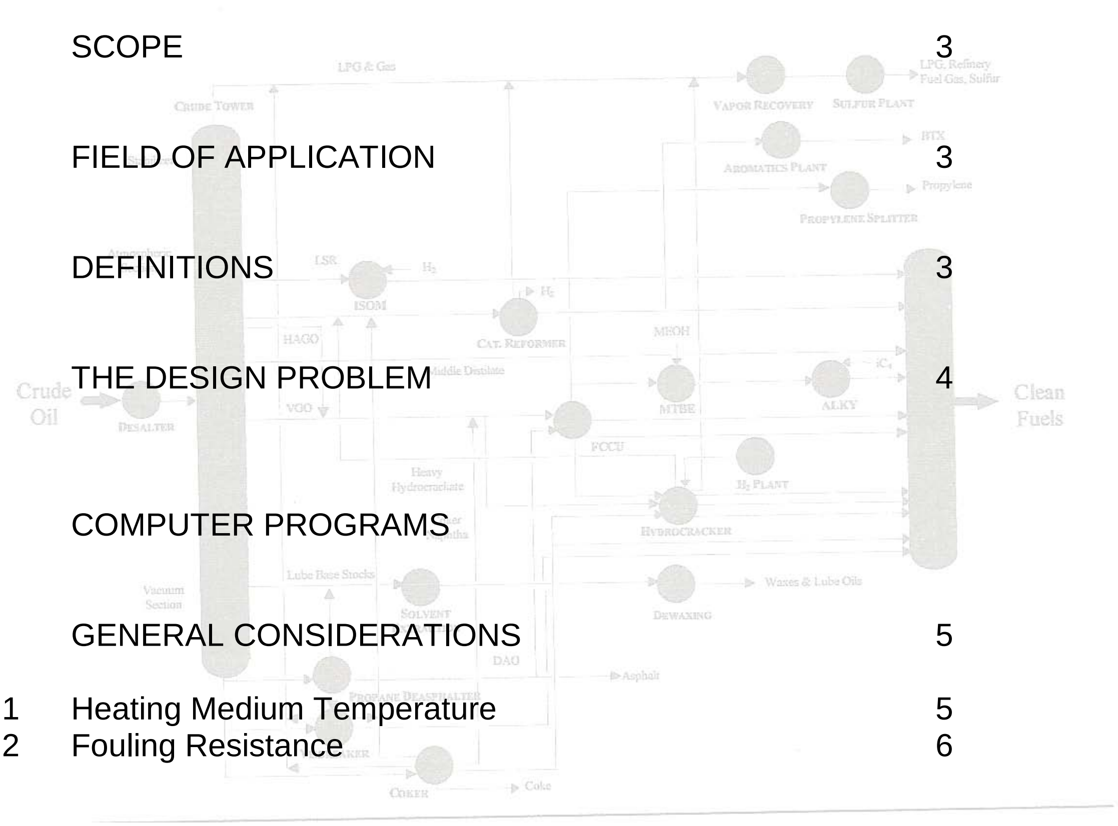

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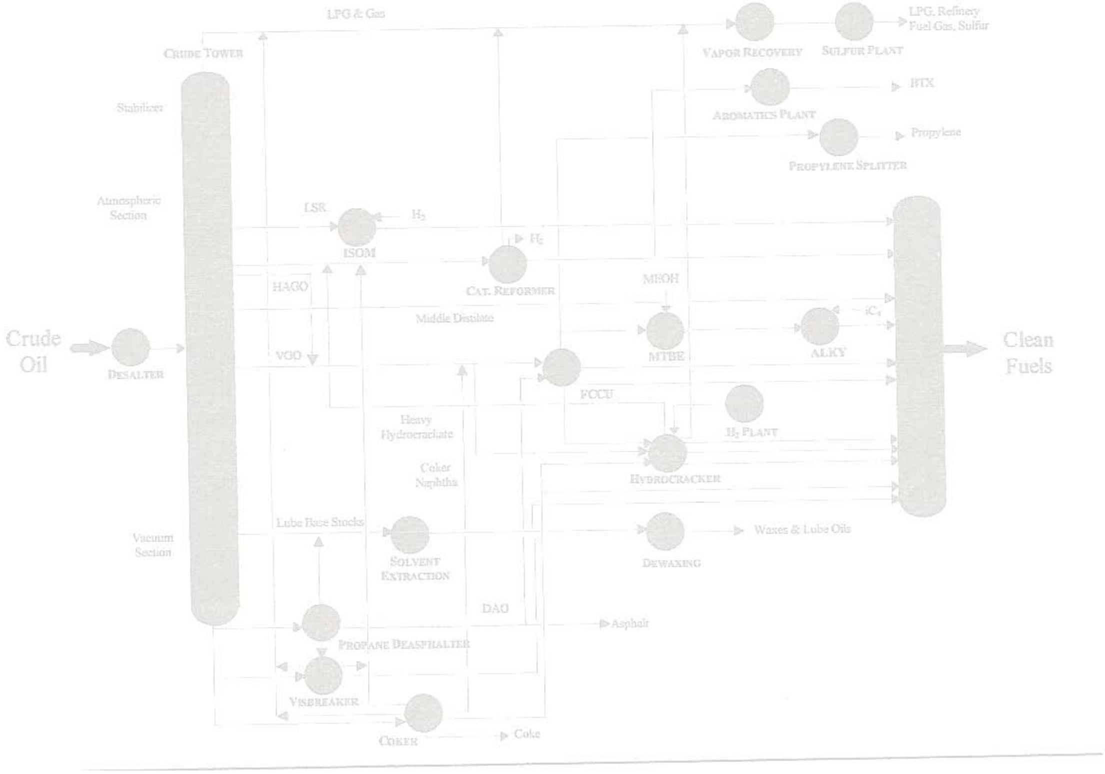
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Crude Tower
Stabilizer
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Vacuum Section
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Middle Distilate
VGO
Heavy Hydrocraclate
Coker Naphtha
Lube Base Stocks
Solvent Extraction
DAO
Propane Deasphalter
Visbreaker
Coker
Coke
Asphalt
Vapor Recovery
Sulfur Plant
LPG, Refinery Fuel Gas, Sulfur
Aromatics Plant
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0 INTRODUCTION/PURPOSE

This Guide is one of a series on heat transfer produced for **GBH Enterprises**.

Vertical thermosyphon reboilers require care in their thermal design and layout to avoid operational problems. This Guide describes the recommended design method and gives advice on layout.

1 SCOPE

Vertical Thermosyphon Reboilers (VTRs) are one of several types of reboiler that may be used on distillation columns. A review of the relative merits of the different types is given in **GBHE-PEG-HEA-507.**

This Guide assumes that the decision has already been taken to specify a VTR. It outlines recommended methods for the process design of vertical thermosyphon reboilers, considering basic thermal design, control and layout.

2 FIELD OF APPLICATION

This Guide is intended for process engineers and plant operating personnel in **GBH Enterprises** worldwide, who may be involved in the specification, design or operation of vertical thermosyphon reboilers.

3 DEFINITIONS

For the purposes of this Guide, the following definitions apply:

FRI	Fractionation Research Incorporated. A co-operative research organization, based in the USA, involved in research into distillation in industrial sized equipment, and the production of design guides and computer programs for the design of such equipment.
HTRI	Heat Transfer Research Incorporated. A co-operative research organization, based in the USA, involved in research into heat transfer in industrial sized equipment, and the production of design guides and computer programs for the design of such equipment.

HTFS Heat Transfer and Fluid Flow Service. A co-operative research organization, with headquarters in the, UK, involved in research into the fundamentals of heat transfer and two phase flow and the production of design guides and computer programs for the design of industrial heat exchange equipment.

4 THE DESIGN PROBLEM

General information on **VTRs** is given in references [3], [4].

When the process fluid boils in the tubes of the reboiler the resulting two-phase mixture has a lower density than the single-phase liquid in the column sump. This density difference induces a circulation of the process fluid from the sump, up through the boiler and back into the column shell. The resulting flow enhances the heat transfer and is responsible for the high performance that can be obtained from a **VTR**.

The basic problem in the design of thermosyphon boilers is that the heat transfer performance is coupled to the circulation rate, which is not known a priori. Iteration is necessary to match the driving force due to the density difference with the pressure drop from the circulation. The iteration is best performed with the aid of a computer program.

An additional consideration is that badly designed thermosyphon boilers may operate in an unstable manner, with circulations and heat loads fluctuating wildly over short time periods. Such instabilities can have a serious effect on column performance, leading in extreme cases to alternate periods of flooding and dumping. The exchanger and associated circulation pipework needs to be designed to avoid this. See 7.2.4 and 7.2.5.

5 COMMERCIAL OMPUTER PROGRAMS: PROPRIETARY

6 GENERAL CONSIDERATIONS

6.1 Heating Medium Temperature

The majority of thermosyphon reboilers are heated with steam. The effective maximum steam temperature is the saturation temperature of the steam at the maximum pressure obtainable in the reboiler shell.

Note:
This is typically 7-10% below the boundary limits steam pressure due to line and control valve pressure drops.

The design steam temperature should preferably be at least 20°C greater than the column sump temperature; with lower temperature differences the reboiler may fail to thermosyphon adequately. However, too high a steam temperature may result in film boiling and increased fouling. Commercially available programs will give warning of this.

Reboilers may also be heated with process fluids, a practice that is becoming more common with the growth of process integration. If the heating medium is a condensing fluid with a high condensing coefficient it can be considered in the same way as steam, but if a single-phase heating medium is used, the shell side thermal resistance is liable to be dominant. Careful attention should be given to maximizing the shell side coefficient to take advantage of the high tubeside coefficients normally obtained from **VTRs**.

Another consequence of using a single-phase fluid, or a process fluid with a wide condensing range, as the heating medium is that its temperature will fall across the exchanger. If the boiling fluid is a single component or a narrow boiling range mixture, the heating medium should be arranged to be co-current to the boiling fluid, to maximize the temperature difference at the bottom of the tubes. This will result in earlier nucleate boiling and improved circulation. On the other hand, with a wide boiling range mixture the boiling point may rise as the fluid passes up the tube, in spite of the reduction in static pressure, and counter-current flow of the heating medium may be better.

6.2 *Fouling Resistance*

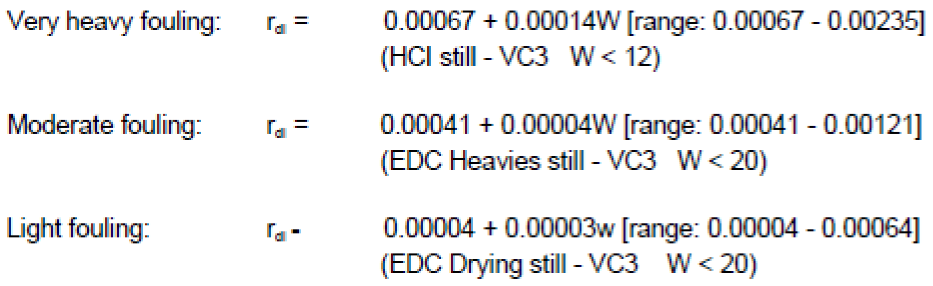
Thermosyphon boilers are designed to achieve a high boiling coefficient. As a result, the fouling resistance may be a major part of the total resistance, and is thus a critical factor in the design.

The fouling resistance for condensing steam can be taken as 0.00005 - 0.0001 m^2K/W. For a process fluid as heating medium, a fouling resistance appropriate for the particular fluid should be used.

At present, the only way to get a realistic boiling fluid fouling resistance for a design is to measure the performance of a comparable boiler, i.e. one with a similar fluid boiling at a similar temperature and with a similar heat flux, flow regime and velocity. The fouling resistance can then be obtained from a comparison of the computed clean performance and the actual performance when fouled. Appendix A details the method. Since any inaccuracies in the program correlations are lumped into the fouling resistance, it is advisable to use the same computer program for design as for calculating the fouling resistance.

The fouling resistance for a boiler usually increases in an approximately linear way with time. The resistance chosen for design, therefore, besides affecting the boiler area, also determines the interval between cleanings. Typical cycle times vary between about 2 months for a very heavy fouling duty to 12 months or more for a light fouling duty. As it may be difficult to produce a sensible design that will perform adequately in both the clean and very fouled conditions, it may be worth installing a spare reboiler, with suitable means for switching over and isolating, to enable one boiler to be cleaned without a lengthy plant shut-down. See also Clause 9.

Some typical fouling resistances for chlorinated hydrocarbons are:



Very heavy fouling: r_d = 0.00067 + 0.00014W [range: 0.00067 - 0.00235]
(HCl still - VC3 W < 12)

Moderate fouling: r_d = 0.00041 + 0.00004W [range: 0.00041 - 0.00121]
(EDC Heavies still - VC3 W < 20)

Light fouling: r_d - 0.00004 + 0.00003w [range: 0.00004 - 0.00064]
(EDC Drying still - VC3 W < 20)

Here r_{di} is the fouling resistance based on the tube inside area in m^2K/W and W is the time since cleaning in weeks. These values were calculated from data in references [6] and [9], using a proprietary program.

7 DESIGN PARAMETERS

7.1 Overall Arrangement and Specifications

The first step in a proper design procedure for a vertical thermosyphon reboiler is a review of the operating specifications and geometric design elements.

The required duty is specified by the Process requirements:

(a) Heat duty.

(b) Boiling fluid pressure, temperature, composition and physical properties.

(c) Heating medium pressure, temperature, composition and properties.

Geometric information is required by the program:

(1) Tube length, inside and outside diameter and pitch.

(2) Baffle spacing and cut.

(3) Inlet piping length, diameter and details of fittings.

(4) Outlet piping diameter, length, layout and details of fittings.

(5) Liquid static head in the column sump, measured above the lower tubesheet.

A sketch of the basic layout, such as shown in Figure 1, is recommended. The major resulting dependent variables obtained from the computer calculation will be the actual heat duty and the circulation rate/exit vapor fraction.

7.2 Geometry Elements

The major variables under the control of the designer are:

(a) Tube diameter.

(b) Tube length.

(c) Liquid head.

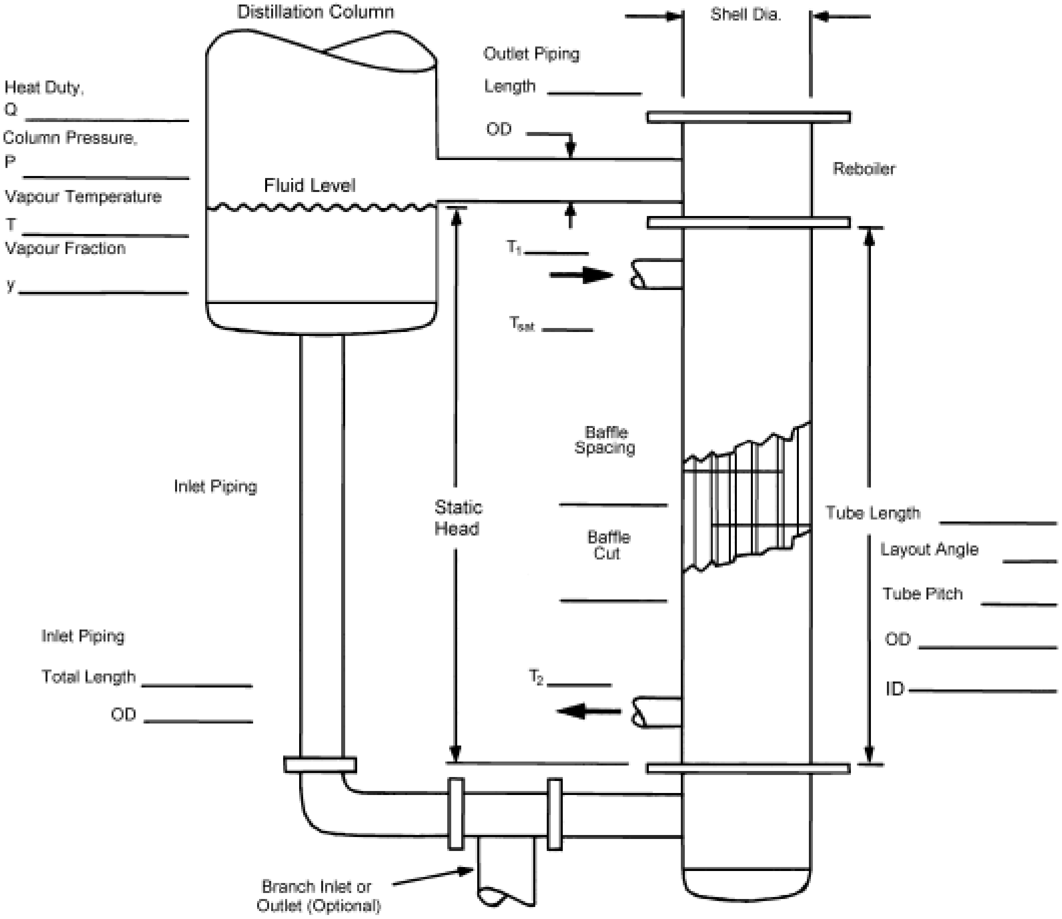
(d) Inlet and outlet pipework design.

Typical ranges of variables are given below as guides. These ranges may be exceeded in special cases when required, but then more careful analysis of the results should be made.

7.2.1 Tube Diameter

The normal range for tube outside diameter is ¾" to 2" (19.05 - 50.8 mm). Within this range, larger values are required for vacuum operation, operation near the critical point or high viscosity fluids. Smaller values, which usually mean lower cost, may be used for moderate pressure and clean fluids. ¾" and 1" are the most common sizes. See **GBHE-PEG-HEA-512** for details on preferred tube size, wail thickness and tube pitch.

FIGURE 1 **TYPICAL SKETCH**



7.2.2 Tube Length

The normal range is 1.5 to 6 m (4 to 20 ft). Short tubes are used when required to obtain sufficient circulation, or because of small available head. Longer tubes, which usually mean lower cost for the exchanger, are used where possible, but circulation should be checked carefully; watch for mist flow. The liquid velocity into a thermosyphon boiler initially increases as the tube length is reduced, but falls off again for short tubes. A reboiler with very short tubes may not thermosyphon adequately.

Note:
Although a long thin exchanger is cheaper than a short fat one, it does require the column base elevation to be greater, which may mean a higher and more expensive skirt.

7.2.3 Liquid Head

For boilers operating from atmospheric to moderate pressures it is common practice to design for the liquid level in the column sump to be on a level with the top tube-plate of the reboiler. This is generally satisfactory.

For high pressure operation, it may be beneficial to increase the liquid head to improve the liquid circulation rate.

Note:
This will require longer exit piping and a taller column skirt.

For vacuum operation a lower liquid level gives improved performance as it reduces the length of the sub-cooled zone, where heat transfer is relatively poor. There is an optimum liquid head for a given duty, which may be less than two thirds of the tube length. However, as static head is reduced, the exit vapor fraction is increased and care should be taken to prevent this rising above 0.5 if possible.

7.2.4 Outlet Piping

Badly designed thermosyphon boilers may operate in an unstable manner, with fluctuating circulations and heat loads. Such instabilities can have a serious effect on column performance, leading in extreme cases to alternate periods of flooding and dumping. Increased flow resistance in the outlet piping from the reboiler to the column increases the tendency to unstable operation, whereas resistance in the inlet pipework has a stabilizing effect.

According to HTRI, more operating problems are due to small exit piping than to any other single reason. The ratio of exit piping frictional pressure drop to total pressure drop should never exceed 0.3; the recommended value is 0.1. The ratio of exit pipe cross-sectional area to total tube cross-sectional area should not be less than 0.75 unless there is a very special reason and careful design. The recommended value is 1.0.

Long radius elbows and 90° tee type exits of the same minimum cross-section were found by HTRI to give similar overall reboiler performance. (See Figure 2 for sketches of the various types.) The 90° tee has the advantage of shorter piping and a lower column first tray; the long radius elbow permits a higher liquid level. For most cases the 90° tee is the cheapest solution. The mitred exit piping ("lobster back") which is sometimes used would seem to have no real advantages.

FIGURE 2 THERMOSYPHON REBOILER EXIT HEADERS

(a) 90° Tee (b) Vertical Exit Long Radius Elbow (c) Mitred Joint

7.2.5 Inlet Piping

This can be small, giving a ratio of the inlet pipe pressure drop to the total pressure drop of up to 0.3, provided the resulting exit vapor fraction does not exceed the recommended maximum value (0.5 for vacuum duties, 0.35 for other cases). Relatively high inlet resistance increases the boiler stability and reduces inlet sub-cooling.

It is almost always possible to stabilize an otherwise unstable boiler by increasing the inlet resistance. It is good practice to install a valve (a butterfly valve is adequate), or at the minimum an orifice plate carrier, in the inlet pipework for this purpose at the design stage.

8 ANALYSIS OF COMMERCIALLY AVAILABLE PROGRAM RESULTS

Results generated by commercially available programs should be studied carefully to identify potential problems. Adjustments to the design can then be made. An illustrated example follows:

The results of particular interest for thermosyphons are:

(a) ‘PERFORMANCE OF THE UNIT’.

(b) ‘THERMOSYPHON STABILITY ASSESSMENT’.

(c) The ‘TUBE WALL TEMPERATURE PROFILE’.

8.1 Main Results

The following items require particular attention. The normal range for the expected values is given.

Note:
Some of these items are not given explicitly, but have to be calculated from the other values.

Weight fraction vapor in the exit: This is the ratio of the total vapor + gas in the outlet to the total fluid flowing.	0.05 – 0.35 (0.5 for vacuum)
Design velocity: (a) above atmospheric	0.3 – 1.5 m/s
(b) vacuum	0.03 – 0.3 m/s

This is the inlet velocity to the tubes, obtained by dividing the volumetric liquid flowrate entering the exchanger by the total inside cross section of the tubes.

Average heat transfer coefficient	1000 – 6000 W/m^2.K
Design heat flux	10000 – 100,000 W/m^2

The total heat duty divided by the inside surface area (corrected by the ratio of inside to outside tube diameters).

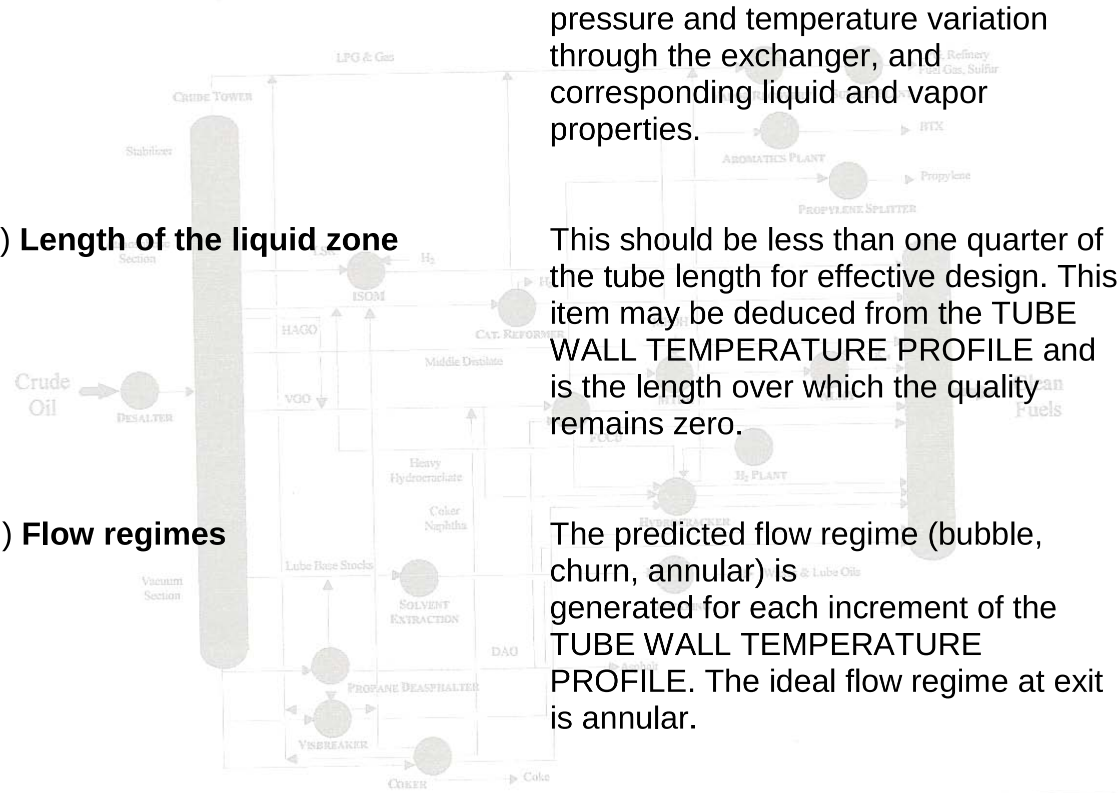
8.2 Supplementary Results

The most important items are:

(a) **Thermosyphon Stability Assessment**

When rating a thermosyphon boiler, commercially available programs will always perform this assessment, based on proprietary methods.

These programs will indicate whether or not the system is stable. If there are indications of stability problems, steps should be taken to correct the design (see below).



(b) **Physical properties**	These should always be checked to see if they are within reasonable range. When rating a thermosyphon boiler, at least two sets of physical properties data for the boiling fluid, at pressures which span the expected pressure change within the boiler, should be given, so that the program can take account of the variation in properties with pressure. The program output should include the predicted pressure and temperature variation through the exchanger, and corresponding liquid and vapor properties.
(c) **Length of the liquid zone**	This should be less than one quarter of the tube length for effective design. This item may be deduced from the TUBE WALL TEMPERATURE PROFILE and is the length over which the quality remains zero.
(d) **Flow regimes**	The predicted flow regime (bubble, churn, annular) is generated for each increment of the TUBE WALL TEMPERATURE PROFILE. The ideal flow regime at exit is annular.
(e) **Temperature profiles**	These should be checked to ensure that no near pinch conditions are present along the tube.

8.3 *Error Analysis*

Should be self explanatory, and the appropriate action should be taken.

8.4 *Adjustments to Design*

If a problem or inadequate performance warning is found it is usually possible to adjust design details to prevent the problem. Some typical adjustments are given below; where more than one solution is given, they are in order of preference.

Problem	*Adjustment*
Vapor fraction too high or mist flow indication	Increase exit pipework diameter. Increase tube diameter. Decrease tube length.
Vapor fraction too low	Decrease tube diameter. Increase inlet flow resistance. Increase tube length.
Film boiling	Decrease temperature difference. Increase tube diameter.
Instability	Decrease exit flow resistance. Increase inlet flow resistance. Decrease temperature difference.
Long liquid zone	Decrease static head. Increase inlet flow resistance. Add sparge gas.

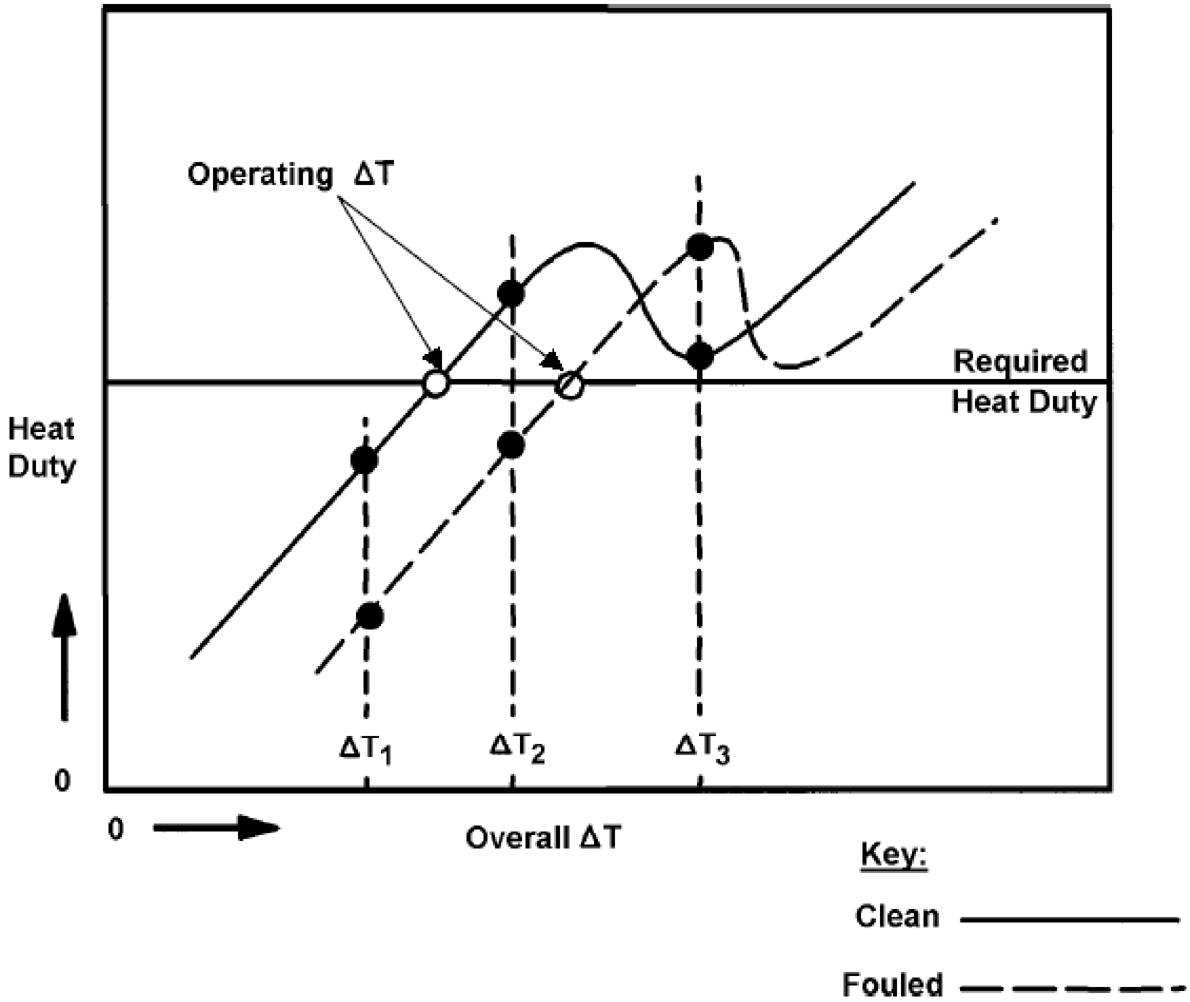
9 OPERATING RANGE

A thermosyphon reboiler will be designed for the maximum anticipated heat duty with the highest anticipated level of fouling. When first installed, or after periodic cleaning, the fouling resistance will be considerably less. Moreover, it is often required to run the boiler at rates below the design heat duty. It is good practice to simulate the performance of the unit at likely operating conditions away from the design point to see if any problems are evident, for example instability. This can be done by repeated runs using commercially available programs. Such a check should also include the design case, using the actual geometry of the exchanger and associated pipework, which may differ from that assumed at the design stage.

The results of such a study can be presented by plotting the heat duty against the overall temperature difference for the clean and fouled condition, as illustrated in Figure 3. The curves will in general have a maximum and minimum, although these may not lie within the range of temperature difference available. The maximum represents the onset of film boiling, with a subsequent fall-off in performance. It can be seen that beyond this point there is a region where increasing the driving force actually results in a fall-off in performance, which is one reason why partial film boiling is to be avoided.

Ideally, the exchanger should perform to the left of the maximum under all conditions. However, it may be found that film boiling results in the clean condition if the maximum heating fluid temperature is used. Unless care is taken to limit the temperature in these circumstances, rapid fouling is likely, which may quickly convert the operation to the more stable, but fouled, condition.

FIGURE 3 ILLUSTRATION OF RECOMMENDED RATING PROCEDURE



The results of the study may also indicate operational problems such as instability. Sometimes it is possible to improve this by suitable changes, but in some cases no totally satisfactory design will be found which meets all the operating requirements under both clean and fouled conditions. In these circumstances it is worth questioning whether a **VTR** is the most appropriate design. This is particularly likely to occur for deep vacuum operation or at pressures approaching the critical pressure.

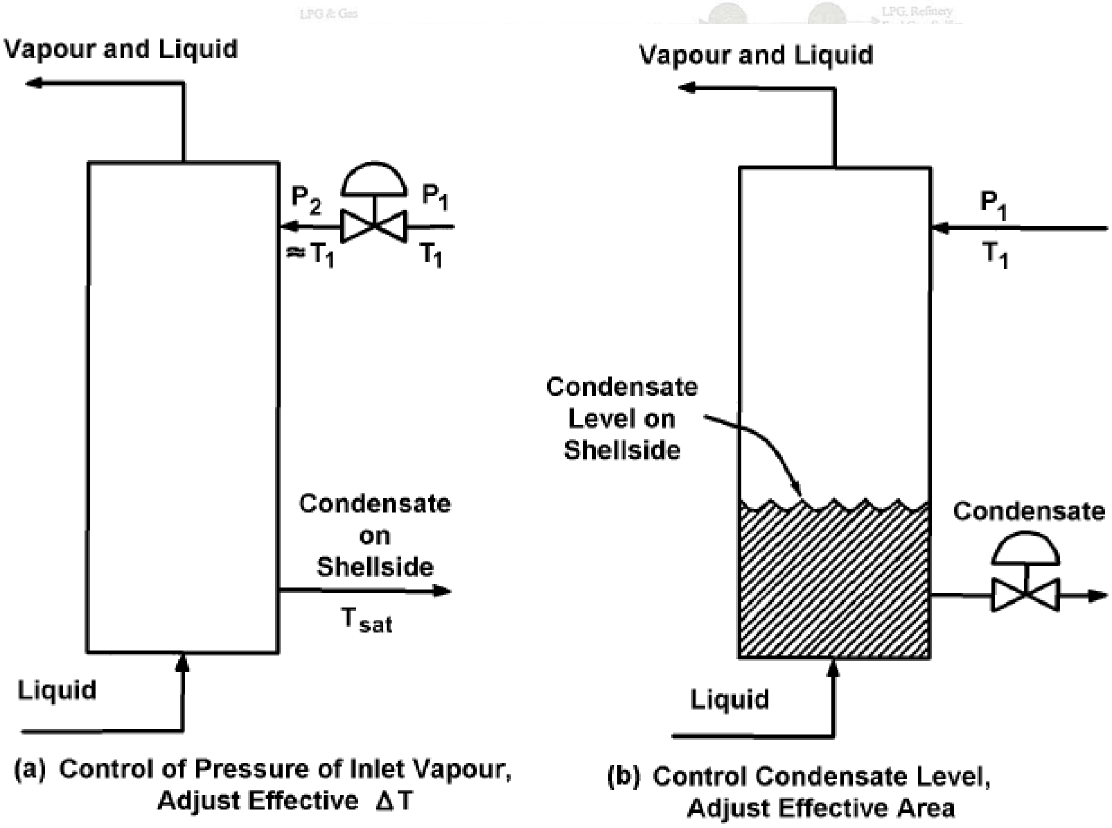
Particular problems can occur if a boiler is required to operate on widely different fluids at different times. This could be because at start-up, before recycle streams have had a full effect, the composition of the column bottoms product differs from the flowsheet case.

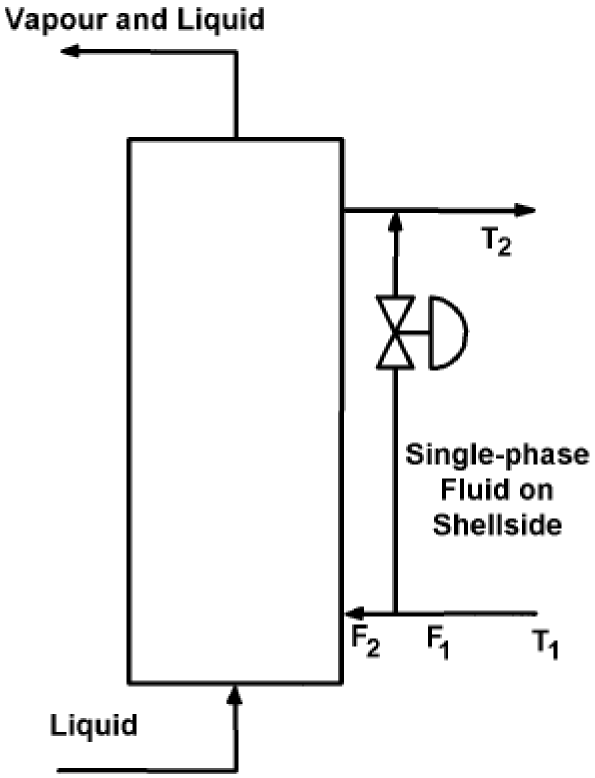
Alternatively, the boiler may be part of a multi-purpose plant and be required to perform different duties, depending on the product being made. Again, it is essential to simulate all likely conditions, and again, a **VTR** may not be the most appropriate choice of boiler.

10 CONTROL

There are three common ways of controlling a **VTR**, which are illustrated in Figure 4.

FIGURE 4 METHODS OF REBOILER CONTROL





(c) Control Flow Rate and Exit ΔT of Sensible Heating Medium

10.1 Control of Condensing Heating Medium Pressure

This is the most common form of control for steam heated boilers and is the preferred method in most cases. A control valve in the steam supply line reduces the pressure in the reboiler shelf, and hence the condensing temperature.

Start-up is typically simulated in commercially available programs by eliminating the fouling resistances and reducing the heating medium temperature and pressure until the design duty is matched.

Note:
If a boiler is designed for a high fouling resistance and heated with LP steam, the required steam pressure for clean conditions may be below atmospheric pressure, which will usually give problems in removing the condensate.

10.2 Control of the Condensate Level

In cases where it is not possible to reduce the heating medium pressure sufficiently, such as where the condensing pressure would be below atmospheric pressure, the condensate exit flow can be restricted to flood the lower portion of the shell. This condensate will then cool to near the boiling fluid temperature, effectively reducing the tube length. This method has many disadvantages and should only be used as a last resort. It should never be used when the design temperature difference is high enough to cause mist flow or film boiling under clean conditions.

Start-up is simulated by eliminating the fouling resistance and decreasing the tube length and static head until the design condition is reached. This ignores the liquid friction loss in the flooded portion of the tubes, but this is usually negligible.

10.3 Control of Sensible Fluid Flow Rate

For a sensible heating medium, flow of the heating medium is by-passed around the reboiler to decrease the heating medium heat transfer coefficient and exit temperature. A potential problem is accelerated shell side fouling due to low velocity on start-up. Start-up is simulated by eliminating the fouling factor and reducing the heating medium flowrate until the design duty is met.

11 LAYOUT

11.1 Factors Influencing Design

(a) The object of the thermosyphon reboiler is to save money by having a fast circulation through the boiler tubes and hence a good heat transfer coefficient. This is to some extent offset by the requirement for long tubes, which increases the overall height of the installation.

(b) The return pipework from the boiler to the column should have a low hydraulic resistance to reduce the possibility of instability. However, as explained above, the tee type return is adequate for most cases.

(c) The vapor-liquid lift over the sump liquid level should be as low as possible.

(d) Possible thermal degradation of the boiler contents, and increasing concerns over large inventories of boiling liquids, require the minimum hold-up in the system. (However, there must be adequate residence time for control purposes.)

(e) Provision is often required for an installed spare boiler. Even if this is not provided initially, the layout should preferably allow for the addition of this feature at a later stage.

(f) Provision should be made for a valve in the liquid line to the boiler to provide variable resistance to improve stability. This is good practice even if the stability checks done at the design stage do not indicate any problems; as such checks cannot be regarded as totally reliable.

(g) A valve or slip-plate in the liquid line, together with a slip plate in the two-phase line to the column should be considered for isolation, particularly if a spare boiler is to be provided.

(h) The large carry-over of liquid in the return pipe to the column, typically over 75% by weight, means that allowance must be made for:

    (1) Separation of the vapor-liquid mixture in the space between the sump and the bottom tray or packing support grid.

    (2) Avoiding erosion of the column wall.

    (3) Avoiding obstruction of the flow of liquid from the bottom tray seal pan in plate columns.

(j) For economic reasons it is usually better to use the column base or skirt as a pumping tank rather than have a separate vessel, especially as the extra height penalty has already been incurred by using a **VTR**.

(k) Control problems.

There are two level control duties, associated with the base of the column, which may be separated: the liquid head above the boiler must be kept at its design value, and the bottoms pump-off rate must be controlled.

Level control can be difficult because of the turbulent conditions in the column sump. Control of the liquid level over the boiler should be accurate and steady, particularly for vacuum duties. Some plant operators have an established practice to carry this out by means of a weir. This has the advantage of separating this duty from the control of the off-take, allowing the level of the latter to fluctuate if necessary, which may permit a shorter residence time in the sump, with consequently less thermal degradation. The pump necessarily requires a LIC of some sort; the requirement will be determined by the degree of smoothing required on the outflow.

In certain cases where heavy fouling is known to occur, it is best to avoid the use of a weir and baffle system because of the risk of blockages. In these cases accurate instrumentation is required to maintain the sump level at the required height over the boiler to within ±25 mm. The system then offers little smoothing of the bottoms flow from the column, particularly in small diameter columns, and an external pumping tank may be required.

Some plant operators control the level for the boiler by a weir is considered unusual, and satisfactory operation is achieved with a single control of level for both the boiler recirculation and the bottoms off-take.

The difference in approach between the, two aforementioned plant operations may be attributed at least partly to the difference in scale of operation. It is recommended that in the one case, the approach to be adopted for columns in excess of 1.5 m in diameter, and the other case, an approach for smaller diameter columns.

(l) Differential expansion. Provision has to be made for differential expansion between the reboiler and the column shell. The return vapor-liquid pipework from the top of the reboiler will be of a relatively large diameter and should be short to reduce flow resistance, so there is little possibility of building flexibility into it other than with a bellows. The liquid pipework, on the other hand, is of relatively small diameter, and extra resistance in it is of little concern; indeed, it may help to stabilize the system. Ideally, the top of the boiler should be supported off the column, or both of them supported at the same level, with the liquid pipework designed to be flexible.

11.2 A Standard Layout

The line diagrams given in Figure 5 show the basic requirements of an installation; 5(a) shows a system with an internal baffle, and 5(b) without. These diagrams will require elaboration to cover the requirements of the particular case under consideration. Figure 6 gives typical dimensions of the lower part of the distillation column and Figure 7 shows an isometric sketch of the layout. Figures 8(a) - 8(c) show the recommendations of FRI (reference [8]) for inlets to large diameter (above 1.5 m) columns.

Points to note are as follows:

(a) For columns below 1.5 m diameter with weir control, the vapor-liquid return pipe is at least 100 mm above the liquid level; 200 mm or more may be necessary to avoid froth interference. This greater height may also be required for systems without a baffle, to allow for less precise level control. For large diameter columns, above 1.5 m diameter, FRI recommend a minimum height of 300 mm.

(b) The two-phase mixture returned to the column can potentially erode the column shell. In small diameter columns this can be avoided by the use of an impingement plate on the column wall. For large diameter columns, where this plate may become excessive, an inlet deflector such as shown on Figure 8(a) may be preferable, to divert the incoming mixture down towards the surface. In this case it is particularly important to provide adequate clearance between the liquid level and the inlet, to avoid splash carry-over. The deflector design type B is the most common; designs C or E will have lower pressure drops, and thus fewer tendencies to restrict circulation or cause instability. Some plant operators install a deflector.

(c) In Figure 5(a), the liquid level in the sump supplying the reboiler is controlled by a weir; the level in the base of the column, acting as a pumping tank is lower than this and is controlled by a level controller acting on the pump discharge. In Figure 5(b), the level controller performs both duties.

(d) With weir control, the bottom downcomer is double sealed to cover the start-up condition.

(e) The vapor-liquid return to the column does not obstruct the downcomer operation. It is desirable to arrange the vapor-liquid return to be at right angles to the centre line of the downcomer.

(f) For the baffled system, the internal pumping tank liquor entry is protected by a baffle acting as an 'umbrella' to prevent spray failing into it.

(g) Adequate space is provided for vapor-liquid disengagement. FRI (Figure 8) recommend a clearance between the top of the return pipe and the bottom tray equal to the tray spacing, with a minimum of 18". This is considered by **GBH Enterprises** to be excessive, especially for small diameter columns, or if a deflector is used. A clearance of 2/3 of the tray spacing, as in Figure 6, is adequate.

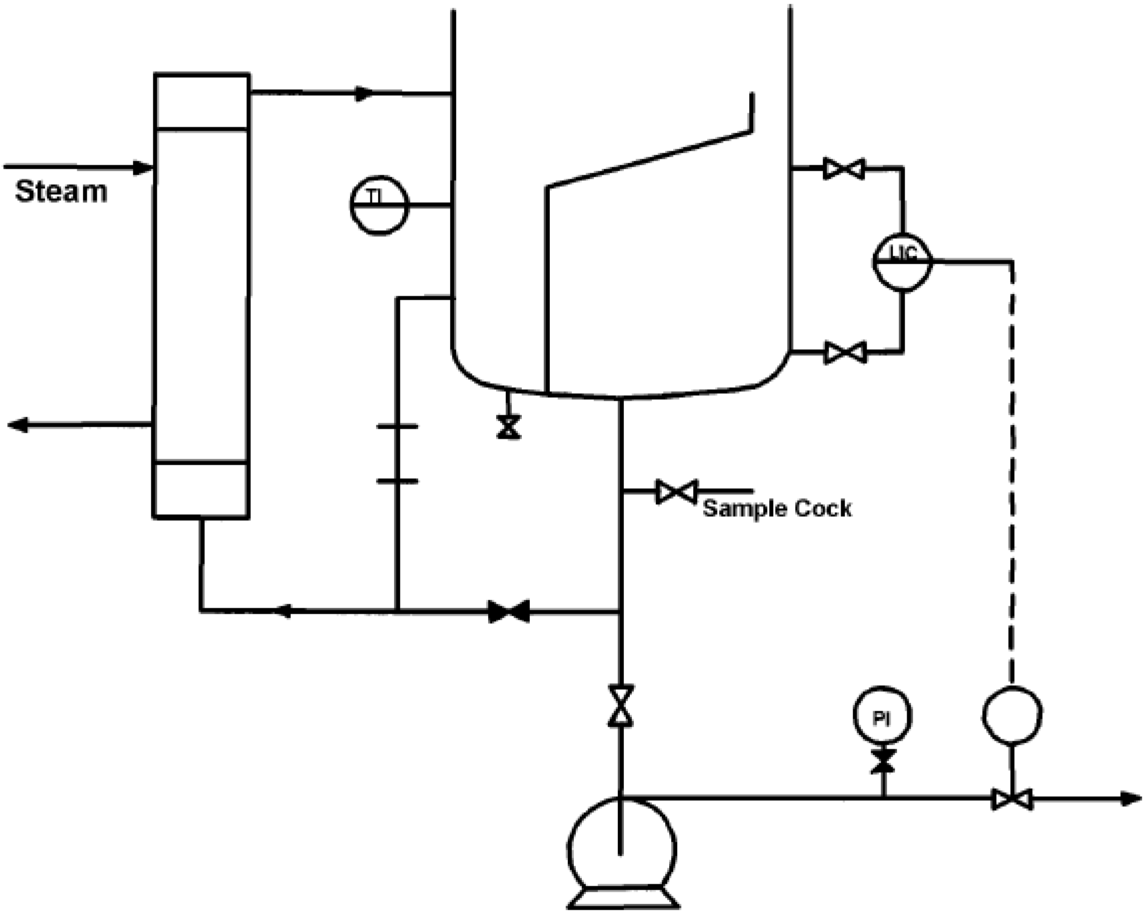
(h) A second boiler can easily be added, arranged as a mirror image.

(j) The liquid feed line to the boiler contains an isolation valve or spool piece as well as a valve to act as a variable resistance. The latter could possibly be combined with the isolation valve.

(k) Note the provision of drain branches, manways and weepholes.

This layout can reasonably be used with columns down to about 0.75 m diameter. For smaller diameter columns, the sump may become too long for a good layout, and there are problems of access. In these cases an external pumping tank should be used. A good layout is shown in Figure 9. Note the baffle opposite the vapor-liquid inlet to the column to avoid erosion of the column wall.

FIGURE 5 (a) BASIC LINE DIAGRAM WITH INTERNAL WEIR



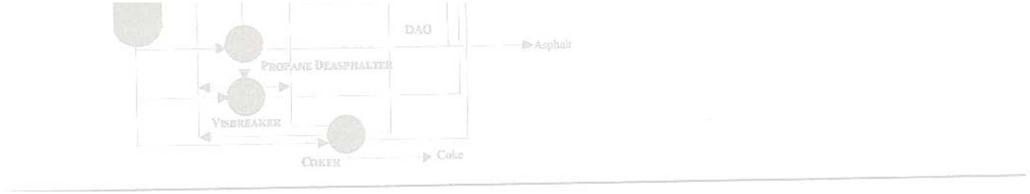
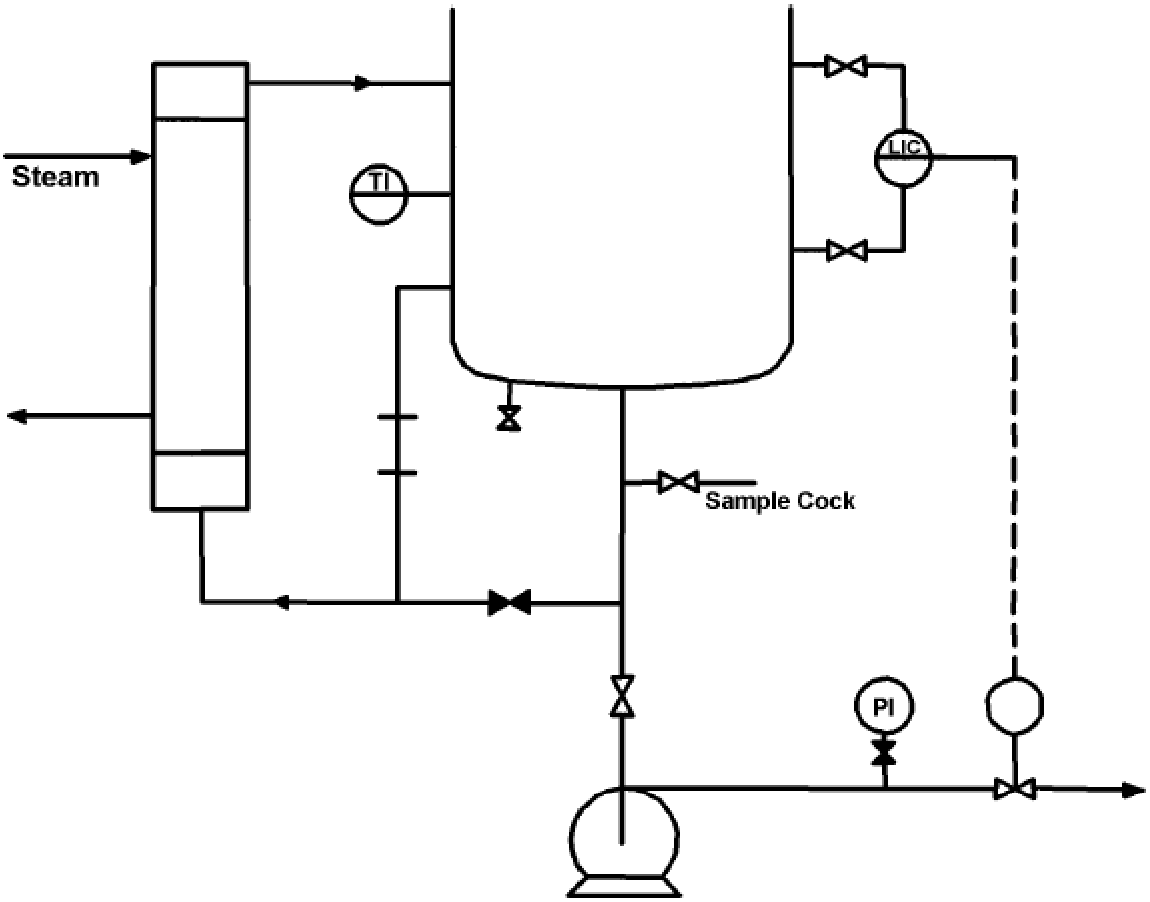


FIGURE 5 (b) BASIC LINE DIAGRAM WITHOUT WEIR



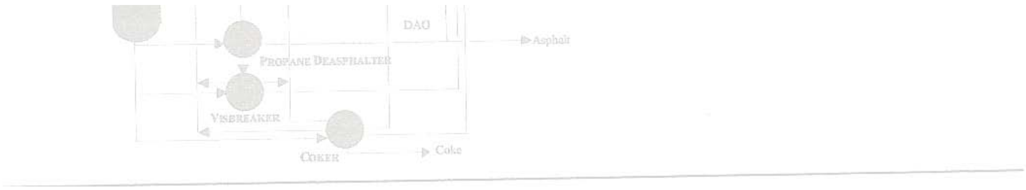


FIGURE 6 (a) TYPICAL DIMENSIONS WITH INTERNAL WEIR

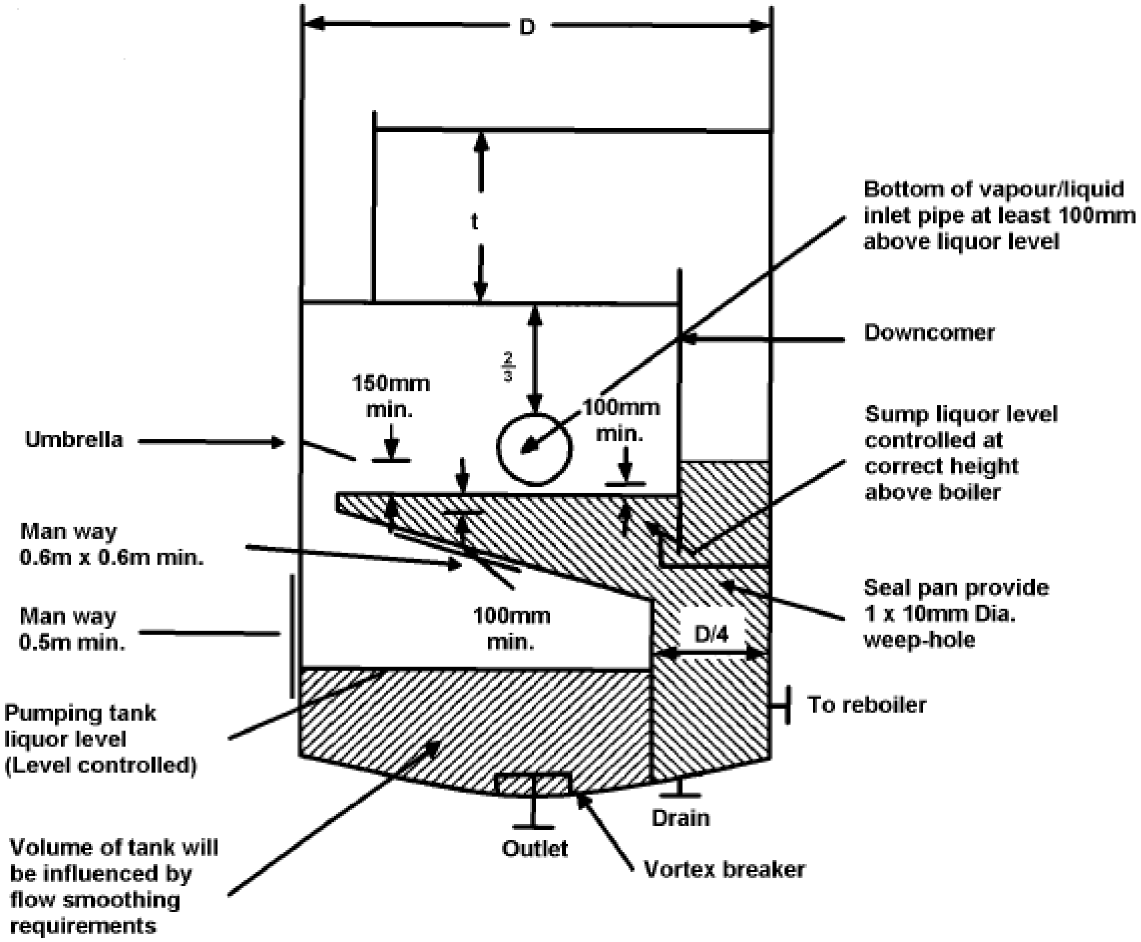
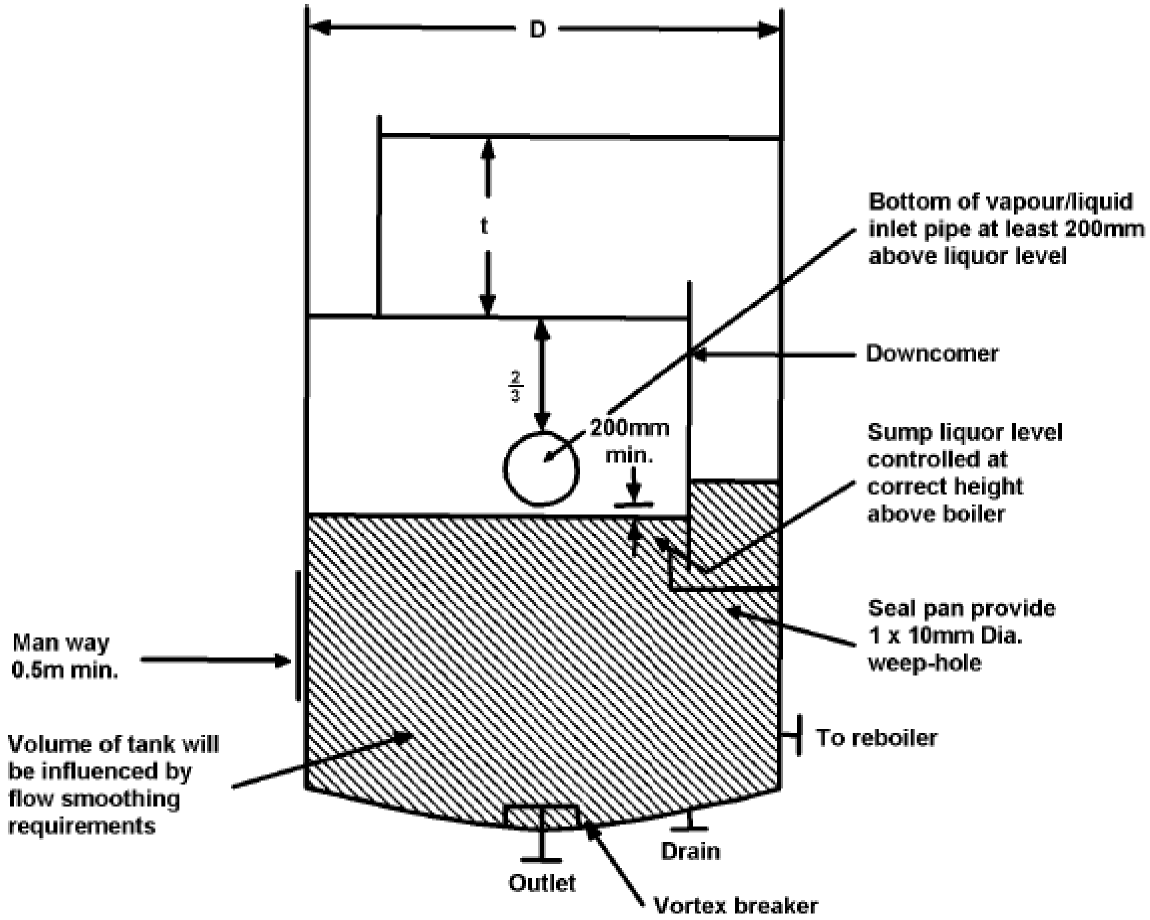


FIGURE 6 (b) TYPICAL DIMENSIONS WITHOUT WEIR



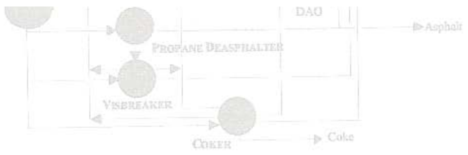
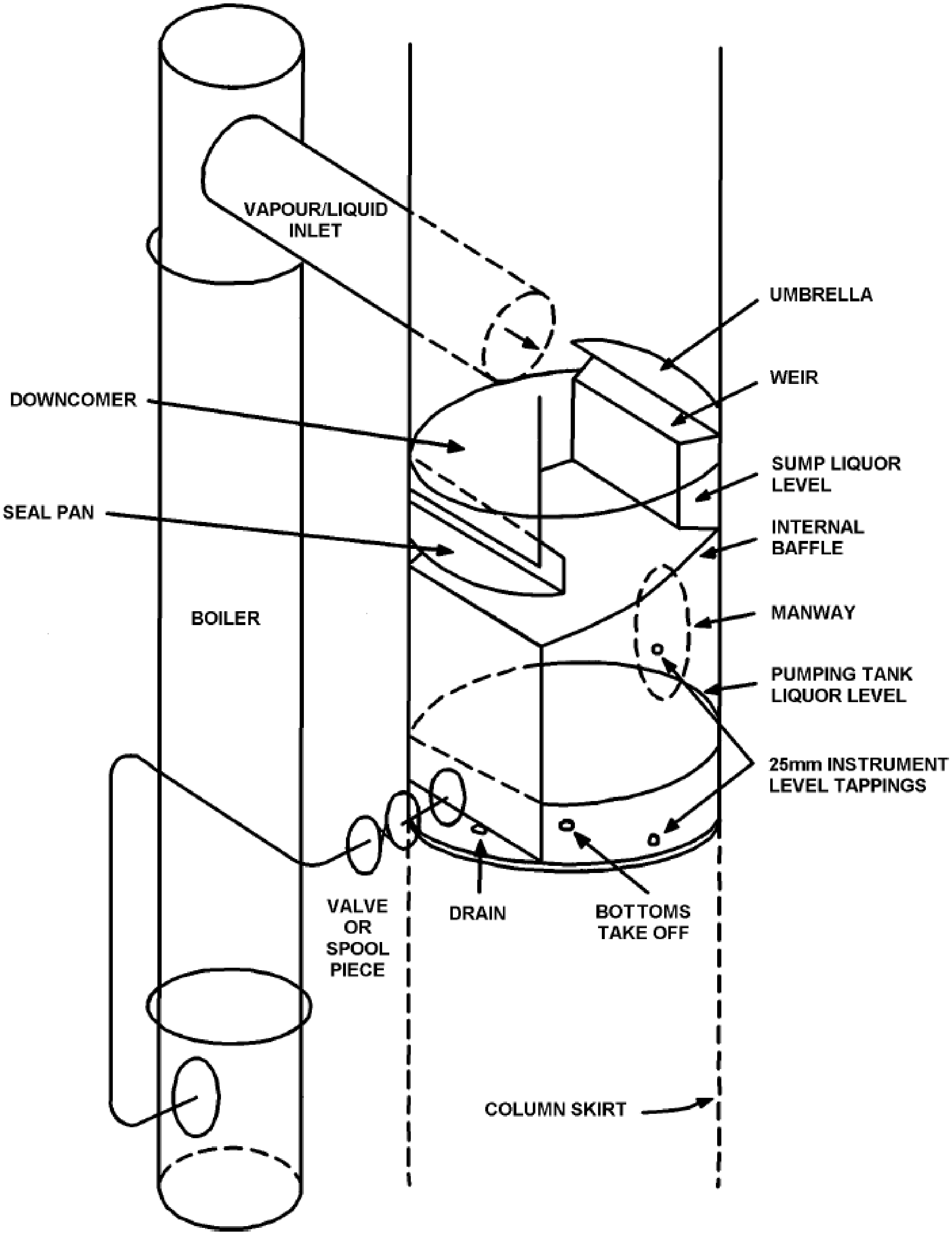


FIGURE 7 ISOMETRIC OF TYPICAL LAYOUT WITHOUT WEIR



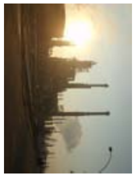


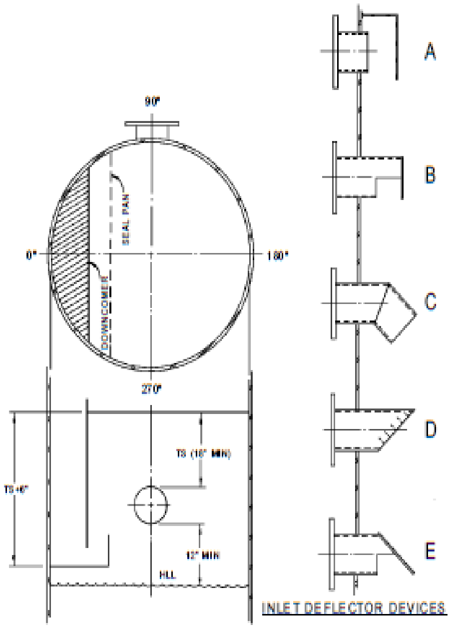
FIGURE 8 FRI RECOMMENDATIONS FOR LARGE COLUMN INLETS

(a)

INLETS BELOW BOTTOM TRAY

SINGLE-PASS TRAYS

THIS IS A PROBLEM AREA. CARE MUST BE TAKEN TO PREVENT DAMAGE TO THE TRAYS ABOVE. IF THE SOURCE OF THE FEED IS A THERMOSYPHON REBOILER, ANY DEVICE USED AT THE NOZZLE INLET SHOULD BE CHECKED FOR PRESSURE DROP AND ITS EFFECT.



DESIGN CRITERIA:

A. ORIENTATION AT 90° OR 270° IS REQUIRED FOR OPEN-ENDED INLETS.

B. OTHER ORIENTATIONS REQUIRE THE USE OF DEFLECTOR DEVICES TO PREVENT IMPINGEMENT ON THE DOWNCOMER OR SEAL PAN.

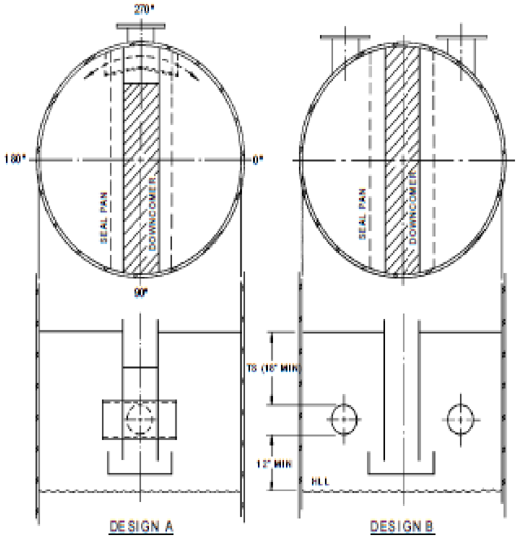
C. LARGE DIAMETER INLETS (i.e. DIAMETER GREATER THAN TRAY SPACING) NOT PROVIDED WITH DEFLECTOR DEVICES MAY REQUIRE A GREATER CLEARANCE BETWEEN THE TOP OF THE INLET AND THE TRAY ABOVE.

(b)

INLETS BELOW BOTTOM TRAY

TWO- PASS TRAYS

THIS IS A PROBLEM AREA. CARE MUST BE TAKEN TO PREVENT DAMAGE TO THE TRAYS ABOVE. IF THE SOURCE OF THE FEED IS A THERMOSYPHON REBOILER, ANY DEVICE USED AT THE NOZZLE INLET SHOULD BE CHECKED FOR PRESSURE DROP AND ITS EFFECT.



DESIGN CRITERIA:

A. ORIENTATION AT 90° OR 270° IS REQUIRED FOR OPEN-ENDED INLETS.

B. OTHER ORIENTATIONS REQUIRE THE USE OF DEFLECTOR DEVICES TO PREVENT IMPINGEMENT ON THE DOWNCOMER OR SEAL PAN.

C. LARGE DIAMETER INLETS (i.e. DIAMETER GREATER THAN TRAY SPACING) NOT PROVIDED WITH DEFLECTOR DEVICES MAY REQUIRE A GREATER CLEARANCE BETWEEN THE TOP OF THE INLET AND THE TRAY ABOVE.

D. IF DESIGN "A" IS USED, INTERRUPTION OF LIQUID CURTAIN FROM SEAL PAN IS RECOMMENDED IF INLET DEVICE IS LOCATED BELOW SEAL PAN.

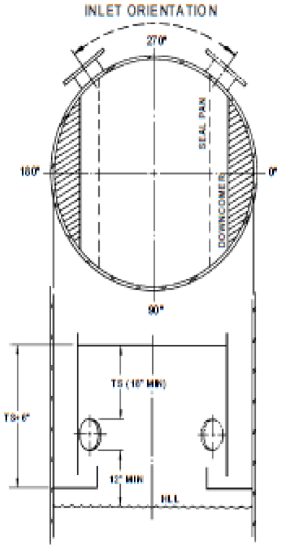
E. SIDE DOWNCOMERS ARE NORMALLY PREFERRED.

(c)

INLET BELOW BOTTOM TRAY

TWO- PASS TRAYS

THIS IS A PROBLEM AREA. CARE MUST BE TAKEN TO PREVENT DAMAGE TO THE TRAYS ABOVE. IF THE SOURCE OF THE FEED IS A THERMOSYPHON REBOILER, ANY DEVICE USED AT THE NOZZLE INLET SHOULD BE CHECKED FOR PRESSURE DROP AND ITS EFFECT.



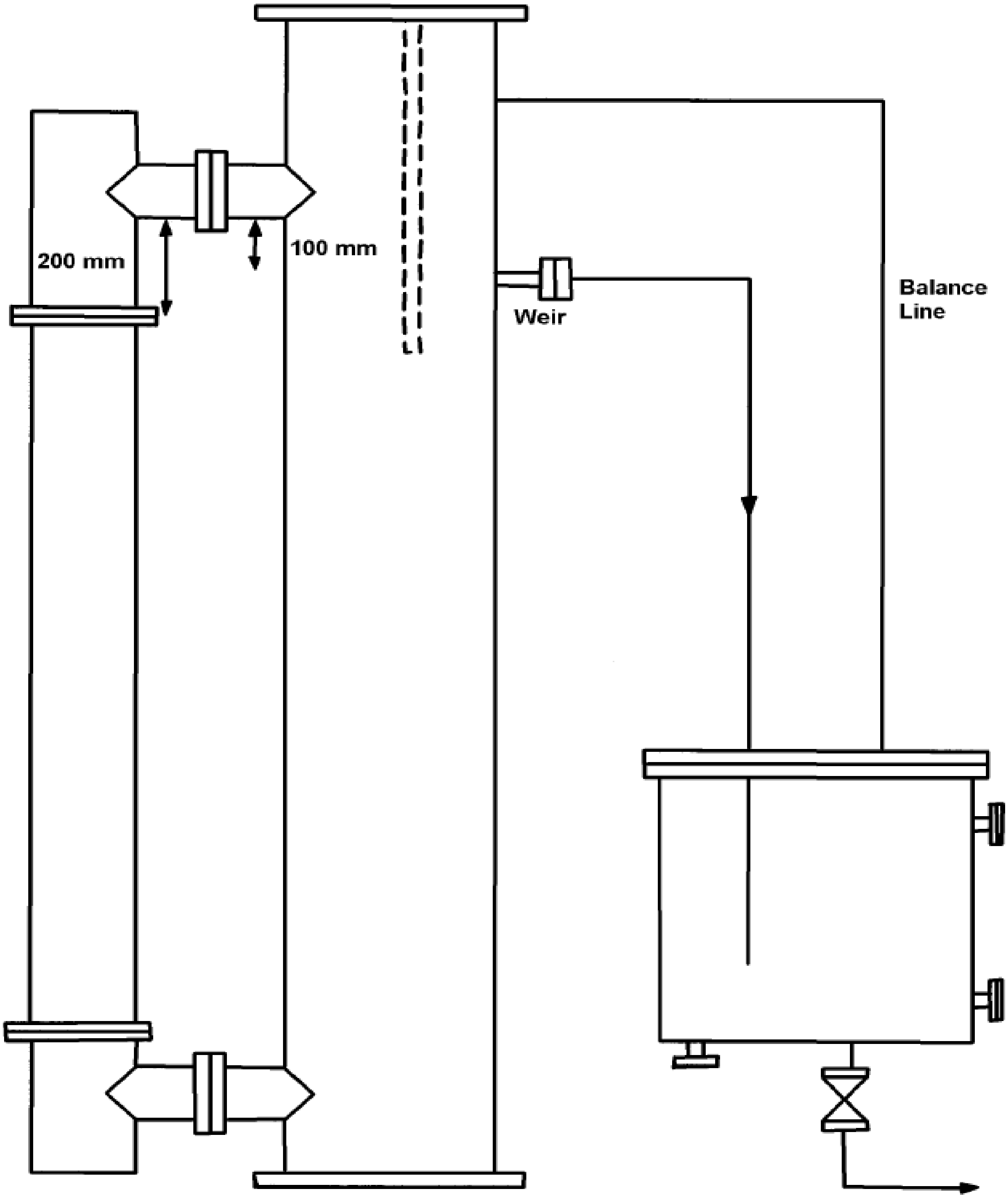
DESIGN CRITERIA:

A. ORIENTATION AT 90° OR 270° IS REQUIRED FOR OPEN-ENDED INLETS.

B. OTHER ORIENTATIONS REQUIRE THE USE OF DEFLECTOR DEVICES TO PREVENT IMPINGEMENT ON THE DOWNCOMER OR SEAL PAN.

C. LARGE DIAMETER INLETS (i.e. DIAMETER GREATER THAN TRAY SPACING) NOT PROVIDED WITH DEFLECTOR DEVICES MAY REQUIRE A GREATER CLEARANCE BETWEEN THE TOP OF THE INLET AND THE TRAY ABOVE.

FIGURE 9 REBOILER, SUMP AND PUMPING TANK SMALL DIAMETER COLUMNS



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[1] 'The layout and general arrangement of vertical thermosyphon reboilers.' W H Orrell, September 1971.

[2] 'Process design of vertical thermosyphon reboilers. 'P D Hills, May 1982.

[3] HTRI Design Manual Volume 2, Section D5.3.

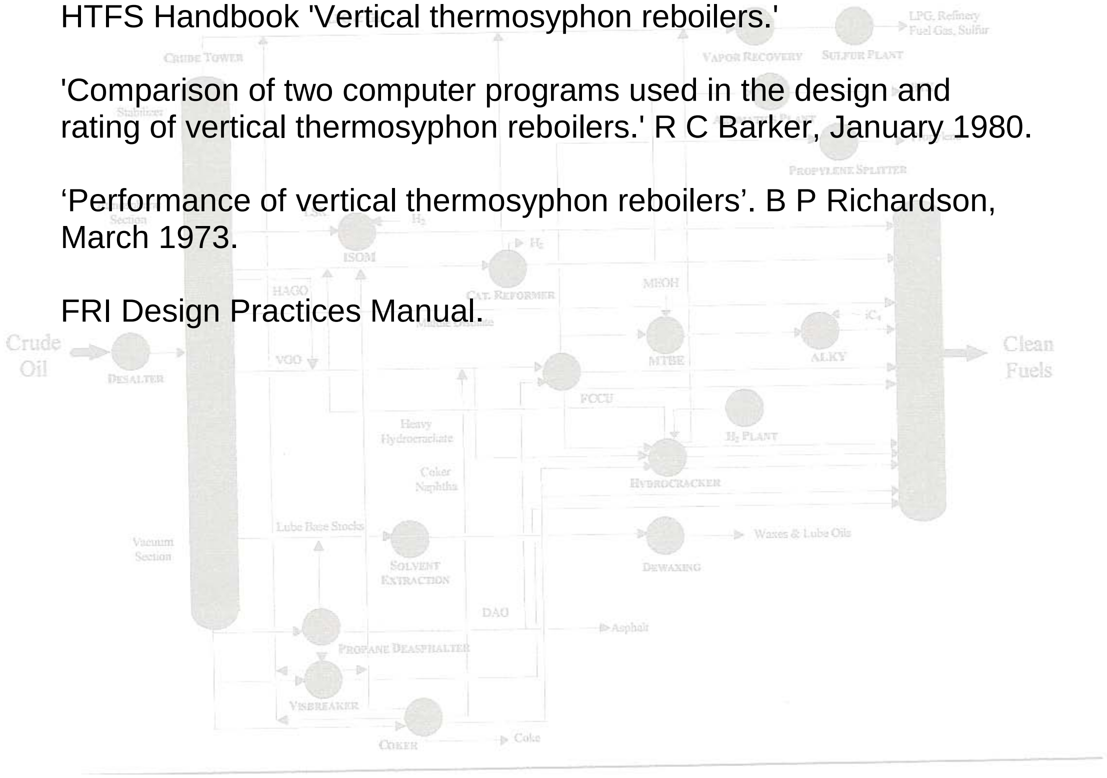
[4] HTFS Design Report 'The design of vertical thermosyphon reboilers.' D Butterworth, R A W Shock, 1975.

[5] HTFS Handbook 'Vertical thermosyphon reboilers.'

[6] 'Comparison of two computer programs used in the design and rating of vertical thermosyphon reboilers.' R C Barker, January 1980.

[7] ‘Performance of vertical thermosyphon reboilers’. B P Richardson, March 1973.

[8] FRI Design Practices Manual.



APPENDIX A ESTIMATION OF FOULING RESISTANCE FROM PLANT DATA

Plant data form the only reliable source of fouling resistances. It should be remembered, however, that such data refer strictly only to the specific boiler from which they were obtained and should be used with caution if the new design differs in process composition, temperature or flowrate.

Some commercially available programs have an option, for evaluating the 'Differential Resistance', which enables the program to estimate the fouling resistance necessary to match program prediction to observed plant performance.

There are two ways to estimate fouling resistances from plant data. In both cases it is necessary to have the heat load (obtained, for example, from the steam flow to the boiler), the conditions in the column sump and the heating medium temperature.

A1 MANUAL ITERATION

This method requires the user to perform repeated runs of the program, adjusting the input fouling resistance until the predicted heat load matches the plant data.

Although this method is easy to understand and use for one or two data sets, and gives the fouling resistance directly, it is very inefficient in computing time if many data sets are to be analyzed, as is the case if a plot of fouling resistance against time since cleaning is to be generated. If there are many sets of data it is better to generate a heat duty/temperature difference curve once, using the 'available duty' method, and obtain the fouling resistance by a simple hand calculation.

A2 AVAILABLE DUTY METHOD

If the program is run with zero fouling resistance, it will calculate the heat load obtainable from a clean exchanger with the given temperature difference. A series of four or five such runs covering the range of heat duty of interest can be used to generate a curve of heat duty against temperature difference. It is convenient to use the apparent temperature difference (steam temperature – sump temperature) rather than the true mean difference generated by the program, as this is readily available from the plant data. Any errors generated from this approximation are small compared with the likely scatter of the plant data.

The procedure for estimating the fouling resistance is as follows:

We have available a set of values of heat load, Q, and apparent temperature difference in the fouled condition ΔT_d.

From the curve of heat duty vs apparent temperature difference generated as above, find the required temperature difference for each heat duty in a clean condition ΔT_c .

The temperature difference across the fouling layer ΔT_f is then given by:

$$\Delta T_f = \Delta T_d - \Delta T_c$$

The total fouling resistance, based on the inside area, is then:

$$r_{fi} = \frac{\Delta T_f \cdot A_i}{Q}$$

Where A_i is the reboiler inside area.

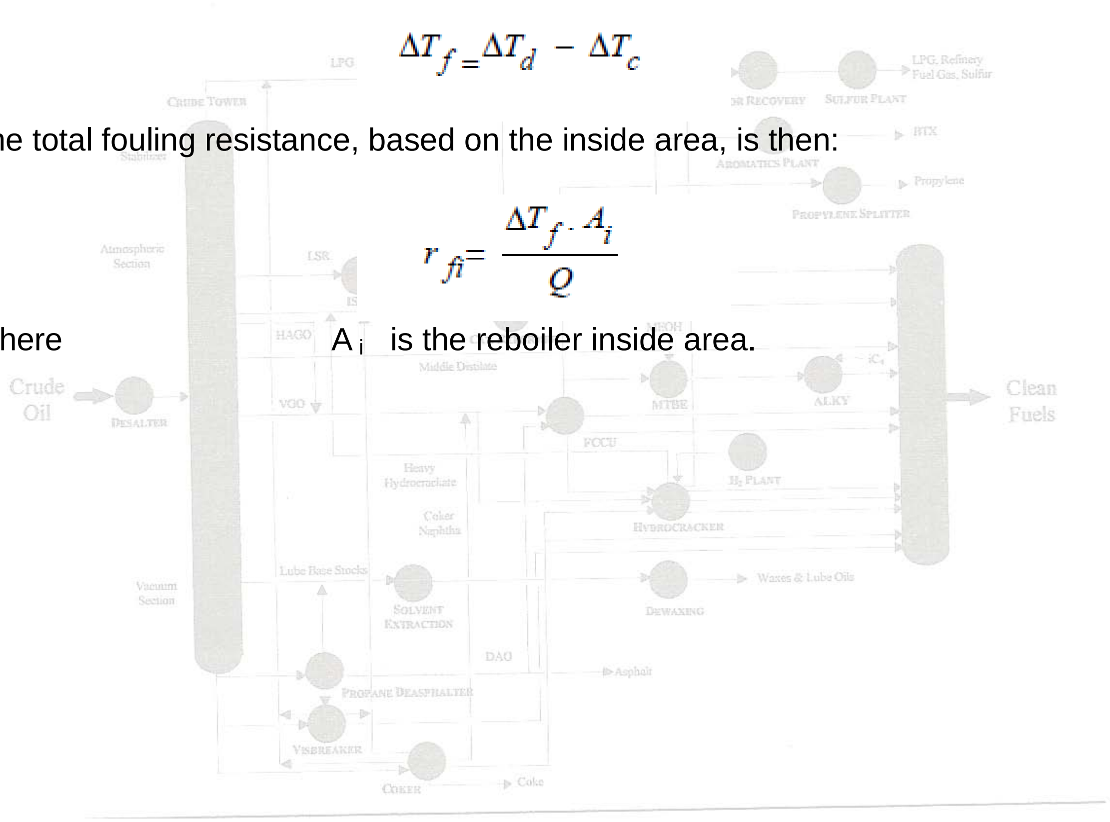
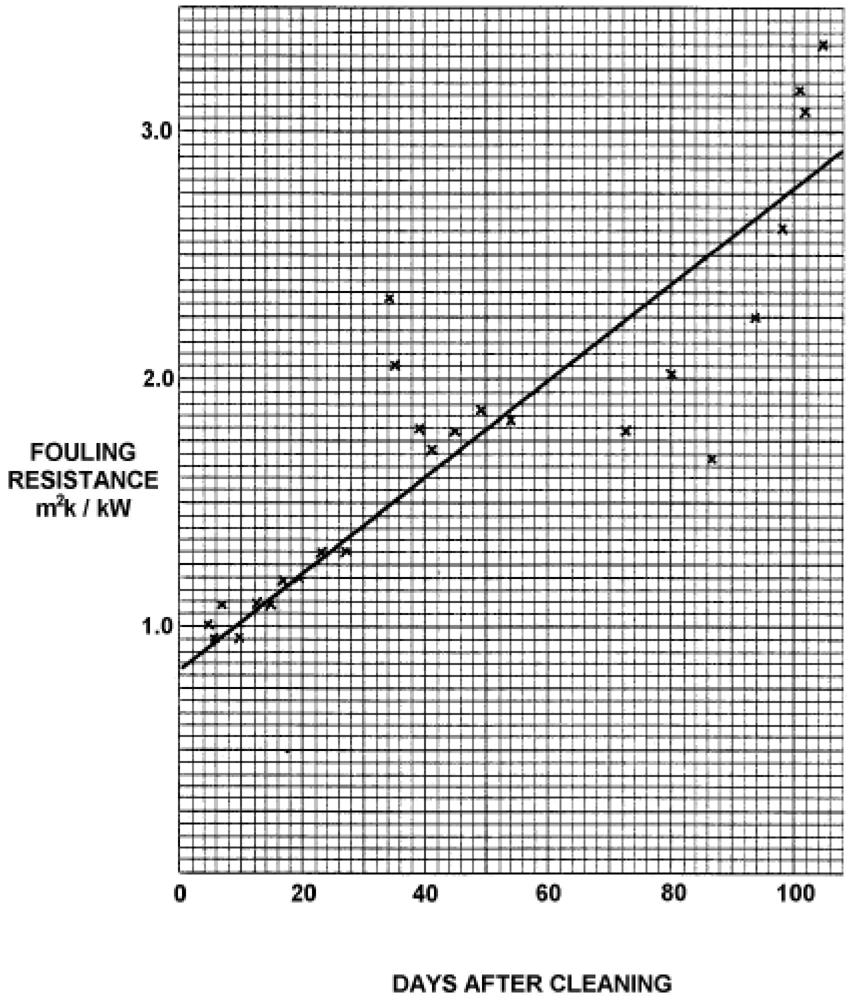


FIGURE 10 TYPICAL FOULING CURVE (VC3 HCl STILL)

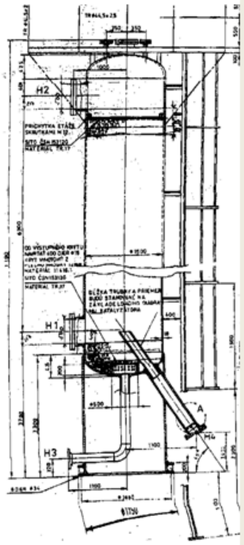


DOCUMENTS REFERRED TO IN THIS PROCESS ENGINEERING GUIDE

This Process Engineering Guide makes reference to the following documents:

GBH Enterprises Engineering Guides

GBHE-PEG-HEA-507	Selection of Reboilers for Distillation Columns (referred to in Clause 1)
GBHE-PEG-HEA-512	Mechanical Constraints on Thermal Design of Shell and Tube Exchangers (referred to in 7.2.1)



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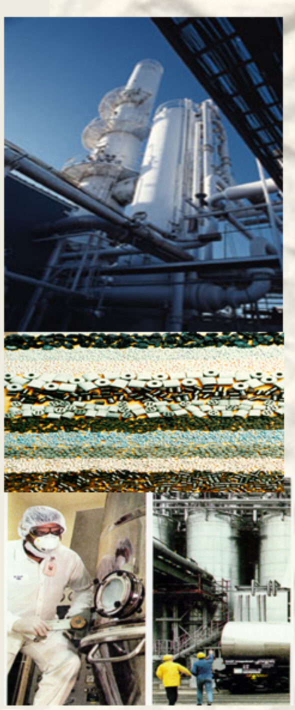

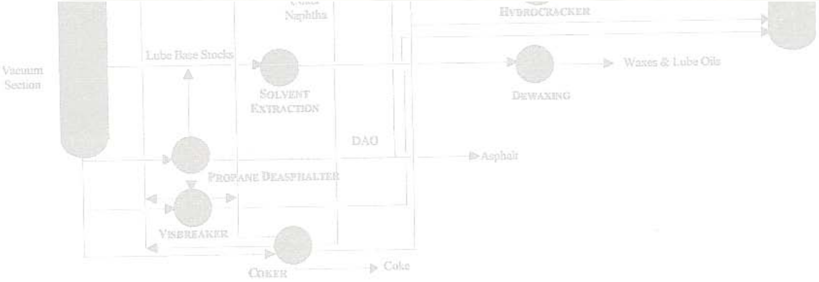

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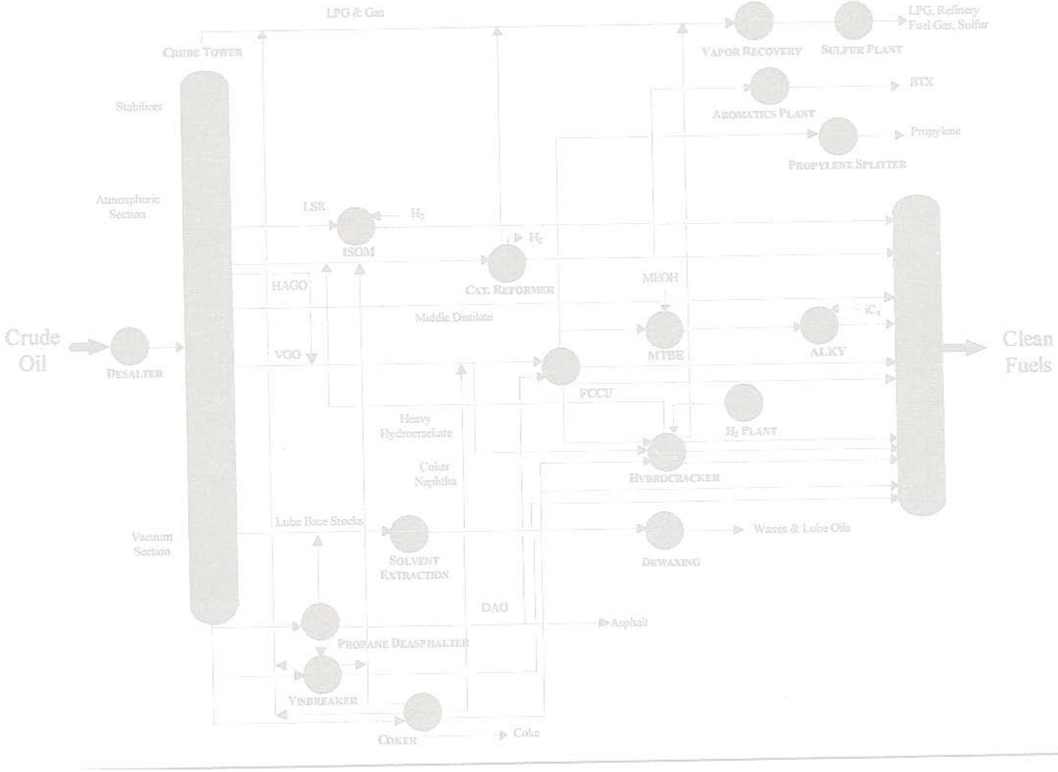

LPG & Gas
Crude Tower
Vapor Recovery
Sulfur Plant
LPG, Refinery Fuel Gas, Sulfur
Aromatics Plant
BTX
Propylene Splitter
Propylene
Stabilizer
Atmospheric Section
LSR
H_2
ISOM
H_2
Cat. Reformer
HAGO
MEOH
Middle Distilate
iC_4
Crude Oil
Desalter
VGO
MTBE
Alky
Clean Fuels
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Heavy Hydrocrackate
H_2 Plant
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DAO
Asphalt
Propane Deasphalter
Visbreaker
Coker
Coke